7

MODERN PHYSICS

ATOMIC STRUCTURE

VARIOUS MODELS FOR STRUCTURE OF ATOM

DALTON'S THEORY

(a) Every material is composed of minute particles known as atom. Atom is indivisible i.e. it cannot be subdivided. It can neither be created nor be destroyed.

(b) All atoms of same element are identical physically as well as chemically, whereas atoms of different elements are different in properties.

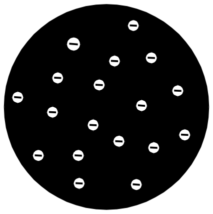
(c) The atoms of different elements are made up of hydrogen atoms. (The radius of the heaviest atom is about 10 times that of hydrogen atom and its mass is about 250 times that of hydrogen).

(d) The atom is stable and electrically neutral.

THOMSON'S ATOM MODEL

(a) The atom as a whole is electrically neutral because the positive charge present on the atom (sphere) is equal to the negative charge of electrons present in the sphere.

(b) Atom is a positively charged sphere of radius 10^{-10} m in which electron are embedded in between.



(c) The positive charge and the whole mass of the atom is uniformly distributed throughout the sphere.

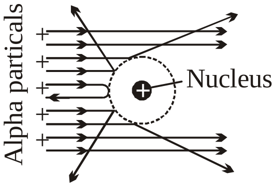
(d) Shortcomings of Thomson's model

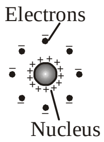
(i) The spectrum of atoms cannot be explained with the help of this model.

(ii) Scattering of α-particles cannot be explained with the help of this model

RUTHERFORD MODEL

In Rutherford experiment α-particles particle are emitted by some radioactive material (polonium), kept inside a thick lead box. A very fine beam of α-particles pass through a small hole in the lead screen. This well collimated beam is then allowed to fall on a thin gold foil. While passing through the gold foil, α-particles are scattered through different angles. A zinc sulphide screen was placed: out the other side of the gold foil, this screen was movable, so as to receive the α-particles, scattered from the gold foil at angles varying from 0 to 180°. When an α-particle strikes the screen, it produces a flash of light and it is observed by the microscope. It was found that :





* Most of the α-particles went straight through the gold foil and produced flashes on the screen as if there were nothing inside gold foil. Thus the atom is hollow.

* Few particles collided with the atoms of the foil which have scattered or deflected through considerable large angles. Few particles even turned back towards source itself.

* The entire positive charge and almost whole mass of the atom is concentrated in small centre called a nucleus.

* The electrons could not deflected the path of a α-particles i.e. electrons are very light.

* Electrons revolve round the nucleus in circular orbits.

So, Rutherford 1911, proposed a new type of model of the atom. According to this model, the positive charge of the atom, instead of being uniformly distributed throughout a sphere of atomic dimension is concentrated in a very small volume (Less than 10^{-13} n is diameter) at it centre. This central core, now called nucleus, is surrounded by clouds of electron makes. The entire atom electrically neutral.

According to Rutherford scattering formula, the number of α-particles scattered at angle θ by a target is :

$$N(\theta) \propto \text{cosec}^4 (\theta/2)$$

$$\text{Impact parameter } b = \frac{2Ze^2 \cot(\theta/2)}{4\pi\varepsilon_0 m v_0^2}$$

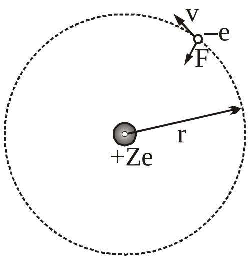
Distance of closest approach

$$r_0 = \frac{2Zeq}{4\pi\varepsilon_0 m v_0^2} = \frac{2(Ze)(2e)}{4\pi\varepsilon_0 m v_0^2}$$

BOHR'S MODEL

(i) Attractive coulomb force between electron and nucleus provide necessary centripetal force.

$$\frac{mv^2}{r} = K\frac{Ze^2}{r^2}$$



(ii) Rule of stable orbits : Electron orbits around nucleus in only those orbit where angular momentum is an integral multiple of $\frac{h}{2\pi}$.

$$mvr = n\frac{h}{2\pi}\left[\because \hbar = \frac{h}{2\pi}\right]$$

(iii) Electromagnetic radiations are emitted if an electron jumps from stationary orbit of higher energy E_2 to another stationary orbit of lower energy E_1. The frequency ν of the emitted radiation is related by the equation.

$$E_2 - E_1 = h\nu$$

Defects of bohr model

(a) This model could not explain the fine structure of spectral lines, Zeeman effect and Stark effect.
(b) This model is valid only for single electron systems.
(c) This model is based on circular orbits of electrons whereas in reality the orbits are elliptical.
(d) Electron is presumed to revolve round the nucleus only whereas in reality it also rotates about its own axis.
(e) This model could not explain the quantisation condition of angular momentum. (i.e. the classical and quantum theories were used simultaneously)
(f) This model could not explain the intensity of spectral lines.
(g) It could not explain the doublets obtained in the spectra of some of the atoms.

VARIOUS PARAMETER OF ELECTRON ACCORDING TO BOHR' THEORY

(i) The radius of n-th orbit :

(a) $r_n = \frac{n^2h^2}{4\pi^2kZe^2m}$

(b) $r_n \propto \frac{n^2}{mZ}$

(c) For hydrogen] $Z = 1, r_n = 0.529\, n^2$ Å

$r_1 : r_2 : r_3 = 1 : 4 : 9$

$r_H : r_{He^+} : r_{Li} = 1 : \frac{1}{2} : \frac{1}{3} = 6 : 3 : 1$

n - order of orbit or principal quantum number
Z - Atomic number of element
m - Mass of particle like electron, Meuon, etc. rotating about nucleus

(ii) The velocity of electron in n-th orbit :

(a) $V_n = \frac{2\pi KZe^2}{nh}$ (b) $V_n = \frac{Z}{n}$ (c) $V_n = \frac{c}{137}\frac{Z}{n}$

(d) For hydrogen] $v_n = \frac{2.188\times10^6}{n} = \frac{c}{137\,n}$ m/s

$v_1 : v_2 : v_3 = 1 : \frac{1}{2} : \frac{1}{3} = 6 : 3 : 2$

(iii) Angular frequency (μ_n) of electron in n-th orbit :

(a) $\omega_n = \frac{8\pi^3K^2Z^2e^4m}{n^3h^3}$ (b) $\omega_n = \frac{z^2m}{n^3}$

(c) $\omega_n = \frac{4.159\times10^{16}Z^2}{n^3}$ Rad/s

(iv) Frequency (f_n) of electron in n-th orbit :

(a) $f_n = \frac{4\pi^2K^2Z^2e^4m}{n^3h^3}$ (b) $f_n \propto \frac{Z^2m}{n^3}$

(c) $f_n = \frac{6.62\times10^{15}Z^2}{n^3}$ Hz

(v) The period (T_n) of an electron in n-th orbit :

(a) $T_n = \frac{n^3h^3}{4\pi^2me^4K^2Z^2}$ (b) $T_n \propto \frac{n^3}{Z^2m}$

(c) $T_n = \frac{1.5\times10^{-16}n^3}{Z^2}$ sec

(vi) Current (I_n) due to orbital motion :

(a) $I_n = ef_n = \frac{4\pi^2K^2Z^2e^5m}{n^3h^3}$

(b) $I_n \propto \frac{Z^2m}{n^3}$ (c) $I_n = \frac{1.06Z^2}{n^3}$ mA

(vii) Magnetic field (B_n) at nucleus due to orbital motion of e^-

(a) $B_n = \frac{\mu_0 I_n}{2r_n} = \frac{8\pi^4K^3Z^3e^7m^2}{n^5h^5}$

μ_0 = Magnetic permeability in vacuum

(b) $B_n \propto \frac{z^3m^2}{n^5}$ (c) $B_n = \frac{12.58Z^3}{n^5}$ T

(viii) Magnetic moment :

(a) $M_n = I_n A_n = \pi r_n^2 I_n$ (b) $M_n = \frac{eh}{4\pi m}n$

(c) If $n = 1$, then $M = \frac{eh}{2m} = 9.26 \times 10^{-24}$ A-m.

It is called Bohr Magneton

(ix) Potential energy (U_n) in n-th orbit :

$$U_n = \frac{-KZe^2}{r_n} = \frac{-27.2}{n^2} Z^2 \text{ eV, For H-atom, } U_n = \frac{-Ke^2}{r_n}$$

(x) Kinetic energy (E_{kn}) in n-th orbit :

$$E_{kn} = \frac{KZe^2}{2r_n} = \frac{13.6Z^2}{n^2} \text{ eV For H-atom, } E_{kn} = \frac{Ke^2}{2r_n}$$

(xi) Total energy in n-th orbit :

= Kinetic energy + Potential energy

$E_n = U_n + E_{kn}$

(a) $E_n = \frac{-KZe^2}{2r_n}$ (b) $E_n = \frac{-2\pi^2k^2me^4Z^2}{n^2h^2}$ (c) $E_n = \frac{-RChZ^2}{n^2}$,

R = Rydberg contant $= \frac{2\pi^2K^2me^4}{ch^3} = 1.1 \times 10^7 \text{ m}^{-1}$

Rhc = 1 Rydberg energy = 13.6 eV

(d) $E_n = -\frac{13.6Z^2}{n^2}$ eV

(e) For H atom $E_1 = -13.6$ eV, $E_2 = -3.40$ eV, $E_3 = -1.51$ eV

(xii) Ionization energy of electron E_{ion} :

(a) $E_{ion.} = E_\infty - E_n$ (b) $E_{ion.} = E_n = \frac{13.6Z^2}{n^2}$ eV

Ionisation energy of H-atom = 13.6 eV

Ionisation energy of He^+ = 54.4 eV

(xiii) Ionization potential of electron V_{ion} :

(a) $V_{ion.} = \frac{E_n \text{ (in J)}}{e}$ (b) $V_{ion.} = \frac{13.6\,Z^2 \text{ (in V)}}{n^2}$

(c) $V_{ion.} \propto \frac{Z^2}{n^2}$ (d) For Hydrogen atom $\left(\frac{V_{n_1}}{V_{n_2}}\right)_{ion.} = \left(\frac{n_2}{n_1}\right)^2$

(xiv) Excitation energy of electron E_{ext} :

$E_{ext.} = E_{high} - E_{low}$

For hydrogen atom,

E_{ext} of 1st excited state $= E_2 - E_1 = (-3.4) - (13.6) = 10.2$eV

E_{ext} of 2nd excited state $= E_3 - E_1 = (-1.51) - (13.6) = 12.09$eV

E_{ext} of 3rd excited state $= E_4 - E_1 = (-0.85) - (13.6) = 12.75$eV

(xv) Excitation potential of electron :

(a) $V_{ext.} = E_{ext.}$ (Joule)/e

(b) $V_{ext.} = 13.6\,Z^2\left[\frac{1}{n^2} - \frac{1}{(n+1)^2}\right]$ (c) $V_{ext.} \propto \frac{Z^2}{n^2}$

(d) For Hydrogen atom $V_{ext.} = \frac{13.6\,(2n+1)}{(n+1)^2 n^2}$

(xvi) Binding energy of electron E_{BE} :

$E_{BE} = -E_n$

BE of e^- of H-atom in n = 4 level is 0.85 eV

BE of 1st excieted state of H-atom is 3.4 eV

BE of 1st excieted state of He^+ atom is 13.6 eV

VARIOUS SERIES OF HYDROGEN SPECTRUM

(i) Lyman series $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$, $n_2 = 2, 3, 4$ ......

Minimum wavelength $\lambda_{min} = 912$ Å

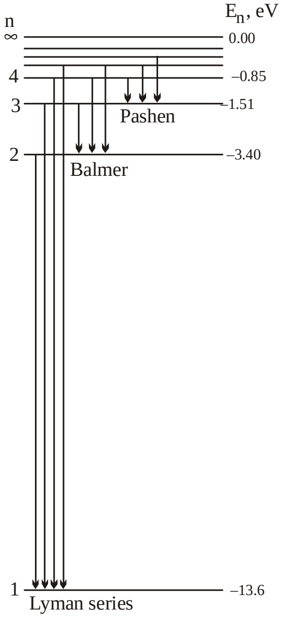
(ii) Balmer series $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$, $n_2 = 3, 4, 5$ .....

Minimum wavelength $\lambda_{min} = 3645$Å

(iii) Paschen series $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]$, $n_2 = 4, 5, 6$ .....

Minimum wavelength $\lambda_{min} = 8201$ Å

(iv) Brackett series $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{4^2} - \frac{1}{n_2^2}\right]$, $n_2 = 5, 6, 7$



(v) Pfund series $\bar{\nu} = \frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n_2^2}\right]$, $n_2 = 6, 7, 8$ ....

(vi) Number of line in emission spectrum $= \frac{n(n-1)}{2}$

Example 1 :

A hydrogen atom in the ground state is excited by radiations of wavelength 975Å. Find (a) the energy state to which the atom is excited. (b) how many lines will be possible in emission spectrum.

Sol. (a) $\lambda = 975\text{Å} = 975 \times 10^{-10}$ m

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

$$\therefore \quad \frac{1}{975 \times 10^{-10}} = 1.1 \times 10^{-7}\left[\frac{1}{1^2} - \frac{1}{n^2}\right] \quad \text{or } n = 4$$

(b) $\because$ Number of spectral lines (N) = $\frac{n\,(n-1)}{2}$

$\therefore$ N = $\frac{4\times(4-1)}{2} = 6$

Possible transition $4\rightarrow3,\ 4\rightarrow2,\ 4\rightarrow1,\ 3\rightarrow2,\ 3\rightarrow1,\ 2\rightarrow1$.

Example 2 :

Find the longest and shortest wavelength when a hydrogen atom in the ground state is excited by radiations of wavelength 975Å.

Sol. $\lambda = \frac{hc}{eE} \approx \frac{12400}{E\ (eV)}$ Å

$\therefore$ For longest wavelength

$$\lambda_{max} = \frac{12400}{E_{4\rightarrow3}} = \frac{12400}{0.66} = 18787.8\ \text{Å}$$

For smallest wavelength

$$\lambda_{min} = \frac{hc}{eE} = \frac{12400}{E_{4\rightarrow1}} = \frac{12400}{12.75} \approx 973\ \text{Å}$$

Example 3 :

Find the atomic number of atom when given that its ionisation potential is equal to 122.4 V.

Sol. I.P. = 122.4 V ; $E = Z^2E_H$ $\because$ $Z = \sqrt{\frac{E}{E_{H_1}}} = \sqrt{\frac{122.4}{13.6}} = 3$

Example 4 :

If the ionisation potential in the ground state for hydrogen is 13.6 eV, then find the excitation potential of third orbit.

Sol. I.P. = 13.6 eV $\therefore$ $E_4 - E_3 = \frac{13.6}{4^2} - \left[\frac{-13.6}{3^2}\right] = 0.66\text{eV}$

TRY IT YOURSELF - 1

Q.1 A spectral line results from the transition n = 2 to n = 1 in the single electron system given below. Which one of these will produce the shortest wavelength emission ?

(A) H (B) He^+

(C) Li^{++} (D) Dueterium atom

Q.2 The wavelength of the first line of the Lyman series of a ten times ionized Na atom (Z = 11) is nearest to

(A) 0.1 Å (B) 10 Å

(C) 100Å (D) 1000 Å

Q.3 Which of the following statement is correct in connection with hydrogen spectrum

(A) The longest wavelength in the Balmer series is longer than the longest wavelength in Lyman series

(B) The shortest wavelength in the Balmer series is shorter than the shortest wavelength in the Lyman series

(C) The longest wavelength in both Balmer and Lyman series are equal

(D) The longest wavelength in Balmer series is shorter than the longest wavelength in the Lyman series.

Q.4 N^{th} level of Li^{2+} has the same energy as the ground state energy of the hydrogen atom. If r_N and r_1 be the radius of the N^{th} Bohr orbit of Li^{2+} and first orbit radius of H atom respectively, then the ratio (r_N/r_i) is

(A) 9 (B) 1/9

(C) 3 (D) None

Q.5 In a hydrogen like atom, energy required to excite the electron from its first excited state to second excited state is 7.55 eV. The energy required to remove the electron from its ground state is

(A) 72.6 eV (B) 67.9 eV

(C) 58.6 eV (D) 54.4 eV

Q.6 The ratio of the binding energies of the hydrogen atom in the first and the second excited states is :

(A) 1/4 (B) 4

(C) 4/9 (D) 9/4

Q.7 An α-particle and a free electron, both initially at rest combine to form a He^+ ion in its ground state with the emission of a single photon. the energy of the photon is

(A) 54.4 eV (B) 27.2 eV

(C) 13.6 eV (D) 40.8 eV

Q.8 An electron orbiting around the nucleus of an atom

(A) has a magnetic dipole moment.

(B) exerts an electric force on the nucleus equal to that on it by the nucleus.

(C) does produce a magnetic induction at the nucleus.

(D) has a net energy inversely proportional to its distance from the nucleus.

Q.9 The difference between the longest wavelength line of the Balmer series and shortest wavelength line of the Lyman series for a hydrogenic atom (Atomic no. Z) equal to $\Delta\lambda$. The value of the Rydberg constant for the given atom is

(A) $\frac{5}{31}\frac{1}{\Delta\lambda\cdot Z^2}$ (B) $\frac{5}{36}\frac{Z^2}{\Delta\lambda}$

(C) $\frac{31}{5}\frac{1}{\Delta\lambda\cdot Z^2}$ (D) none

Q.10 Hydrogen atom emits blue light when it changes from n = 4 energy level to n = 2 level. Which colour of the light would the atom emit, when it changes from n = 5 level to n = 2 level?

(A) Red (B) Yellow

(C) Green (D) Violet

ANSWERS

(1) (C) **(2)** (B) **(3)** (A)

(4) (C) **(5)** (D) **(6)** (D)

(7) (A) **(8)** (ABCD) **(9)** (C)

(10) (D)

PHOTO ELECTRIC EFFECT

PHOTONS

Photon is a packet of energy emitted from a source of radiation. Photons are carrier particle of electromagnetic interaction. Photons travel is straight lines with speed of light c = 3 × 10^8 m/s. The energy of photons is given as

$$E = h\nu = \frac{hc}{\lambda} = mc^2$$

where ν is frequency, λ is wavelength, h is Planck's constant.

The effective or motional mass of photon is given as

$$m = \frac{E}{c^2} = \frac{h\nu}{c^2} = \frac{h}{\lambda c}$$

The momentum of a photon is given as

$$p = mc = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$$

Photons are electrically neutral. They are not deflected by electric and magnetic fields.

If E is the energy of source in joule then number of photons emitted is $n = \frac{\text{total energy radiated}}{\text{energy of each photon}} = \frac{E}{h\nu} = \frac{E\lambda}{hc}$

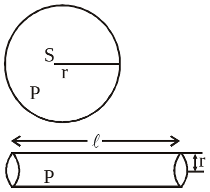
Intensity of photons is defined as amount of energy carried per unit area per unit time or power carried per unit area

$$\text{Intensity } (I_p) = \frac{\text{Energy}}{\text{area} \times \text{time}} = \frac{\text{Power}}{\text{area}},$$

$$I_p = nh\nu = \frac{N}{4\pi r^2}P$$

where n = number of photons per unit area per unit time

N = number of photons, P = power of source



e.g. (a) For a point source $I_p = nh\nu = \frac{N}{4\pi r^2}P$

(b) For a line source $I_p = nh\nu = \frac{N}{2\pi r\ell}P$

Force due to radiation (Photon) (no transmission)

(i) When light is incident perpendicularly

(a) Completely absorbing surface ,

$$(a = 1, r = 0) \quad F = \frac{IA}{c}, \text{ Pressure} = \frac{I}{c}$$

where a = absorption coefficient, r = reflection coefficient

(b) Completely reflecting surface, (a = 0, r = 1)

$$F = \frac{2IA}{c}, \quad P = \frac{2I}{c}$$

(c) When 0 < r < 1 and a + r = 1, $F = \frac{IA}{c}(1+r)$, $P = \frac{I}{c}(1+r)$

(ii) When light is incident at an angle θ with vertical

(a) Completely absorbing surface,

$$F = \frac{IA\cos q}{c}, \quad P = \frac{F\cos q}{A} = \frac{I}{c}\cos^2 q$$

(b) Completely reflecting surface,

$$F = \frac{2IA\cos^2 q}{c}, \quad P = \frac{2I\cos^2 q}{c}$$

(c) When 0 < r < 1 and a + r = 1, $P = \frac{I\cos^2 q}{c}(1+r)$

Example 5 :

Find the number of photons in 6.62 joule of radiation energy of frequency 10^{12} Hz?

Sol. No. of photons $n = \frac{E}{h\nu} = \frac{6.62}{6.62 \times 10^{-34} \times 10^{12}} = 10^{22}$

Example 6 :

Calculate the energy and momentum of a photon of wavelength 6600Å.

Sol. Energy of photon

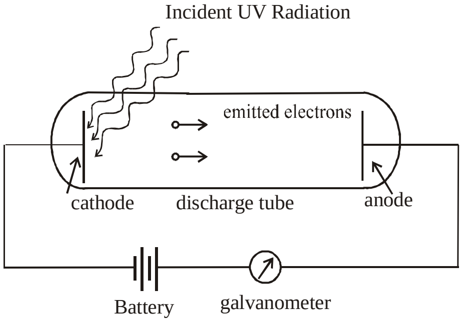
$$E = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{6600 \times 10^{-10}} = 3 \times 10^{-19}\,\text{J}$$

Momentum of photon

$$p = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{6600 \times 10^{-10}} = 10^{-27}\,\text{kg m/sec}$$

HISTORICAL FACTS ABOUT PHOTO ELECTRIC EFFECT

In 1887 Hertz observed that when UV radiation falls on cathode of an electric discharge tube then conduction takes place easily. This shows that electrons are ejected from a metal surface when irradiated by radiation of suitable wavelength. In 1888 Hallwach confirmed these observations. He found that **(a)** When UV radiation fall on a negatively charged cathode there was loss of negative charge and a current was recorded in galvanometer.



(b) When UV radiations fall on an uncharged plate ; it acquired a positive charge and current was recorded in galvanometer.

(c) When UV radiations fall on a positively charged anode no current was recorded in galvanometer.

Lenard explained these observations as

(a) When UV radiations fall on negatively charged cathode electrons are ejected causing a loss in negative charge. Similarly when they fall on uncharged plate electrons are ejected making it positively charged. In both cases electrons when reach the anode cause current to flow.

(b) When UV radiations fall on positively charged anode electrons are emitted but they are unable to reach cathode due to negative charge so no current flows.

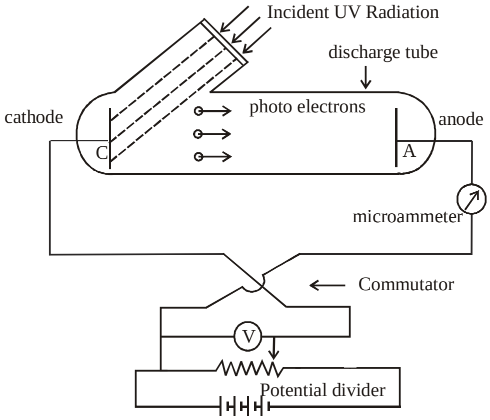
Photo electric effect : The phenomenon of emission of electrons from the surface of metal when light of suitable frequency falls on it is called photo electric effect.

1. The ejected electrons are called photo electrons
2. The current produced due to emitted electrons is called photo current.
3. Photo electric effect proves quantum nature of radiation.
4. The classical electromagnetic theory fails to explain photo electric effect.
5. Einstein explained photo electric effect using quantum nature of radiation .
6. Hallwach is credited with discovery of photo electric effect.

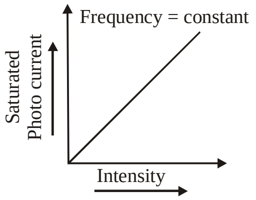
EXPERIMENTAL STUDY OF PHOTO ELECTRIC EFFECT

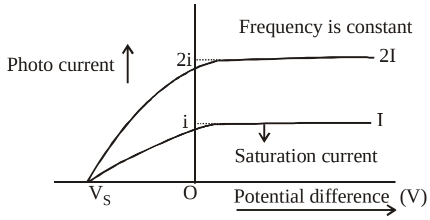
Effect of intensity of incident radiation :

(a) The number of incident photons per second on a metal plate is called intensity of incident radiation.



(b) For a fixed incident frequency the saturation photo current is directly proportional to intensity of incident radiation.





e.g. when intensity of radiation is doubled at constant frequency saturation photo current is also doubled.

(c) **Saturation current** When all photo electrons produced reach anode the photo current becomes maximum and is independent of applied potential difference. This current is called saturation or maximum current .

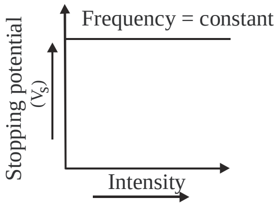
Effect of potential :

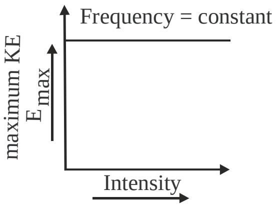
(a) When polarity of electrodes is reversed with commutator the current is reduced but does not become zero. This shows that emitted photo electrons have kinetic energy.

(b) The negative potential of anode at which the photo current becomes zero is called stopping potential (V_S). At this potential the electrons with maximum kinetic energy are stopped from reaching the anode.

(c) No photo current is produced even on increasing the intensity of incident radiation when anode is at stopping potential. Thus stopping potential is independent of intensity of incident radiation.

(d) The stopping potential is a measure of maximum kinetic energy of photo electrons. $E_{max} = eV_S$

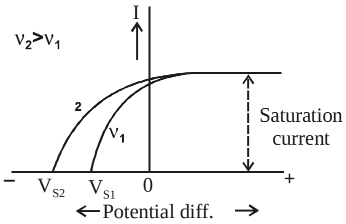


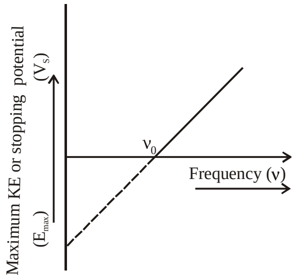


Effect of frequency of incident radiation :

Threshold frequency The minimum frequency of incident radiation which can eject photo electrons from a metal is known as threshold frequency (ν_0).

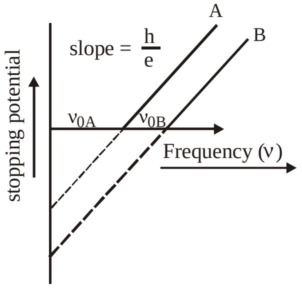
At stopping potential if frequency of incident radiation is increased then current starts flowing again. This can be made zero by increasing stopping potential. Thus maximum kinetic energy of photo electron or stopping potential increases with increase in frequency of incident radiation. The maximum kinetic energy of photo electron increases linearly with increase in frequency of incident light.





Effect of material of cathode :

The stopping potential, work function and threshold frequency depend on nature of material of cathode.



Work function : The minimum energy required for emission of electrons from a metal is called work function work function $\phi = h\nu_0$ where ν_0 is threshold frequency.

LAWS OF PHOTOELECTRIC EMISSION

1. For a given metal and frequency of incident radiation the number of photo electrons emitted per second is directly proportional to intensity of incident radiation.

2. For a given a metal there is a minimum frequency of incident radiation below which no photon emission is possible. This is called threshold frequency (ν_0).

3. Above threshold frequency the maximum kinetic energy of emitted photo electron is independent of intensity of incident radiation but is directly proportional to frequency of incident radiation.

4. The photo electric emission is an instantaneous process. The time lag between incidence of radiation and emission of photo electrons is less than 10^{-9} second.

EINSTEIN'S PHOTO ELECTRIC EQUATION

Einsten explained photo electric effect using quantum nature of radiation .

Emission of a photo electron is a result of interaction of one photon with a loosely bound electron in which photon is completely absorbed by electron.

Some part of incident energy equal to work function is used to remove an electron from metal and remaining is given to electron as its kinetic energy.

$$h\nu = W + E_{max} = W + \frac{1}{2}mv^2_{max} = h\nu_0 + \frac{1}{2}mv^2_{max}$$

$$\frac{1}{2}mv^2_{max} = h(\nu - \nu_0) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = eV_S \qquad ...(1)$$

equation 1 is called Einstein photo electric equation.

maximum velocity of emitted electron

$$v_{max} = \sqrt{\frac{2h(\nu - \nu_0)}{m}} = \sqrt{\frac{2hc(\lambda_0 - \lambda)}{m\lambda\lambda_0}} = \sqrt{\frac{2eV_s}{m}}$$

The stopping potential $V_S = \frac{h(\nu - \nu_0)}{e} = \frac{hc(\lambda_0 - \lambda)}{e\lambda\lambda_0}$

The Einstein's photo electric equation is in accordance with conservation of energy. Here light energy is converted into electric energy.

The equation explains the laws of photo electric emission.

(a) The increase in intensity increases the number of photons with same energy hν. So number of photo electrons will proportionally increase.

(b) If $\nu < \nu_0$ then KE will become negative which is not possible so in this condition photoemission is not possible.

(c) If $\nu > \nu_0$ Then KE $\propto (\nu - \nu_0)$ so maximum kinetic energy or stopping potential increases linearly with frequency of incident radiation.

Note :

1. In photoelectric effect all photoelectrons do not have same kinetic energy. Their KE ranges from zero to E_{max} which depends on frequency of incident radiation and nature of cathode.

2. The photo electric effect takes place only when photons strike bound electrons because for free electrons energy and momentum conservations do not hold together.

3. Cesium is the best photo sensitive material.

4. Efficiency of a photoemission

$$\eta = \frac{\begin{array}{c}\text{Number of photo electrons emitted}\\ \text{per unit area per unit time}\end{array}}{\begin{array}{c}\text{Number of photons incident}\\ \text{per unit area per unit time}\end{array}} = \frac{n_e}{n_p}$$

$$\eta = \frac{\text{Intensity of emitted electrons}}{\text{Intensity of incident radiation}} = \frac{I_e}{I_p} \quad \text{i.e.,} \quad \eta = \frac{n_e}{n_p} = \frac{I_e}{I_p}$$

Example 7 :

Light of wavelength 3500 A° is incident on two metals A and B. Which metal will emit photoelectron if their work functions are 4.2 eV and 1.9 eV respectively?

Sol. Energy of incident light

$$E = h\nu = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{3500 \times 10^{-10} \times 1.6 \times 10^{-19}} \text{eV} = 3.546 \text{ eV}$$

Incident light will eject electrons if E > ϕ (work function) since E > ϕ_B (1.9 eV) so metal B will emit photo electrons.

Example 8 :

Find frequency of light which ejects electrons from a metal surface fully stopped by a retarding potential of 3 volt. The photoelectric effect begins at a frequency of 6 × 10^{14} Hz. Find work function of metal.

Sol. $\frac{1}{2}mv^2_{max} = eV_S$, $\qquad h\nu = h\nu_0 + eV_S$

$$\text{So } \nu = \nu_0 + \frac{eV_S}{h} = 6 \times 10^4 + \frac{1.6 \times 10^{-19} \times 3}{6.62 \times 10^{-34}} = 13.25 \times 10^{14} \text{Hz}$$

work function

$$\phi = h\nu_0 = \frac{6.62 \times 10^{-34} \times 6 \times 10^{14}}{1.6 \times 10^{-19}} = 2.48 \text{ eV}$$

Example 9 :

Lithium has a work function of 2.3 eV. It is exposed to light of wavelength 4.8×10^{-7} m. Find maximum KE of photo electron and what is the longest wavelength which can produce them.

Sol. $E_{max} = h\nu - h\nu_0 = h\nu - \phi = \frac{hc}{\lambda} - \phi$

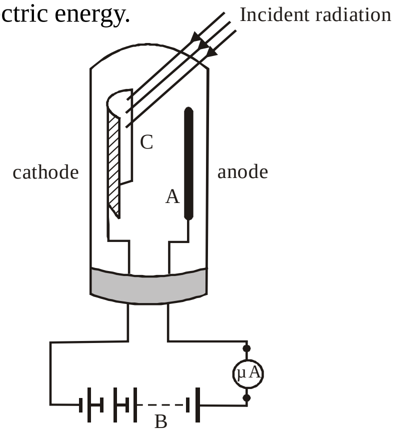
$$= \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{4.8 \times 10^{-7} \times 1.6 \times 10^{-19}} - 2.3 = 0.28\,\text{eV}$$

For longest wavelength $\frac{hc}{\lambda} = \phi$

or $\lambda = \frac{hc}{\phi} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{2.3 \times 1.6 \times 10^{-19}} = 5.38 \times 10^{7}\,\text{m}$

PHOTO ELECTRIC CELL

A photoelectric cell is device which converts light energy into electric energy.



This is a device which works on principle of photo electric effect. It consists of a semicylindrical plate coated with a photo sensitive material of low work function which works as cathode. The anode is in form a wire. The area of anode is very small as compared to cathode. Inside the photo cell an inert gas is filled in it. Electrons are emitted from photo sensitive surface when light falls on it. The photo current depends on

a. Potential difference between electrodes. On increasing the voltage the photocurrent first increases and then becomes constant.
b. Intensity of incident light.
c. Nature of surface producing photoelectron.
d. Distance of photo cell from the source. If the source is at a distance r from the photo cell then the saturated photo current (I) is inversely proportional to square of distance from the source $I \propto \frac{1}{r^2}$

The different type of photo cells are

a. **Photo emissive cell :** These work on photo electric effect
b. **Photo conducting cell :** This is based on increase of electrical conductivity of material like selenium when they are exposed to light e.g. LDR (light dependent resistance)
c. **Photo voltaic cell :** When the region of contact between two specially prepared conducting surfaces is illuminated a current begins to flow. e.g. photo diode

Applications of photo electric cells :

1. Photocells are used in television cameras for telecasting scenes and photo telegraphy
2. Photocells are used in reproduction of sound in motion pictures.
3. Photocells are used to switch on and off the street lights automatically.
4. These are used to obtain electric energy from sun light during space travel.
5. These are used to control temperature in furnaces and chemical reactions.
6. These are used in fire and burglar's alarm, to open and close the doors automatically and in counting devices
7. These are used to compare illuminating power of two sources.
8. Photocells are used to detect opacity of solids, defects in materials etc.

TRY IT YOURSELF - 2

Q.1 When a certain metallic surface is irradiated with monochromatic light wavelength λ, the stopping potential for photoelectric current is $3V_0$. When the same surface is irradiated with light of wavelength 2 λ, the stopping potential is V_0. The threshold wavelength for the given surface is

(A) 4 λ (B) 6 λ
(C) 8 λ (D) 4 λ / 3

Q.2 If the surface of a metal is successfully exposed to radiation of $\lambda_1 = 350$ nm and $\lambda_2 = 450$ nm the maximum velocity of photoelectrons will differ by a factor 2. The work function of this metal is

(A) 2.84×10^{-19} J (B) 1.6×10^{-19} J
(C) 3.9×10^{-19} J (D) 2.4×10^{-19} J

Q.3 A metal begins emitting photoelectrons with green light. It will also give photoemission with

(A) blue light (B) yellow light
(C) orange light (D) red light

Q.4 Polychromatic light described at a place by the equation $E = 100\,[\sin(0.5\pi \times 10^{15}t) + \cos(\pi \times 10^{15}t) + \sin(2\pi \times 10^{15}t)]$ where E is in V/m and t in sec, falls on a metal surface having work function 2.0 eV. The maximum kinetic energy of the photoelectron is

(A) zero (B) 1 eV
(C) 2 eV (D) 3 eV

[Take h = Planck's constant = 6.4×10^{-34} J-s]

Q.5 If c is the velocity of electromagnetic radiation
e is the charge of an electron
m is the mass of an electron and
h is the Planck's constant,
then the combination of these universal constants that is dimensionless, is

(A) $me^2/(hc)$ (B) $ch/(me)$
(C) mc^2/h (D) none

Q.6 A beam of fast moving electrons having cross-sectional area A falls normally on a flat surface. The electrons are absorbed by the surface and the average pressure exerted by the electrons on this surface is found to be P. If the electrons are moving with a speed v, then effective current through any cross-section of the electron beam is

(A) APe / (mv) (B) APe / (mv^2)

(C) APv / (me) (D) APm / (eV)

Q.7 Photons are incident from vacuum on a transparent material with a refractive index n for a given wavelength. Determine the momentum of the incident photon, if its wavelength in the material is equal to λ.

(A) nh/λ (B) h/λ

(C) h / nλ (D) h / λ (n+1)

Q 8 An LED is made from semiconducting material having a band gap of 1.1eV. What type of radiation does the LED emit?

(A) Ultraviolet (B) Blue light

(C) Red light (D) Infrared

Q.9 Which of the following are not dependent on the intensity of the incident radiation in a photoelectric experiment?

(A) Amount of photoelectric current.

(B) Stopping potential to reduce the photoelectric current to zero.

(C) Work function of the surface.

(D) Maximum kinetic energy of photoelectrons.

Q.10 Which of the properties should be in metal for thermoionic emission:

(A) low melting point & high work function

(B) high melting point & low work function

(C) high melting point & high work function

(D) low melting point & low work function

ANSWERS

(1) (A)	**(2)** (C)	**(3)** (A)
(4) (C)	**(5)** (D)	**(6)** (A)
(7) (C)	**(8)** (D)	**(9)** (BCD)
(10) (B)		

RADIOACTIVITY

The phenomenon of spontaneous emission of radiations from a substance is called radioactivity. Radioactivity was discovered by Henry Becquerel in 1896 in Uranium salts. The substances like Uranium, Radium, Thorium, Polonium etc. which show radioactivity are called radioactive substances. Nuclei with Z > 83 spontaneously disintegrate with emission of α and β particles. In radioactivity emission of alpha (α), Beta (β) and gamma (γ) radiation takes place. These are called radioactive radiations or Becquerel rays. The simultaneous emission of α and β particles is not possible. Only one particle is emitted at a time. Radioactivity is a nuclear phenomenon. α, β and γ radiations originate from the nucleus. The electronic configuration is unaffected in radioactivity.

The emission of radiations causes a change in structure of nucleus. This causes transformation of an atom to new lighter atom or changes a radioactive element into element of lower atomic weight. All heavier radioactive elements emit radiations till they are converted to stable $_{82}Pb^{206}$. Radioactivity is a statistical process, so it is governed by the laws of probability. The disintegration of all atoms has equal probability.

Radioactivity is a spontaneous process which is independent of all external conditions. It is not affected by temperature, pressure, electric or magnetic field.

TYPE OF RADIOACTIVE PROCESSES

A. Alpha decay

$$_ZX^A \text{ (parent nucleus)} \longrightarrow {}_{Z-2}Y^{A-4} \text{ (daughter nucleus)} + {}_2He^4 \text{ (alpha particle)}$$

e.g. $_{92}U^{238} \longrightarrow {}_{90}Th^{234} + {}_2He^4$

Alpha particle consists of 2 neutrons, 2 protons and carries positive charge in magnitude 2 electrons. It is doubly ionized helium nuclei. α emission takes place when size of nucleus becomes too large. The decay reduces the size of nucleus. α emission is explained on basis of quantum mechanical tunnel effect. The energy released in α decay

$Q = (M_x - M_y - M_\alpha)\, c^2$

The kinetic energy of α particle $E_\alpha = \left(\frac{A-4}{A}\right) Q$, where A is mass number and Q is disintegration energy

B. Beta decay

(a) Electron emission ($^{-}$)

$$_ZX^A \longrightarrow {}_{z+1}Y^A + {}_{-1}e^0 \,(\beta^- \text{ particle}) + \bar{\nu}$$

e.g. $_6C^{14} \longrightarrow {}_7N^{14} + {}_{-1}e^0 + \bar{\nu}$ (antineutrino)

β^- particles are fast moving electrons carrying negative charge. β^- particles are emitted when nucleus has too many neutrons relative to number of protons i.e. N/Z ratio is larger than required. The emission of electron takes place when a neutron is converted to proton inside the nucleus. This helps in correction of N/Z ratio.

$$_0n^1 \longrightarrow {}_1p^1 + {}_{-1}e^0 + \bar{\nu}$$

The interaction responsible for β decay is weak interaction.

(b) Positron emission

$$_ZX^A \longrightarrow {}_{Z-1}X^A + {}_{+1}e^0 \,(\beta^+ \text{ particle}) + \nu$$

eg. $_{29}Cu^{64} \longrightarrow {}_{28}Ni^{64} + {}_{+1}e^0 + \nu$ (neutrino)

β^+ particles are positrons with mass equal to an electron but carry a unit positive charge. β^+ particles are emitted when nucleus has too many protons relative to number of neutrons i.e. N/Z ratio is smaller than required. The emission of positron takes place when a proton is converted to neutron inside the nucleus. This increases N/Z ratio .

$_1p^1 = {}_0n^1 + {}_{+1}e^0 + \nu$

(c) Gamma decay

$$_ZX^{A*} \longrightarrow {}_ZX^A + \gamma$$

e.g. $_5B^{12} \longrightarrow {}_6C^{12*} + {}_{-1}e^0 + \bar{\nu}$

$${}_6C^{12*} \longrightarrow {}_6C^{12} + \gamma$$

γ rays are electromagnetic radiations which are chargeless and massless. γ rays are emitted when nucleus has excess energy. γ rays are emitted when nucleus jumps from excited state to lower level or ground state. This reduces the energy of nucleus. γ rays are electromagnetic radiations of short wavelength (~ 10^{-12}m) which travel with speed of light.

(d) Electron capture

$${}_ZX^A + {}_{+1}e^0 \longrightarrow + {}_{z-1}Y^A + \nu$$

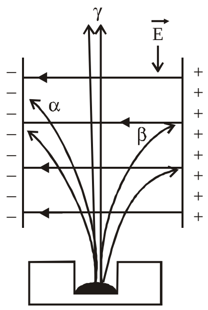
$${}_4Be^7 + {}_{-1}e^0 \longrightarrow {}_3Li^7 + \nu$$

This process takes place when nucleus has too many protons relative to number of neutrons. i.e. N/Z ratio is larger than required. This process occurs when a parent nucleus captures one of its own orbital atomic electron and emits a neutrino.

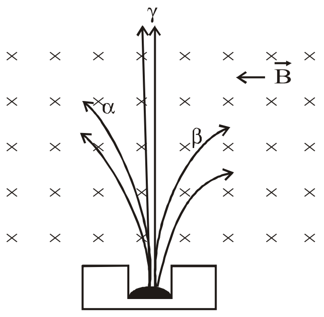
COMPARISON OF PROPERTIES OF ~, :AND ¥ RADIATIONS

Property	~– rays	:– rays	¥– rays
1. Nature	These are doubly ionized helium atom ${}_2He^4$ charge q = +2e = 3.2 × 10^{-19}C mass m = 2p + 2n = 4amu = 4 × 1.6 × 10^{-27} kg	These are beam of fast moving electrons (β^-) and positions (β^+) charge β^-=–e=–1.6×10^{-19}C β^+ =+e =1.6×10^{-19}C m (β^-) =m(β^+)=9.1×10^{-31} kg	These are electromagnetic radiations of high frequency and travel in form of photons. charge q = 0 (chargeless) rest mass = 0 effective mass = $\frac{hn}{c^2} = \frac{h}{l\,c}$
2. Velocity	Speed ranges between 1.4 × 10^7 to 2.20 × 10^7 m/s $v_\alpha \sim 0.05$ c	speed ranges from 1% to 90% of velocity of light $v_\beta \sim 0.9$c	speed equals velocity of light v_γ = c
3. Ionising power	These have maximum ionizing power (1000)	There ionizing power is less than α particles and more than γ rays (100)	There ionizing power is least (1)
4. Penetration power	The penetration power is smallest. Can only penetrate through 0.01 mm thick Al sheet (1)	Penetration power is about 100 times that of α rays, can penetrate through 1 mm thick Al sheet (100)	Penetration power is very large. Can penetrate about 30 cm thick Al sheet (10000)
5. Range	Range is very small (few cms in air)	Range is more than α rays. (few meters in air)	Range is very large (many hundreds of meter is air)
6. Nature of spectrum	Line spectrum	continuous spectrum	line spectrum
7. Interaction with matter	produces heat	produces heat	produces photoelectric effect Compton effect, pair production
8. Effect of electric and magnetic field	Suffers small deflection	suffers large deflection	pass undeflected
9. Effect of photo graphic plate a nd ZnS	Affects photographic plate and produces fluorescense	Affects photographic plate and produces fluorescence	Affects photographic plate and produces fluorescence.

Behaviour in electric and magnetic field :



Behaviour in E-field



Behaviour in B-field

RADIOACTIVE DECAY LAW

The rate of decay (number of disintegrations per second) is proportional to number of radioactive atoms (N) present at that time t. Rate of decay $\frac{-dN}{dt} \propto N$ or $\frac{dN}{dt} = -\lambda N$

or $N = N_0 e^{-\lambda t}$ ...(1)

where λ is disintegration constant, N_0 = number of active atoms at t = 0.

Equation one is the radioactive decay law. It shows that number of active nuclei decreases exponentially with time.

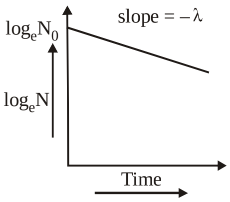
Note :

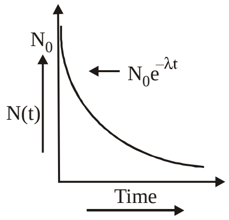
1. The fraction of active atoms remaining at time t is

$$\frac{N}{N_0} = e^{-\lambda t}$$

2. The number of atoms that have decayed in time t is

$$N_0 - N = N_0 (1 - e^{-\lambda t})$$





3. The fraction of atoms that have decayed in time t is

$$\frac{N_0 - N}{N_0} = 1 - e^{-\lambda t}$$

DECAY CONSTANT

Decay constant is rate of decay of radioactive atoms per active atom.

$$\lambda = \frac{-dN/dt}{N} = \frac{\text{rate of decay}}{\text{number of active atoms}}$$

Note :

1. At $t = \frac{1}{\lambda}$; $N = \frac{N_0}{e}$

The decay constant of radioactive element is equal to reciprocal of the time after which number of remaining active atoms reduce to 1/e times of original value.

2. At $t = \frac{1}{\lambda}$, fraction of active nuclei left $\frac{N}{N_0} = \frac{1}{e} = 0.37$ or 37%

fraction of decayed nuclei $1 - \frac{N}{N_0} = 0.63 = 63\%$

3. $\lambda = \frac{dN/N}{dt}$. The decay constant is the probability of decay per active atom per unit time.
4. The decay constant depends on nature of radioactive substance and is independent of temperature, pressure, force etc.
5. The decay constant for a stable substance is zero
6. Unit of decay constant is second^{-1} and dimension is T^{-1}
7. If their are more than one radioactive elements in a group then the resultant decay constant is equal to sum of individual decay constants

$$\lambda = \lambda_1 + \lambda_2 + \lambda_3 + \text{.................or} \quad \frac{1}{T} = \frac{1}{T_1} + \frac{1}{T_2} + \text{........}$$

HALF LIFE

The time in which number of radioactive atoms reduce to half of its initial value is known as half life i.e. at $t = T, N = \frac{N_0}{2}$

from radioacitve decay law $\frac{N_0}{2} = N_0 e^{-\lambda T}$ or $T = \frac{0.693}{\lambda}$

Note :

1. The half life depends on nature of radioactive elements.
2. The half life of an element indicates the rate of decay. When half life is large rate of decay is small.
3. After $t = nT$ number of active atoms left

$$N = \frac{N_0}{2^n} = \frac{1}{2^{t/T}} . N_0$$

where T = half life and n = number of half lives.

4. Number of radioacitve atoms decayed in n half lives

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

5. Half life for a given radioactive substance is constant. It does not change with time. It is unaffected by pressure, temperature etc.

Example 10 :

How long will it take for a radioacitve sample to decrease to 10%, it its half life is 22 years?

Sol. Using $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ we get $\left(\frac{1}{2}\right)^{t/22} = \frac{10}{100}$

or $10 = 2^{t/22}$ or $\log_{10} 10 = \frac{t}{22} \log_{10} 2$

$$t = \frac{22 \log_{10} 10}{\log_{10} 2} = \frac{22 \times 1}{0.3010} \approx 73 \text{ years.}$$

Example 11 :

What is the decay constant of a radioactive substance whose half life is 5 hours

Sol. $\lambda = \dfrac{0.693}{T} = \dfrac{0.693}{5 \times 3600} = 3.85 \times 10^{-5}$ per sec

Example 12 :

The amount of active substance reduces to 1/64 of its initial value in 15 hours. What is the half life?

Sol. using $\dfrac{N}{N_0} = \left(\dfrac{1}{2}\right)^{t/T}$ or $\dfrac{1}{64} = \left(\dfrac{1}{2}\right)^{15/T}$

or $\left(\dfrac{1}{2}\right)^{6} = \left(\dfrac{1}{2}\right)^{15/T}$ so $\dfrac{15}{T} = 6$ or $T = 2.5$ hour

AVERAGE OR MEAN LIFE (^{2})

The life time of various atoms in a radioactive substance ranges from 0 to infinity. The mean life of an atom in a radioactive substance is called average life of radioactive substance.

$$\text{Mean life, } \tau = \frac{\text{the sum of lives of all active atoms}}{\text{total number of active atoms}}$$

$$\text{or} \quad \tau = \frac{\int_0^{N_0} t\,dN}{N_0} = \frac{N_0\lambda \int_0^{N_0} t\,e^{-\lambda}dt}{N_0} = \frac{1}{\lambda}$$

Thus mean life is equal to reciprocal of decay constant $(\tau = 1/\lambda)$. Half life $T = \dfrac{0.693}{\lambda} = 0.693\tau$

and average life, $\tau = \dfrac{T}{0.693} = 1.44T$

$\tau > T$ i.e. average life is greater than half life.

Mean life of a radioactive substance is constant. It does not change with temperature or pressure.

From $N = N_0e^{-\lambda t}$

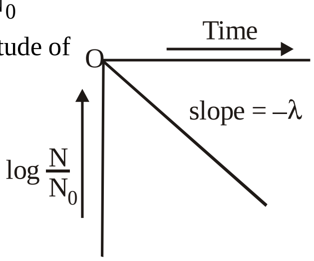
At $t = \tau = \dfrac{1}{\lambda}$; $N = \dfrac{N_0}{e} = 0.37N_0$

So mean life is the time in which (a) number of active atoms reduces to 37% of its initial value

OR (b) number of decayed atoms is 63%

$N = N_0e^{-\lambda t}$ so $\log\dfrac{N}{N_0} = -\lambda t$

Mean life is equal to magnitude of reciprocal of slope of $\log\dfrac{N}{N_0}$ v/s t curve.



Example 13 :

One gram of Radium emits 3.7×10^{10} α particles per second. Calculate half life and mean life of Radium. Given Atomic mass of Radium = 226

Sol. Rate of decay of Radium = rate of emission of α particles

or $\dfrac{-dN}{dt} = \lambda N = 3.7 \times 10^{10}$ per second

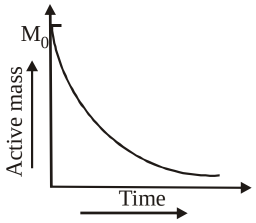
Number of active atoms $N = \dfrac{6.023 \times 10^{23} \times 1}{226}$

$\therefore \quad \lambda N = \dfrac{0.693}{T} \times \dfrac{6.023 \times 10^{23}}{226} = 3.7 \times 10^{10}$

or $T = 1583$ years

Mean life $\tau = 1.44\,T = 1.44 \times 1580 = 2279$ years

DECAY OF ACTIVE MASS



The mass of radioactive substance (m) $\propto$ number of active atoms (N). So $N = N_0e^{-\lambda t}$ becomes $M = M_0e^{-\lambda t}$

Mass of radioactive substance decreases exponentially with time. The time in which mass of active substance is reduced to half is known as half life.

$$\frac{M}{M_0} = \left(\frac{1}{2}\right)^{t/T}$$

Mean life is the time in which mass reduces to 37% of its initial value. Number of active atoms is given mass M in grams is $n = \dfrac{6.023 \times 10^{23} \times M}{A}$, where A is mass number

Example 14 :

If a radioactive material contains 0.1 mg of Th^{234} how much of it will remain unchanged after 120 days. Given Half life is 24 days.

Sol. Using $\dfrac{M}{M_0} = \left(\dfrac{1}{2}\right)^{t/T} = \left(\dfrac{1}{2}\right)^{120/24} = \left(\dfrac{1}{2}\right)^{5} = \dfrac{1}{32}$

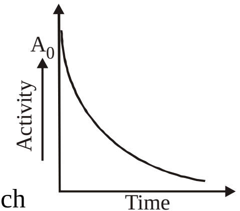
So $M = \dfrac{M_0}{32} = \dfrac{0.1\text{ mg}}{32} = 3.125\ \mu g.$

ACTIVITY

The number of decays per unit time or decay rate is called activity. Activity $A = \dfrac{dN}{dt}$

$= N_0\lambda\, e^{-\lambda t} = A_0e^{-\lambda t} = N\lambda$

where $N_0\,\lambda = A_0$ is initial activity



$A = A_0e^{-\lambda t}$ is the activity law which shows activity decreases exponentially with time. Activity is proportional to number of active atoms ($A \propto N$) which depends on mass of radioactive sample.

The activity of one gram of radioactive substance called specific activity. Half life is the time in which activity of radioactive substance is reduced to half. Mean life is the time in which the activity reduces to 37% of the original value.

The variation of Activity with time is $\frac{A}{A_0} = \left(\frac{1}{2}\right)^{t/T}$

where T is half life.

Units of activity

Curie : The specific activity of 1 gm of Radium 226 is called one curie.

1 curie = 3.7×10^{10} disintegrations per second

Rutherford 1 rutherford = 10^6 disintegrations per second

Becquerel 1 Becquerel = 1 disintegration per second

Example 15 :

Determine the amount of Th^{227} required to produce an activity of 1 milli Curie if its half life is 1.9 years.

Sol. A = 1 milli curie = 3.7×10^7 disintegration /sec

$$\lambda = \frac{0.693}{T} = \frac{0.693}{1.9 \times 365 \times 24 \times 60 \times 60}$$

number of active atoms = $\frac{6.023 \times 10^{23}}{227} m$ (where m is mass)

$A = \lambda N$

$$\text{or} \quad 3.7 \times 10^7 = \frac{0.693}{1.9 \times 365 \times 24 \times 60 \times 60} \times \frac{6.023 \times 10^{23}}{227} m$$

$$\text{or} \quad m = \frac{3.7 \times 10^7 \times 1.9 \times 365 \times 24 \times 60 \times 60 \times 227}{0.693 \times 6.023 \times 10^{23}} = 1.206 \mu g$$

Example 16 :

For a radioactive sample the counting rate changes from 6520 counts/minute to 3260 counts/minute in 2 minutes. Determine the decay constant.

Sol. At time t = 0 $\quad A_0 = \frac{dN_0}{dt}$ and at time t $\quad A = \frac{dN}{dt}$

$$\frac{A}{A_0} = \frac{dN/dt}{dN_0/dt} = \frac{3260}{6520}$$

from activity law $A = A_0 e^{-\lambda t}$

$$e^{\lambda t} = \frac{A_0}{A} \quad \text{or} \quad \lambda = \frac{2.303}{t} \log \frac{A_0}{A}$$

$$\lambda = \frac{2.303}{2 \times 60} \log 2 = \frac{2.303}{2 \times 60} \times 0.3010 = 5.78 \text{ per sec}$$

SODDY AND FAJAN'S DISPLACEMENTS LAWS

1. **For ~-decay :** When an element emits an α particle, the new element has mass number A reduced by 4 and atomic number Z reduced by 2. The new element is displaced by two places on left in periodic table.

$${}_Z X^A \longrightarrow {}_{Z-2} Y^{A-4} + {}_2 He^4$$

2. For ¯ **decay :** When an element emits a β^- particle the mass number A remains unchanged and atomic number Z is increased by 1 . The new element is displaced by one place on right in periodic table

$${}_Z X^A \longrightarrow {}_{Z+1} Y^A + {}_{-1} e^0 + \text{antineutrino} \, (\bar{\nu})$$

3. **For $^{+}$ decay :** When an element emits a β^+ particle the mass number remains unchanged and atomic number Z is decreased by one. The new element is displaced by one place on left in periodic table

$${}_Z X^A \longrightarrow {}_{Z-1} Y^A + {}_{+1} e^0 + \text{neutrino} \, (\nu)$$

4. **For ¥-decay :** When an element emits a γ particle the mass, charge or position of element in periodic table remains unchanged. Here the excited nucleus returns to ground state by emission of γ ray photon.

Example 17 :

How many α and β particles are emitted when ${}_{90}Th^{232}$ converts to ${}_{82}Pb^{208}$.

Sol. Change in mass number $\Delta A = 232 - 208 = 24$

A changes only in α decay so number of α particles= $\frac{24}{4} = 6$

This decreases Z by 6 × 2 = 12 giving final Z = 90 – 12 = 78

But final Z given is 82. β^- emission increases Z by 1 so no. of β^- particle = 82 – 78 = 4

Example 18 :

A radioactive nucleus decays as

$$X \xrightarrow{\alpha} X_1 \xrightarrow{\beta^-} X_2 \xrightarrow{\alpha} X_3 \xrightarrow{\gamma} X_4$$

If mass number and charge number of X are 180 and 72 then find these values of X_4.

Sol. $${}_{72}X^{180} \xrightarrow{\alpha} {}_{70}X_1^{176} \xrightarrow{\beta^-} {}_{71}X_2^{176}$$

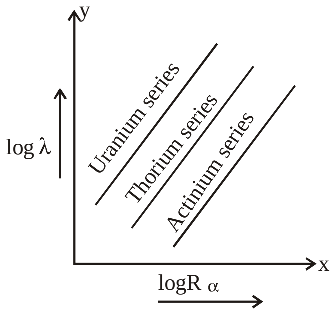
$$\xrightarrow{\alpha} {}_{69}X_3^{172} \xrightarrow{\gamma} {}_{69}X_4^{172}$$

CHARACTERISTICS OF ~-DECAY

1. The spectrum of α particles is discrete line spectrum.
2. The discrete spectrum of α particles shows that nucleus also has discrete energy levels like atoms.
3. All α particles emitted from the same nucleus do not have same energy. They are emitted in different energy groups.
4. α emission is always followed by γ ray emission. The nucleus after α emission is in excited an state so decays back to ground state by γ emission.
5. The α particles loose energy by ionization of gaseous medium.
6. The distance travelled by α particles in a medium before loosing their power of ionization is called Range.
   range $R = 0.318 \, E^{3/2}$ where E is energy of α particle.
   i.e. $R \propto E^{3/2} \propto v^3$ where v is velocity of α particle
7. The range of α particle depends on their energy and nature of medium

8. Geiger and Nuttal showed that larger is the decay constant of radioactive substance larger is the velocity, range and energy of α particle.

- **a.** Geiger and Nuttal experimentally studied a relation between range (or energy) of α particle in air and half life (or decay constant)
- **b.** He found that nuclei with longest half life (or smallest decay constant) emits an α particle of lowest energy.
- **c.** The nuclei with smallest half life (or largest decay constant) emit an α particle of largest energy.
- **d.** The Geiger Nuttal law in empirical form is log $\lambda = a + b \log R_\alpha$, where λ is decay constant, R_α is range of α particles in air and a and b are constants.
- **e.** The constant **b** is same for Uranium, Actinium and Thorium series while **a** is different for each series.
- **f.** The graph between log λ and log R_α are straight lines which are parallel to each other for the three series.



Tunnel Effect :

- **a.** The phenomenon of α emission is explained on the basis of quantum mechanical tunnel effect.
- **b.** The phenomenon of penetration of Coulomb barrier by an α particle even when its energy is less than height of potential barrier (~ 26 MeV for $_{92}U^{238}$) is known as tunnel effect.
- **c.** An α particle may exist as an entity within the heavy nucleus.
- **d.** The α particle is in constant motion and is kept inside the nucleus by Coulomb potential barrier.
- **e.** The α particle makes continuous collisions with barrier surface till conditions are good enough for penetration.
- **f.** In one of the collision it may leak through the barrier and is emitted. This is tunnel effect.
- **g.** In $_{92}U^{238}$ an α particle makes 10^{38} tries to come out i.e. it makes 10^{22} tries per second for 10^{16} seconds or 10^9 years before it is able to come out.

Example 19 :

Determine the disintegration energy of the process

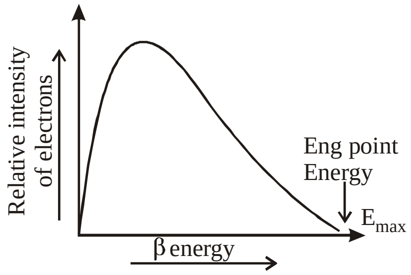
$_{84}P_0^{210} \longrightarrow {}_{82}Pb^{206} + {}_2He^4 + Q$ if an α particle of energy 5.3 MeV is emitted in it.

Sol. Kinetic energy of α particle $E_\alpha = \frac{A-4}{A}Q$

$$\text{So } Q = \frac{A}{A-4}E_\alpha = \frac{210}{210-4} \times 5.3 = 5.40 \text{ MeV}$$

CHARACTERISTICS OF β DECAY

1. The energy spectrum of β particles is continuous i.e. energy of emitted β particle varies continuously between 0 to a maximum value E_{max}



2. The maximum energy of a β particle E_{max} is known as end point energy

3. The end point energy is equal to the energy equivalent to mass difference between parent and daughter nuclide. This energy is later shared by β particle and neutrino.

NEUTRINO HYPOTHESIS

1. The experimental results which could not be explained were

- **(a)** continuous β energy spectrum
- **(b)** neutron is a particle of spin half, so it cannot decay into two particles of spin half i.e. proton and electron
- **(c)** After β emission no change in rest mass energy of nucleus was observed.

These led to violation of law of conservation of angular momentum, linear momentum and energy.

2. To remove these difficulties Pauli postulated emission of third particle neutrino in β emission.

3. Neutrino is a particle with zero rest mass, zero charge and half spin.

4. The energy Q is shared between β particle and neutrino. When neutrino carries maximum energy then energy of β particle is minimum and vice versa

CHARACTERISTICS OF γ DECAY

1. The energy spectrum of gamma rays is a discrete line spectrum.

2. Whey γ rays fall on matter they are absorbed like X-rays. The intensity reduces exponentially with thickness as $I = I_0 e^{-\mu x}$, where μ is absorption coefficient

3. γ rays when interact with matter produce (a) photo electric effect (b) Compton effect (c) pair production.

RADIOACTIVE SERIES

1. The heavy natural nuclides can decay to stable end products by four paths. The four paths have mass numbers given as 4n, 4n + 1, 4n + 2, 4n + 3 where n is integer.
2. Last element of series is stable and has a decay constant zero.

Series	Mass number	Starting isotope	Stable end product	
Thorium	4n	${}_{90}Th^{232}$	${}_{82}Pb^{208}$	Natural
Neptunium	4n+1	${}_{93}Np^{237}$	${}_{83}Bi^{209}$	Artificial
Uranium	4n+2	${}_{92}U^{238}$	${}_{82}Pb^{206}$	Natural
Actinium	4n+3	${}_{92}U^{235}$	${}_{82}Pb^{207}$	Natural

RADIOACTIVE EQUILIBRIUM

When the rate of formation of daughter nuclei becomes equal to rate of its decay then this is called as state of radioactive equilibrium

$$N_A \lambda_A = N_B \lambda_B = \ldots\ldots\ldots\ldots \quad \text{or} \quad \frac{N_A}{T_A} = \frac{N_B}{T_B} = \ldots\ldots\ldots\ldots$$

CARBON DATING/RADIOACTIVE DATING

Radioactive dating is the process of determination of time interval which has passed by making use of radioactive decay of a sample containing radioactive substance.

It helps in calculating age of geological specimens like rocks, biological specimens likes bones of animals or trunk of trees and age of earth.

The isotope of carbon ${}_6C^{14}$ is radioactive. It is formed in atmosphere by bombardment of nitrogen atoms with cosmic rays ${}_7N^{14} + {}_0n^1 \rightarrow {}_6C^{14} + {}_1H^1$

The ${}_6C^{14}$ combines with oxygen to form carbondioxide which is absorbed by plants so concentration of ${}_6C^{14}$ is constant with time.

The living plants and animals have a fixed ratio of ${}_6C^{14}$ to ordinary carbon ${}_6C^{12}$.

When a plant or animal dies the content of ${}_6C^{14}$ decreases while that of ${}_6C^{12}$ remains constant. The ratio of two indicates the time that has passed since death of plant or animal.

The time interval is calculated from the laws of radioactive disintegration

$$t = \frac{1}{\lambda}\log_e \frac{N_0}{N} = \frac{2.303}{\lambda}\log_{10}\frac{N_0}{N} \quad \left(\frac{N_0}{N} = \frac{A_0}{A}\right)$$

where N_o is number of ${}_6C^{14}$ nuclei at time of death, λ is decay constant of ${}_6C^{14}$ and N is number of ${}_6C^{14}$ nuclei currently present in sample.

Example 20 :

The charcoal sample showed a C^{14} activity of 11.3 counts/gm min . The absolute activity of C^{14} is 15.3 counts/gm-min. Estimate the age of charcoal sample. Half life of C^{14} is 5568 years

Sol. A_0 = 15.3 counts/gm - min, A = 11.3 counts/gm-min

$$\lambda = \frac{0.693}{5568} \text{ per year}$$

$$t = \frac{2.303}{\lambda}\log_{10}\frac{A_0}{A} = \frac{2.303 \times 5568}{0.693}\log_{10}\frac{15.3}{11.3}$$

$$= \frac{2.303 \times 5568 \times 0.1316}{0.693} = 2434 \text{ years}$$

USES OF RADIOACTIVE ISOTOPES

1. **In Medicine**
   - **(i)** Co^{60} for treatment of cancer
   - **(ii)** Na^{24} for circulation of blood
   - **(iii)** I^{131} for thyroid
   - **(iv)** Sr^{90} for treatment of skin & eye
   - **(v)** Fe^{59} for location of brain tumor
   - **(vi)** radiographs of castings and teeth
2. **In Industries**
   - **(i)** for detecting leakage in water and oil pipe lines
   - **(ii)** for investigation of wear & tear, study of plastics & alloys, thickness measurement.
3. **In Agriculture**
   - **(i)** C^{14} to study kinetics of plant photosynthesis
   - **(ii)** P^{32} to find nature of phosphate which is best for given soil & crop
   - **(iii)** Co^{60} for protecting potato crop from earth worm
   - **(iv)** Sterilization of insects for pest control.
4. **In Scientific research**
   - **(i)** K^{40} to find age of meteorites
   - **(ii)** S^{35} in factories
5. **Carbon dating**
   - **(i)** It is used to find age of earth and fossils
   - **(ii)** The age of earth is found by Uranium disintegration and fossil age by disintegration of C^{14}.
   - **(iii)** The estimated age of earth is about 5×10^9 years.
   - **(iv)** The half life of C^{14} is 5700 years.
6. **As Tracers**
   - **(i)** A very small quantity of radio isotope present in any specimen is called tracer.
   - **(ii)** This technique is used to study complex biochemical reactions, in detection of cracks, blockages etc, tracing sewage or silt in sea
7. **In Geology**
   - **(i)** For dating geological specimens like ancient rocks, lunar rocks using Uranium
   - **(ii)** For dating archaeological specimens, biological specimens using C^{14}.

TRY IT YOURSELF - 3

Q.1 The half life of a radioactive substance is ________ than its mean life by _________.

(A) smaller, 69.13% (B) smaller, 30.7%
(C) larger, 30.7% (D) larger, 69.3%

Q.2 The half life of ${}^{131}I$ is 8 days. Given a sample of ${}^{131}I$ at time t = 0, we can assert that

(A) no nucleus will decay before t = 4 days.
(B) no nucleus will decay before t = 8 days.
(C) all nuclei will decay before t = 16 days.
(D) a given nucleus may decay at any time t = 0.

Q.3 The probability of disintegration per second of a nucleus in a given radio active sample :

(A) increases proportional to the life time lived by the nucleus.
(B) decreases with the life time lived.
(C) is independent of the life time lived.
(D) depends upon the total number of identical nuclei present in the sample.

Q.4 Heavy radioactive element eventually turn into

(A) Barium (B) Hydrogen
(C) Lead (D) Radius

Q.5 Two radioactive nuclei A and B are present in equal numbers to begin with. Three day later, number of A nuclei are 3 times number of B nuclei. Choose the correct statement.

(A) $\lambda_B - \lambda_A = \dfrac{\ell n3}{3\text{ days}}$

(B) $\lambda_A - \lambda_B = \dfrac{\ell n3}{3\text{ days}}$

(C) the ratio of activity rate of A and B after 3 days is 3:1
(D) the ratio of activity rate of A and B after 3 days is less than 3:1.

Q.6 A sample contains 16 gm of radioactive material, the half life of which is two days. After 32 days, the amount of sample is

(A) less than 1 milligram (B) 1/4 gm
(C) 1/2 gm (D) 1 gm

Q.7 The half life Po-218 is 3 minutes. What fraction of a 10 gram sample of Po-218 will remain after 15 min?

(A) 1/32 (B) 1/64
(C) 1/25 (D) 1/15

Q.8 There are three lumps of a radioactive substance. Their activities are in the ratio of 1 : 2 : 3. What will be the ratio of their activities at any future time?

(A) 1 : 2 : 3 (B) 2 : 1 : 3
(C) 3 : 2 : 1 (D) 2 : 3 : 1

Q.9 The activity of a fresh radioactive solution, of volume 1 litre, is 1200 Bq. A volume ΔV of the same liquid has an activity 120 Bq after three half lives. Then ΔV must be

(A) 600 c.c. (B) 800 c.c.
(C) 400 c.c. (D) 880 c.c.

Q.10 Two radioactive samples X and Y having half life 3 years and 2 years respectively have been decaying for many years. Today both samples have equal number of atoms. The number of atoms in the sample X will be twice of the number of atoms in the sample Y after

(A) 6/5 years (B) 5/6 years
(C) 6 years (D) 2 years

ANSWERS

(1) (B) **(2)** (D) **(3)** (CD)
(4) (C) **(5)** (AD) **(6)** (A)
(7) (A) **(8)** (A) **(9)** (B)
(10) (C)

NUCLEAR PHYSICS

Rutherford proposed the existence of a nucleus in 1911 to explain the results of his α scattering experiment. Nucleus is the central core of an atom in which the entire positive charge and almost the entire mass of an atom is concentrated. The nucleus is made of elementary particles called neutrons and protons. All nuclei except hydrogen are made up of neutrons and protons. Hydrogen nucleus contains a single proton.

Neutron is a neutral particle carrying no charge

(i) mass of neutron $m_n = 1.6749 \times 10^{-27}$ kg $= 1.008665$ amu
(ii) they are not deflected by external electric and magnetic fields
(iii) neutrons have high penetrating power and low ionizing power
(iv) neutrons are stable inside the nucleus. Outside the nucleus they are unstable with a half life of about 13 minutes
(v) neutron was discovered by James Chadwick in 1932 when he tried to explain results of collision of α particles with Berrylium. ${}_2Be^4 + {}_2He^4 \longrightarrow {}_6C^{13} \longrightarrow {}_6C^{12} + {}_0n^1 + Q$
(vi) The spin angular momentum of a neutron is $\dfrac{1}{2}(h/2\pi)$
(vii) depending on speed they are classified as fast and slow (thermal) neutrons.

Proton is a charged particle carrying unit positive charge.

(i) mass of proton $m_p = 1.6726 \times 10^{-27}$ kg $= 1.007825$ amu
(ii) proton was discovered by Goldstein in 1919.
(iii) The number of protons present inside the nucleus of an atom is called **a**tomic number (Z) of an element.
(iv) As atom is electrically neutral so number of protons inside the nucleus is equal to number of electrons in an atom.

According to Heisenberg a proton and neutron can be regarded as two different charge states of same particle called nucleon. The total number of protons and neutrons present inside the nucleus is known as mass number (A) of an element. Number of nucleons or Mass number (A) = proton number (Z) + neutron number (N)

In lighter nuclei the number of neutrons and protons are equal while in heavier nuclei number of neutrons is greater than number of protons. A nuclide is a specific nucleus of an atom characterized as ${}_Z X_N^A$ where A is mass number, Z is proton number and N is neutron number

TYPES OF NUCLEI

ISOTOPES

These are nuclei of same element having same Z but different A e.g. ${}_8O^{16}$, ${}_8O^{17}$, ${}_8O^{18}$; ${}_1H^1$, ${}_1H^2$, ${}_1H^3$; ${}_{92}U^{234}$, ${}_{92}U^{235}$, ${}_{92}U^{238}$

All isotopes of an element have same chemical properties They occupy same place in periodic table. They cannot be separated by chemical analysis. They can be separated by mass spectrometers or mass spectrographs

ISOTONES

These are nuclei of different elements having same N but different A.

e.g. ${}_6C_7^{13}$ & ${}_7N_7^{14}$; ${}_1H_2^3$ & ${}_2He_2^4$; ${}_2Be_5^9$ & ${}_5B_5^{10}$

Isotones are different elements with different chemical properties. They occupy different positions in periodic table. They can be separated by chemical analysis and mass spectrometers

ISOBARS

These are nuclei of different elements having same A but different N and Z.

e.g $_6C^{14}$ and $_7N^{14}$; $_{18}Ar^{40}$ and $_{20}Ca^{40}$

Isobars are different elements with different chemical properties. They occupy different positions in periodic table. They can be separated by chemical analysis but cannot be separated by mass spectrometers

MIRROR NUCLEI

These are nuclei with same A but in which neutron and proton number are interchanged.

e.g. $_4Be_3^7$ $(Z = 4,\ N = 3)$ and $_3Li_4^7$ $(Z = 3,\ N = 4)$

ISOMER NUCLEI

These are nuclei with same A and same Z but differ in their nuclear energy states. They have different life times and internal structure. These nuclei have different radioactive properties. e.g. Co^{60} & Co^{60*}

NUCLEAR FORCES

The strong forces of attraction which firmly hold the nucleons in the small nucleus and account for stability of nucleus are called as nuclear forces.

Characteristics of nuclear force :

1. **The nuclear force is a short range force.**
   - **(i)** They are appreciable when distance between nucleons is of the order of 2.2×10^{-15} m
   - **(ii)** They become negligible when distance between nucleons is greater than 4.2×10^{-15} m
   - **(iii)** When distance between two nucleons is less than 1×10^{-15} m the nuclear forces become strongly repulsive
2. **Nuclear forces are strongest force in nature**

Nature of force	**Relative strength**	**Interaction time**
Nuclear	$1 - 10^{39}$	10^{-22} sec
Electromagnetic	$10^{-3} - 10^{36}$	10^{-15} sec
Weak	$10^{-13} - 10^{26}$	10^{-8} sec
Gravitational	$10^{-39} - 1$	10^{-2} sec

3. **Nuclear forces are charge independent**
   - **(a)** force between a pair of protons, a pair of neutrons and a pair of neutron and proton is equal.
     $F(n-n) = F(p-p) = F(n-p)$
   - **(b)** The net force between pair of neutrons and a pair of neutron and proton is equal. This is slightly greater than force between pair of protons because force between protons is reduced due to electrostatic repulsion

   Net force $F(n-n)$ = Net force $F(n-p)$ > Net force $F(p-p)$
4. **Nuclear forces are spin dependent**
   - **(a)** Nuclear force depends on relative orientation of spins between two interacting nucleons
   - **(b)** The force of attraction between two nucleons with parallel spin is greater than force between nucleons with antiparallel spin.
   - **(c)** Deutron is formed in a bound state only if spins of neutron and proton are parallel.
5. **Nuclear forces show saturation property**
   - **(a)** The nucleon in nucleus interacts with its nearest neighbour only.
   - **(b)** It remains unaffected by the presence of other surrounding nucleons.
   - **(c)** The nuclear force between a pair of nucleons in light and heavy nucleus is equal.
6. **Nuclear forces are non-central forces**
   - **(a)** They do not act along line joining the centre of two nucleons.
   - **(b)** The non-central component depends on orientation of spins relative to line joining the centre of two nucleons.
7. **Nuclear forces are exchange forces**
   - **(a)** The nuclear forces originate by exchange of mesons $(\pi^+, \pi^\circ, \pi^-)$ between the nucleons
   - **(b)** mass of meson = 0.15 amu = 140 MeV = 280 × mass of electron
   - **(c)** p – p force $p + \pi^\circ \longleftrightarrow p$

     n – n force $n + \pi^\circ \longleftrightarrow n$

     n – p force $p + \pi^- \longleftrightarrow n$; $n + \pi^+ \longleftrightarrow p$
   - **(d)** The theory of exchange forces was given by Yukawa
   - **(e)** The potential energy of a particle in this force field is given by Yukawa potential $U(r) = U_0 e^{-r/r_0}$ where r_0 & U_0 are constants.

SIZE OF NUCLEUS

Rutherford in his α scattering experiment calculated the distance of closest approach at which α particle approaching nucleus is turned around by Coulomb repulsion. When α particle is turned the kinetic energy must be converted to electric potential energy since collision is elastic

$$\frac{1}{2}mv^2 = \frac{K(2e)\ (Ze)}{d}$$

distance of closest approach $d = \dfrac{4K\ Ze^2}{mv^2}$

for gold Z = 79 , $\frac{1}{2}mv^2 = 7\text{MeV} = 7 \times 1.6 \times 10^{-13}\,\text{J}$

$$\text{so } d = \frac{2 \times 9 \times 10^9 \times 79 \times (1.6 \times 10^{-19})^2}{7 \times 1.6 \times 10^{-13}} = 3.2 \times 10^{-14}\,\text{m}$$

Rutherford assumed the distance of closest approach as a measure of size of nucleus. Radius of nucleus is related to mass number as $R = R_0 A^{1/3}$ where R_0 is constant & $R_0 = 1.25 \times 10^{-15}$m

DENSITY OF NUCLEUS

Volume of nucleus $V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$, so volume $V \propto A$

Mass of nucleus = mass of protons + mass of neutrons = mA, where m is mass of one nucleon

Density of nucleus

$$\rho = \frac{\text{mass of nucleus}}{\text{volume of nucleus}} = \frac{mA}{\frac{4}{3}\pi R_0^3 A} = \frac{3m}{4\pi R_0^3}$$

The nuclear density is independent of mass number A

The nuclear density is nearly constant and is equal to

$$\rho = \frac{3m}{4\pi R_0^3} = \frac{3 \times 1.67 \times 10^{-27}}{4 \times 3.14 \times (1.25 \times 10^{-15})^3} = 2.04 \times 10^{17}\ \text{kg}/\text{m}^3$$

The nuclear density is maximum at centre of nucleus and decreases as one moves away from the centre. The distance from the centre of nucleus where density becomes 50% of its density at centre is called nuclear radius. The high density of nucleus indicates compactness of nucleus.

ATOMIC MASS UNIT

1 atomic mass unit (amu)= $\frac{1}{12}$ of mass of carbon ($_6C^{12}$) atom

$$1\ \text{amu} = \frac{1}{12}\left(\frac{12}{6.023 \times 10^{23}}\right) = 1.66 \times 10^{-24}\ \text{g} = 1.66 \times 10^{-27}\ \text{kg}$$

energy equivalent to 1 amu mass

$E = mc^2 = 1.66 \times 10^{-27} (3 \times 10^8)^2$ joule $= 1.49 \times 10^{-10}$ joule

$= 931.5$ MeV ; 1 amu $= 1.49 \times 10^{-10}$ J $= 931.5$ MeV

Example 21 :

Determine the number of electrons, protons and neutrons in 8g of $_6C^{12}$.

Sol. Each atom of $_6C^{12}$ of has 6n, 6p, 6e

$$\text{No. of atoms in 8gm} = \frac{6.023 \times 10^{23}}{12} \times 8 = 4.015 \times 10^{23}\ \text{atoms.}$$

number of neutron, proton and electron

$= 6 \times 4.015 \times 10^{23} = 24 \times 10^{23}$

Example 22 :

Determine the ratio of radius of nuclei $_{13}Al^{27}$ and $_{52}Te^{125}$

Sol. As $R \propto A^{1/3}$

$$\text{So } \frac{R_{Al}}{R_{Te}} = \left(\frac{A_{Al}}{A_{Te}}\right)^{1/3} = \left(\frac{27}{125}\right)^{1/3} = \left(\frac{3^3}{5^3}\right)^{1/3} = \frac{3}{5}$$

MASS DEFECT

The mass of the nucleus is always less than the sum of masses of nucleons composing the nucleus. The difference between the rest mass of nucleus and sum of rest masses of nucleons constituting the nucleus is known as mass defect.

Mass defect $\Delta m = [Zm_p + (A - Z)m_n] - M(_ZX^A)$

Example 23 :

Calculate the mass defect of a deutron ($_1H^2$).

Given $M(_1H^2) = 2.014102$ amu,

$m_n = 1.008665$ amu, $m_p = 1.007825$ amu.

Sol. mass defect $\Delta m = [Zm_p + (A - Z)m_n] - M(_1H^2)$

$= (1 \times 1.007825 + (2 - 1)\, 1.008665) - 2.014102$

$\Delta m = 0.002388$ amu

BINDING ENERGY

The energy required to break a nucleus into its constituent nucleons and place them at infinite distance is called binding energy. The energy equivalent to mass defect is called binding energy. This is the energy with which the nucleons are held together. The binding energies (~MeV) are very large as compared to molecular binding energies (~eV)

Binding energy

$$BE = (\Delta m)\, c^2 = c^2\, [\, Zm_p + (A - Z)m_n - M(_ZX^A)\,]$$

rest mass of protons + rest mass of neutrons = rest mass of nucleus + BE.

Example 24 :

Calculate binding energy of $_{92}U^{238}$.

Given M (U^{238}) = 238.050783 amu, $m_n = 1.008665$ amu and $m_p = 1.007825$ amu

Sol. mass defect $\Delta m = [Zm_p + (A - Z)m_n] - M(U^{238})$

$= [92 \times 1.007825\ (238 - 92) \times 1.008665] - 238.050783$

$\Delta m = 1.93421$ amu

$BE = 1.93421 \times 931.5\text{MeV} = 1801.7$ MeV

BINDING ENERGY PER NUCLEON

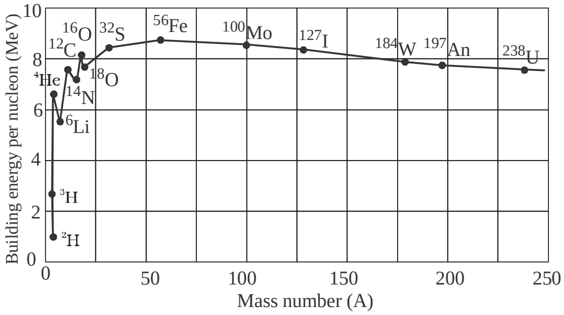
The binding energy per nucleon of a nucleus is the average energy required to extract a nucleon from the nucleus .

Binding energy per nucleon

$$\bar{B} = \frac{\text{Total binding energy}}{\text{Total number of nucleons}} = \frac{BE}{A} = \frac{\Delta mc^2}{A}$$

$$= \frac{c^2}{A}[Zm_p + (A - Z)m_n - M(_ZX^A)]$$

The plot of binding energy per nucleon with mass number A is shown as



Binding energy per nucleon gives a measure of stability of nucleus. More is binding energy per nucleon more is the stability of nucleus. Binding energy per nucleon is small for lighter nuclei i.e. ${}_1H^1$, ${}_1H^2$ etc.
For $A < 28$ at $A = 4n$ the curve shows some peaks at ${}_2He^4$, ${}_4Be^8$, ${}_6C^{16}$, ${}_8O^{16}$, ${}_{10}Ne^{20}$, ${}_{12}Mg^{24}$.
This represents extra stability of these elements with respect to their neighbours. The binding energy per nucleon is almost constant about 8.5 MeV in range $40 < A < 120$. The binding energy per nucleon is maximum about 8.8 MeV for Fe^{56}. The binding energy per nucleon decreases for $A > 200$ They become less stable and exhibit radioactivity. In fusion lighter nuclei fuse to form heavier nuclei. The process in accompanied by increase in binding energy per nucleon. In fission a heavy nucleus splits into two lighter nuclei. Here also increase in binding energy per nucleon takes place. The heaviest stable nuclide is ${}_{83}Bi^{209}$.

Example 25 :

Calculate the binding energy per nucleon for ${}_{17}C^{35}$. Given $M (Cl^{35}) = 34.9800$ amu $m_n = 1.008665$ amu and $m_P = 1.007825$ amu.

Sol. $BE = Zm_P + (A - Z)\, m_n - M (Cl^{35})$
$= 17 \times 1.007825 + 18 \times 1.008665 - 34.9800 = 0.308995$ amu
$BE = 0.308995 \times 931.5 = 287.83$ MeV

$$\bar{B} = \frac{BE}{A} = \frac{287.75}{35} = 8.22 \text{ MeV/nucleon}$$

Example 26 :

The mass of ${}_7N^{15}$ is 15.00011 amu, mass of ${}_8O^{16}$ is 15.99492 amu and $m_P = 1.00783$ amu. Determine binding energy of last proton of ${}_8O^{16}$.

Sol. $M({}_8O^{16}) = M ({}_7N^{15}) + 1m_P$
binding energy of last proton $= M (N^{15}) + m_P - M ({}_1O^{16})$
$= 15.00011 + 1.00783 - 15.99492 = 0.01302$ amu $= 12.13$ MeV

NUCLEAR REACTION

The transformation of one stable nucleus into another nucleus by bombardment with suitable high energy particles like proton, neutron, α particle etc is known as nuclear reaction.

${}_ZX^A$	$+$	${}_2He^4$	$\longrightarrow$	${}_{Z+2}C^{A+4}$	$\longrightarrow$	${}_{Z+1}Y^{A+3}$	$+ \; {}_1H^1 \; +$	Q
Target nucleus		projectile		compound nucleus		product nucleus		energy change

e.g.
$${}_{13}Al^{27} + {}_2He^4 \to {}_{15}P^{31} \to {}_{14}Si^{30} \to + {}_{+1}e^0 + {}_0n^1 + Q$$
The nuclear reactions obey following conservation laws

- **(a)** conservation of linear momentum
- **(b)** conservation of total energy
- **(c)** conservation of charge
- **(d)** conservation of number of nucleons.
- **(e)** conservation of angular momentum.

NUCLEAR FISSION

Nuclear fission was discovered by Otto Hahn and Strassman.

The process of splitting of a heavy nucleus into two nuclei of comparable size and release of large energy is called fission.

$${}_{92}U^{235} + {}_0n^1 \to {}_{92}U^{236} \to {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_0n^1 + \text{energy}$$

U^{235} nucleus captures a thermal neutron
This forms a compound nucleus U^{236} in excited state
The shape of nucleus is distorted and nucleus splits into two fragments emitting several neutrons.
The neutrons emitted in fission are fast neutrons. Their energy is about 2MeV. On an average 2.5 neutrons are emitted per fission.
The binding energy per nucleon of products is greater than the reactants. The energy released in fission of Uranium is about 200 MeV. The fission energy released per nucleon is about 0.84 MeV The fission of U^{235} may take place by different routes but amount of energy released per fission is nearly equal.

$${}_{92}U^{235} + {}_0n^1 \to {}_{92}U^{236} \to {}_{38}Sr^{95} + {}_{54}Xe^{139} + 2{}_0n^1$$

$$\to {}_{41}Nb^{99} + {}_{51}Sb^{133} + 4\,{}_0n^1$$

$$\to {}_{57}La^{148} + {}_{56}Br^{85} + 3\,{}_0n^1 \text{ etc.}$$

The fission fragments are highly radioactive. Nuclear fission can be explained on basis of liquid drop model. The natural Uranium has following isotopes

$${}_{92}U^{234}(0.006\%)\,;\; {}_{92}U^{235}(0.72\%)\;;\; {}_{92}U^{238}(99.27\%)$$

${}_{92}U^{238}$ is not fissionable. This can be converted to plutonium which is fissionable by neutrons.

$${}_{92}U^{238} + {}_0n^1 \to {}_{93}Np^{239} + {}_{-1}e^0 + \bar{\nu}$$

$${}_{93}Np^{239} \to {}_{94}Pu^{239} + {}_{-1}e^0 + \bar{\nu}$$

The Uranium in which fraction of U^{235} is increased from 0.7% to 2.3% is called enriched Uranium.

Energy released per gm of Uranium :

Energy released per gm of Uranium

$$= \frac{\text{Avogadro number}}{\text{mass number}} \times \text{energy released per fission}$$

$$= \frac{6.023 \times 10^{23}}{235} \times 200 = 5.12 \times 10^{23} \text{MeV}$$

energy released by 1gm of $U^{235} = 5.12 \times 10^{23}$ MeV
$= 8.2 \times 10^{10}$ J $= 2.28 \times 10^4$ kWh $= 2 \times 10^{10}$ calorie
This energy is equivalent to

- **(i)** energy obtained by burning 2560 kg of coal
- **(ii)** energy obtained by burning 20 tonne of explosive TNT

The energy is released in form of kinetic energy of fission fragments, γ–rays, heat, sound and light energy.
The fission process can take place at normal pressure and temperature.

Example 27 :

Calculate the energy released in the fission process

$${}_{92}U^{235} + {}_{0}n^{1} \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\ {}_{0}n^{1} + Q$$

Given M (U^{235}) = 235.0439 amu, M (Ba^{141}) = 140.9129 amu

M (Kr^{92}) = 91.8973 amu, m_n = 1.0087 amu

Sol. Mass defect

$$\Delta m = (235.0439 + 91.8973) - (140.9129 + 91.8973 + 3 \times 1.0087)$$

$$= 0.2163\ \text{amu} = 201.5\ \text{MeV}$$

$$\text{Energy released per nucleon } = \frac{201.5}{236} = 0.85\text{MeV / nucleon}$$

Example 28:

The energy released per fission of Uranium is 200 MeV. Determine the number of fission per second required to generate 2MW power.

Sol. Energy obtained per fission

$$= 200\ \text{MeV} = 200 \times 1.6 \times 10^{-13}\ \text{J} = 3.2 \times 10^{-11}\ \text{J}$$

No. of fission per second required

$$= \frac{2 \times 10^{6}}{3.2 \times 10^{-11}} = 6.25 \times 10^{16}$$

CHAIN REACTION

In fission of Uranium atom 2.5 neutrons are produced on an average. In favourable conditions these may produce fission of other Uranium nuclei. At each stage number of neutrons available for fission gets multiplied which can cause further fission of Uranium nuclei. The process once started continues by itself till entire Uranium is consumed. This process is called nuclear chain reaction. The neutrons produced in each fission may be lost due to following reasons

(a) Leakage of neutrons from the system

(b) absorption of neutrons by U^{238}

(c) absorption of neutrons by impurities

Neutron multiplication factor

neutron multiplication factor

$$K = \frac{\text{rate of production of neutrons}}{\text{rate of loss of neutrons}}$$

(a) If K = 1 chain reaction is sustained.

- **(i)** This leads to a controlled chain reaction.
- **(ii)** **Controlled chain reaction :** When only one of the neutron produced in each fission is able to produce fission then reaction is called controlled chain reaction.
- **(iii)** The energy is produced at a uniform rate.
- **(iv)** This forms working principle of nuclear reactor
- **(v)** The size of fissionable material is called critical size and its mass as critical mass.
- **(vi)** The minimum mass of Uranium for which chain reaction is possible is called critical mass. For U^{235} it is 10 kg.

(b) If K > I chain reaction is accelerated because number of neutrons available for fission at each stage increases rapidly

- **(i)** This leads to uncontrolled chain reaction
- **(ii)** Energy is produced at rapidly increasing rate.
- **(iii)** This is working principle of atom bomb.
- **(iv)** The size of material is super critical.

(c) If K < I the chain reaction stops because number of neutrons available for fission decreases at each stage.

- **(i)** The energy produced decreases
- **(ii)** The size of material is sub critical

The rate of decay of neutrons is proportional to surface area (r^2) of Uranium block. The rate of production of neutrons is proportional to number of nuclei present in Uranium block or volume (r^3) of the block.

CONTROLLED CHAIN REACTION/NUCLEAR REACTOR

When only one of the neutron produced in each fission is able to produce fission then reaction proceeds slowly and is called controlled chain reaction. Nuclear reactor is a device in which controlled nuclear chain reaction is initiated and maintained to produce energy. Reactors are used **(i)** for power generation **(ii)** to produce radioactive isotopes used in medicine, industry and agriculture **(iii)** to produce Plutonium Pu^{239} used in making atom bomb

Thermal reactor Reactor in which energy is produced by fission of U^{235} by slow neutron is called thermal reactor.

Main parts of reactor

(a) **Fuel** It is fissionable material used for fission. The common fuels are U^{233}, U^{235}, Pu^{239}

(b) **Moderator** These slow down the fast neutrons to thermal neutrons. e.g. Heavy water, graphite, beryllium oxide

(c) **Control rods** These help in controlling the rate of fission by absorbing the neutrons produced in fission. e.g. Cadmium rods

(d) **Coolant** A substance which is used to remove the heat produced and transfer it from core of nuclear reactor to the surrounding is called coolant. e.g. air, water or carbondioxide

(e) **Shield** The whole reactor is protected with concrete walls 2 to 2.5 m thick so that radiations emitted during nuclear reactions do not produce harmful effects.

Very small fraction of about 1.2% of natural Uranium fuel is used.

BREEDER REACTOR

A reactor which can produce more fissionable fuel than it consumes is called a breeder reactor. No moderator is used in these reactors. Sodium is used as coolant. The mixture of natural Uranium and Plutonium works as fuel.

$${}_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{92}U^{239*} \longrightarrow {}_{92}U^{239} + \gamma$$

$$\downarrow$$

$${}_{92}U^{239} \longrightarrow {}_{92}Np^{239} + \beta^{-} + \overline{\nu}$$

$$\downarrow$$

$${}_{93}Np^{239} \longrightarrow {}_{92}Pu^{239} + \beta^{-} + \overline{\nu}$$

Using unfissonable ${}_{92}U^{238}$ we can produce fissionable ${}_{92}Pu^{239}$.

The chain reaction is maintained by fast neutrons. About 60 to 70% of natural Uranium is used in the process.

NUCLEAR FUSION

The process in which two or more lighter nuclei combine to form a heavy nucleus is known as nuclear fusion.

$$4\,{}_1H^1 \longrightarrow {}_2He^4 + 2\,{}_{+1}e^0 + 2\nu + Q$$

The binding energy per nucleon of product is greater than the reactants. The energy released per nucleon is large ~ 6.75 MeV. Fusion is possible at high pressure (~ 10^6 atom) and high temperature (~ 10^8 °C). The proton-proton cycle happens at lower temperature as compared to carbon-nitrogen cycle. Nuclear fusion in possible at a place which has reactants in large quantity. Hydrogen bomb works on principle of nuclear fusion. The explosion of a hydrogen bomb needs an explosion of atom bomb to generate required temperature. No harmful radiations are produced in fusion.

Example 29 :

Determine the energy released in the process

$${}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4 + Q$$

Given M $({}_1H^2)$ = 2.01471 amu M $({}_2He^4)$ = 4.00388 amu

Sol. mass defect $\Delta m = 2 \times 2.01471 - 4.00388 = 0.02554$ amu

energy liberated = 0.02554×931.5 MeV = 23.79 MeV

Example 30 :

The binding energies per nucleon for deutron $({}_1H^2)$ and helium $({}_2He^4)$ are 1.1 MeV and 7 MeV respectively. Determine energy released when two deuterons fuse to form a helium nucleon.

Sol. ${}_1H^2 + {}_1H^2 \longrightarrow {}_2He^4 + Q$

Binding energy of deutron = 2 × 1.1 = 2.2 MeV

Binding energy of helium = 4 × 7 MeV = 28 MeV

Energy released = (28 – 2 × 2.2) = 23.6 MeV

TRY IT YOURSELF - 4

Q.1 The energy released in a fission of uranium nucleus is of the order of:

(A) 200 MeV (B) 20 MeV

(C) 200 eV (D) 200 meV

Q.2 Number of α and β emitted during the radioactive decay chain starting from ${}_{88}Ra^{226}$ and ending at ${}_{82}Pb^{206}$ is :

(A) $3\alpha, 6\beta$ (B) $4\alpha, 5\beta$

(C) $5\alpha, 4\beta$ (D) $6\alpha, 6\beta$

Q.3 α-rays passing through a strong uniform electric field, get deflected

(A) In the direction of the electric field.

(B) In the direction opposite to that of the electric field.

(C) In the direction perpendicular to both the electric field and direction of motion of rays

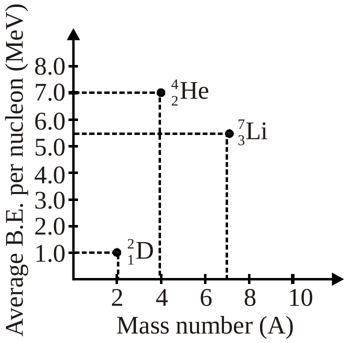
(D) Do not get deflected at all.

Q.4 When α, β, γ radiations pass through a gas, their ionizing powers, in decreasing order, are :

(A) γ, α, β (B) γ, β, α

(C) α, β, γ (D) β, γ, α

Q.5 The positions of ${}^2_1D$, ${}^4_2He$ and ${}^7_3Li$ are shown on the binding energy curve as shown in figure. The energy released in the fusion reaction ${}^2_1D + {}^7_3Li \rightarrow 2\,{}^4_2He + {}^1_0n$ will be closest to



(A) 20 MeV (B) 16 MeV

(C) 8 MeV (D) 4 MeV

Q.6 The decay of neutron inside a nucleus results in the emission of a (from the nucleus)

(A) proton (B) gamma rays

(C) alpha particle (D) electron

Q.7 When a high energy neutron bombard a ${}_7N^{14}$ nucleus producing a ${}_6C^{14}$ nucleus, the other particle released is

(A) Electron (B) Positron

(C) Proton (D) Gamma ray photon

Q.8 When Uranium $({}_{92}U^{238})$ decays to lead $({}_{82}Pb^{206})$, number of alpha particles and beta particles emitted, respectively, are

(A) 6 & 6 (B) 8 & 8

(C) 6 & 8 (D) 8 & 6

Q9 A nucleus at rest disintegrates into two nuclear fragments with velocities in the ratio 8 : 27. The ratio of their nuclear radii will be

(A) 3 : 2 (B) 9 : 4

(C) 27 : 8 (D) 8 : 27

Q.10 The emission of a gamma photon from a radioactive substance is associated with

(A) the transition of an orbiting electron

(B) de excitation of the nucleus

(C) breaking of a an inter atomic bond

(D) none

Q.11 In the α-decay of a U-238 nucleus the energy released in the decay is Q. The U-238 nucleus was initially stationary. Which of the following is (are) true?

(A) Ratio of K.E. of α-particle and Thorium nucleus is 117 : 2

(B) Ratio of K.E. of Thorium nucleus and α-particle and 1 : 234

(C) Momentum of a-particle is $(234Qm_\alpha/119)^{1/2}$

(D) Recoil velocity of Thorium nucleus is $[234Q/119 \times 117m_{Th}]^{1/2}$

ANSWERS

(1) (A) **(2)** (C) **(3)** (A)

(4) (C) **(5)** (B) **(6)** (D)

(7) (C) **(8)** (D) **(9)** (A)

(10) (B) **(11)** (AC)

X-RAY

ROENTGEN EXPERIMENT

Roentgen discovered X-ray. While performing experiment on electric discharge tube Roentgen observed that when pressure inside the tube is 10^{-3} mm of Hg and applied potential is kept 25 kV then some unknown radiation are emitted by anode. These are known as X-ray.

X-rays are produced by bombarding high speed electrons on a target of high atomic weight and high melting point.

To Produce X-ray Three Things are Required

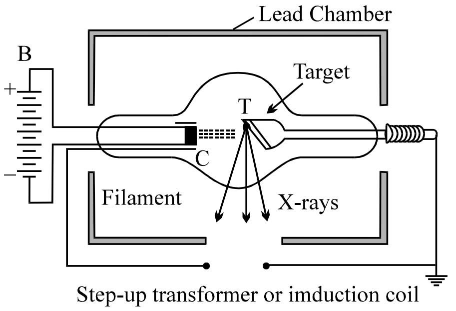
(i) Source of electron

(ii) Means of accelerating these electron to high speed

(iii) Target on which these high speed electron strike

COOLIDGE METHOD

Coolidge developed thermoionic vacuum X-ray tube in which electron are produced by thermoionic emission method. Due to high potential difference electrons (emitted due to thermoionic method) move towards the target and strike from the atom of target due to which X-ray are produced. Experimentally it is observed that only 1% or 2% kinetic energy of electron beam is used to produce X-ray rest of energy is wasted in form of heat.



Characteristics of target :

(a) Must have high atomic number to produce hard X-rays.

(b) High melting point to withstand high temperature produced.

(c) High thermal conductivity to remove the heat produced.

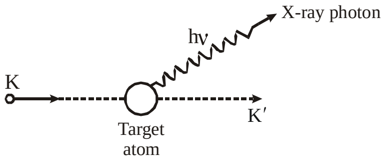
(d) Tantalum, platinum, molybdenum and tungsten serve as target materials.

Control of intensity: The intensity of X-ray depend on number of electrons striking the target and number of electron depend on temperature of filament which can be controlled by filament current. Thus intensity of X-ray depend on current flowing through filament.

Control of Penetrating Power : The Penetrating power of X-ray depend on the energy of incident electron. The energy of electron can be controlled by applied potential difference. Thus penetrating power of X-ray depend on applied potential difference. Thus the intensity of X-ray depend on current flowing through filament while penetrating power depend on applied potential difference.

	Soft X-ray	**Hard X-ray**
Wavelength	10Å to 100 Å	0.1 Å – 10 Å
Energy	$\frac{12400}{\lambda}$ eV-Å	$\frac{12400}{\lambda}$ eV-Å
Penetrating power	Less	More
Use	Radio photograph	Radio therapy

Continuous spectrum of X-ray : When high speed electron collide from the atom of target and passes close to the nucleus. There is coulomb attractive force due to this electron is deaccelerated i.e. energy is decreased. The loss of energy during deacceleration is emitted in the form of X-rays. X-ray produced in this way are called Braking or Bremstralung radiation and form continuous spectrum.



In continuous spectrum of X-ray all the wavelength of X-ray are present but below a minimum value of wavelength there is no X-ray. It is called cut off or threshold or minimum wavelength of X-ray. The minimum wavelength depends on applied potential.

Loss in kinetic energy

$$\frac{1}{2}mv_1^2 - \frac{1}{2}mv_2^2 = h\nu + \text{heat energy}$$

If $v_2 = 0, v_1 = v$ (In first collision, heat = 0)

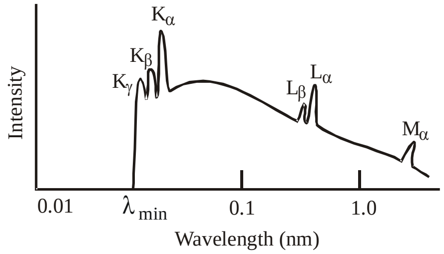
$$\frac{1}{2}mv^2 = h\nu_{max} \quad .... (1) \qquad \frac{1}{2}mv^2 = eV \quad .... (2)$$

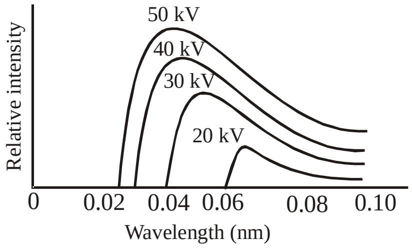
(Here V is applied potential)

From eq. (1) and (2), $h\nu_{max} = eV \Rightarrow \frac{hc}{\lambda_{min}} = eV$

$$\Rightarrow \lambda_{min} = \frac{12400}{V} \times \text{volt} = \frac{12400}{V} \times 10^{-10}\, m \times \text{volt}$$

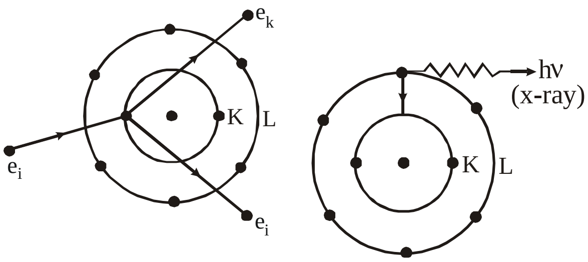
Continuous X-rays also known as white X-ray. Minimum wavelength of these spectrum only depend on applied potential and don't depend on atomic number.





Characteristic Spectrum of X-ray : When the target of X-ray tube is collide by energetic electron it emits two type of X-ray radiation. One of them has a continuous spectrum whose wavelength depend on applied potential while other consists of spectral lines whose wavelength depend on nature of target. The radiation forming the line spectrum is called characteristic X-rays.

When highly accelerated electron strike with the atom of target then it knockout the electron of orbit, due to this a vacancy is created. To fill this vacancy electron jump from higher energy level and electromagnetic radiation are emitted which form characteristic spectrum of X-ray. Whose wavelength depend on nature of target and not on applied potential.



(a) Knocking out e^- of K shell (b) Emission of X-ray photon
by incident electron e_i (K_α- series)

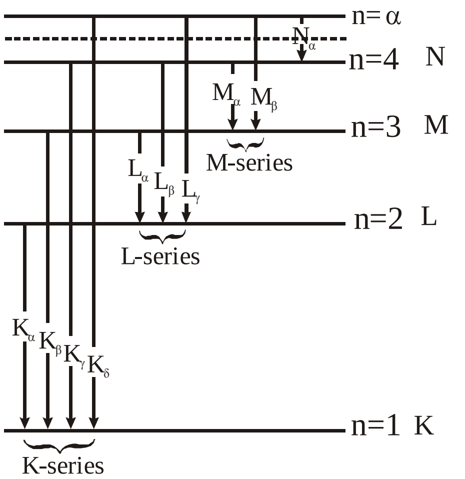
$n_1 = 1,\ n_2 = 2, 3, 4$ .... K series

$n_1 = 1,\ n_2 = 3, 4, 5$.............. L series

$n_1 = 3,\ n_2 = 4, 5, 6$.............. M series

First line of series = α ; Second line of series = β

Third line of series = γ



Transition	Wavelength	Energy	Energy difference	Wavelength
$L \rightarrow K\ (2 \rightarrow 1)$	$\lambda_{K\alpha}$	$h\nu_{K\alpha}$	$E_K - E_L = h\nu_{K\alpha}$	$\lambda_{K\alpha} = \frac{hc}{(E_K - E_L)} = \frac{12400}{(E_K - E_L)} eVÅ$
$M \rightarrow K\ (3 \rightarrow 1)$	$\lambda_{K\beta}$	$h\nu_{K\beta}$	$E_K - E_M = h\nu_{K\beta}$	$\lambda_{K\beta} = \frac{hc}{(E_K - E_M)} = \frac{12400}{(E_K - E_M)} eVÅ$
$M \rightarrow L\ (3 \rightarrow 2)$	$\lambda_{L\alpha}$	$h\nu_{L\alpha}$	$E_L - E_M = h\nu_{L\alpha}$	$\lambda_{L\alpha} = \frac{hc}{(E_L - E_M)} = \frac{12400}{(E_L - E_M)} eVÅ$

MOSELEY'S LAW

Moseley studied the characteristic spectrum of number of many elements and observed that the square root of the frequency of a K-line is closely proportional to atomic number of the element. This is called Moseley's law.

$$\sqrt{\nu} \propto (Z - b) \Rightarrow \nu \propto (Z - b)^2$$

$$\nu = a\,(Z - b)^2 \qquad \text{........ (i)}$$

Z = atomic number of target,
ν = frequency of characteristic spectrum
b = screening constant (for K-series b = 1, L series b=7.4),
a = proportionality constant

From Bohr Model $\nu = RcZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ .... (ii)

Comparing (i) and (ii), $a = Rc\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Thus proportionality constant 'a' does not depend on the nature of target but depend on transition.

Bohr model	**Moseley's correction**
1. For single electron species	1. For many electron species
2. $\Delta E = 13.6\, Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] eV$	2. $\Delta E = 13.6\, (Z-1)^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] eV$
3. $\nu = Rc\, Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	3. $\nu = Rc\, (Z-1)^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$
4. $\frac{1}{\lambda} = RZ^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	4. $\frac{1}{\lambda} = R\, (Z-1)^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

For X-ray production, moseley formulae are used because heavy metal are used.

When target is same, $\lambda \propto \dfrac{1}{\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}}$

When transition is same, $\lambda \propto \dfrac{1}{(Z-b)^2}$

Example 31 :

Find out wavelength of K_α X-ray.

Sol. K_α means transition from $n_2 = 2$ to $n_1 = 2$ and $b = 1$ for K series.

$$\Rightarrow \frac{1}{\lambda_{K\alpha}} = R\,(Z-1)^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\Rightarrow \frac{1}{\lambda_{K\alpha}} = R\,(Z-1)^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right] \Rightarrow \frac{1}{\lambda_{K\alpha}} = \frac{3\,R\,(Z-1)^2}{4},$$

$$R = 1.097 \times 10^7\, m^{-1}, \ \& \ \frac{1}{R} = 912\ Å$$

$$\lambda_{K\alpha} = \frac{4}{3\,R\,(Z-1)^2} \Rightarrow \lambda_{K\alpha} = \frac{1216}{(Z-1)^2}\,Å$$

Example 32 :

The K_α X-rays emission line for tungsten is at $\lambda = 0.021$nm. What is the energy difference between K and L levels in this atom.

Sol. $\lambda_{K\alpha} = \dfrac{hc}{E_K - E_L}$

$$\text{So, } E_K - E_L = \frac{hc}{\lambda_{K\alpha}} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{0.021 \times 10^{-9}}$$

$$= 9.46 \times 10^{-15}\ J = 59\ keV$$

ABSORPTION OF X-RAY

When X-ray pass through x thickness then its intensity

$I = I_0 e^{-\mu x}$

I_0 = Intensity of incident X-ray,
I = Intensity of X-ray after passing through x distance
μ = absorbtion coefficient of material
Intensity of X-ray decrease exponentially.
Maximum absorbtion of X-ray → Lead
Minimum absorbtion of X-ray → Air

Half thickness ($x_{1/2}$) :

The distance travelled by X-ray when intensity become half the original value

$$x_{1/2} = \frac{\ln 2}{\mu}$$

Example 33 :

When X-rays of wavelength 0.5 Å pass through 10 mm thick Al sheet then their intensity is reduced to one sixth. Find the absorption coefficient for Aluminium.

Sol. $\mu = \dfrac{2.303}{x} \log\left(\dfrac{I_0}{I}\right)$

$$= \frac{2.303}{10} \log_{10} 6 = \frac{2.303 \times 0.7781}{10} = 0.198 / mm$$

DIFFRACTION OF X-RAY

Diffraction of X-ray is possible by crystals because the interatomic spacing in a crystal lattice is order of wavelength of X-rays it was first verified by Lauve.

Diffraction of X-ray take place according to Bragg's law

$2d \sin\theta = n\lambda$

d = spacing of crystal plane or lattice constant or distance between adjacent atomic plane
θ = Bragg's angle or glancing angle
φ = Diffracting angle ; n = 1, 2, 3 ....

For maximum wavelength

$\sin\theta = 1, n = 1$

$\Rightarrow \lambda_{max} = 2d$

so if $\lambda > 2d$ diffraction is not possible i.e. solution of Bragg's equation is not possible.

PROPERTIES OF X-RAY

- X-ray always travel with the velocity of light in straight line because X-rays are em waves
- X-ray is electromagnetic radiation it show particle and wave both nature.
- In reflection, diffraction, interference, refraction X-ray shows wave nature while in photoelectric effect it shows particle nature.
- There is no charge on X-ray thus these are not deflected by electric and magnetic field
- X-ray are invisible.
- X-ray affect the photographic plate.
- When X-ray incident on the surface of substance it exert force and pressure and transfer energy and momentum
- Characteristic X-ray can not obtained from hydrogen because the difference of energy level in hydrogen is very small.

TRY IT YOURSELF - 5

Q.1 What is the essential distinction between X-rays & γ-rays

(A) γ-rays have shorter wavelength than X-rays

(B) γ-rays are extraterrestrial, X-rays are man-made

(C) γ-rays have less penetrating power than X-rays

(D) γ-rays originate from within an atomic nucleus, X-rays from outside an atomic nucleus.

Q.2 The energy of a tungsten atom with a vacancy in L shell is 11.3 KeV. Wavelength of K_α photon for tungsten is 21.3pm. If a potential difference of 62 KV is applied across the x-rays tube following characteristic x-rays will be produced.

(A) K, L series (B) only K_α & L series

(C) only L series (D) none

Q.3 In the Coolidge tube experiment, the short wavelength limit of the continuous X–ray spectrum is equal to 66.3pm

(A) Electrons accelerate through a potential of 12.75 kV in a Coolidge tube

(B) Electrons accelerate through a potential of 18.75 KV in a Coolidge tube

(C) De-broglie wavelength of the electrons reaching the anticathode is of the order of 10 pm

(D) De-broglie wavelength of the electrons reaching the anticathode is 0.01 Å.

Q.4 The potential difference applied to an X-ray tube is V. The ratio of debroglie wavelength of electron to the minimum wavelength of X-ray is directly proportional to

(A) V (B) $V^{1/2}$

(C) $1/V^{1/2}$ (D) independent of V

Q.5 The wavelength λ of K-α, X-ray line from a target element of atomic number Z varies as

(A) Z^2 (B) $(Z-1)^2$

(C) $(Z+1)^2$ (D) $(Z-1)^{-2}$

Q.6 The minimum wavelength of the continuous X-ray radiation, having operating potential V, is :

(A) eV/h (B) hc/eV

(C) eV/hc (D) ec/hV

Q.7 The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation :

(A) The intensity increases.

(B) The minimum wavelength increases.

(C) The intensity remains unchanged.

(D) The minimum wavelength is decreases.

Q.8 When a beam of accelerated electrons hits a target, which one of the following wavelengths is absent in the X-ray region of the spectrum, if the tube is operated at 40000 V?

(A) 1.5 Å (B) 1.0 A

(C) 0.5 Å (D) 0.25 Å

Q.9 The intensity of X-ray depends upon

(A) Kinetic energy of electron striking the target.

(B) Total momentum of the electrons.

(C) Number of electrons striking the target.

(D) None

Q.10 Characteristic X-ray

(A) Have only discrete wavelength which are characteristic of the target.

(B) Have all the possible wavelength.

(C) Are characteristic of speed of projectile electrons.

(D) None

Q.11 Mosley law relates :

(A) Frequency of emitted X-ray with applied voltage

(B) Wavelength and intensity of X-ray.

(C) Frequency of emitted X-ray with atomic number

(D) Wavelength and angle of scattering.

Q12 On a heavy atom electrons are fired with kinetic energy E. If binding energy of electrons in this atom corresponding to K, L and M shells are 40.2 keV, 21.8 keV and 11.5 keV respectively, what should be the minimum value of E to produced L_α X–ray from the atom :

(A) 11.5 keV (B) 21.8 keV

(C) 40.2 keV (D) 10.3 keV

ANSWERS

(1) (D)	**(2)** (C)	**(3)** (BC)
(4) (B)	**(5)** (D)	**(6)** (B)
(7) (D)	**(8)** (D)	**(9)** (A)
(10) (A)	**(11)** (C)	**(12)** (B)

MATTER WAVE

Dual nature of light : Experimental phenomena of light reflection, refraction, interference, diffraction are explained only on the : basis of wave theory of light. These phenomena verify the wave nature of light. Experimental phenomena of light photoelectric effect and Compton effect, pair production and positron anhilational can be explained only on the basis of the particle nature of light. These phenomena verify the particle nature of light. It is inferred that light does not have any definite nature, rather its nature depends on its experimental phenomenon. This is known as the dual nature of light.

The wave nature and particle nature both can not be possible simultaneously.

DE BROGLIE HYPOTHESIS

De Broglie imagined that as light possess both wave and particle nature, similarly matter must also posses both nature, particle as well as wave.

De Broglie imagined that despite particle nature of matter, waves must also be associated with material particles. Wave associated with material particles, are defined as matter waves.

De Broglie wavelength associated with moving particles

If a particle of mass m moving with velocity v

Kinetic energy of the particle $E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$

Momentum of particle $p = mv = \sqrt{2mE}$

The wave length associated with the particles is

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}\ ;\ \lambda \propto \frac{1}{p}, \lambda \propto \frac{1}{v}, \lambda \propto \frac{1}{\sqrt{E}}$$

The order of magnitude of wave lengths associated with macroscopic particles is 10^{-24} Å.

The smallest wavelength whose measurement is possible is that of γ-rays ($\lambda \approx 10^{-5}$ Å). This is the reason why the wave nature of macroscopic particles is not observable. The wavelength of matter waves associated with the microscopic particles like electron, proton, neutron, α-particle, atom, molecule etc. is of the order of 10^{-10} m, it is equal to the wavelength of X-rays, which is within the limit of measurement. Hence the wave nature of these particles is observable.

De Broglie wavelength associated with the charged particles : Let a charged particle having charge q is accelerated by potential difference V

Kinetic energy of this particle $E = \frac{1}{2}mv^2 = qV$

Momentum of particle $p = mv = \sqrt{2mE} = \sqrt{2mqV}$

The De Broglie wavelength associated with charged particle $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$

For an electron :

$m = 9.1 \times 10^{-31}$ kg, $q = 1.6 \times 10^{-19}$ C, $h = 6.62 \times 10^{-34}$ J-S

De Broglie wavelength associated with electron

$$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} V}}$$

or $\lambda = \frac{12.27 \times 10^{-10}}{\sqrt{V}}$ meter $\Rightarrow \lambda = \frac{12.27}{\sqrt{V}}$ Å so $\lambda \propto \frac{1}{\sqrt{V}}$

Potential difference required to stop an electron of wavelength λ is $V = \frac{150.6}{\lambda^2}$ Volt (Å)^2

For proton : $m_p = 1.67 \times 10^{-27}$ kg

De Broglie wavelength associated with proton

$$\therefore\ \lambda_p = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 1.6 \times 10^{-19} V}}$$

or $\lambda_p = \frac{0.286 \times 10^{-10}}{\sqrt{V}}$ meter $= \frac{0.286}{\sqrt{V}}$ Å

For Deutron :

$m_d = 2 \times 1.67 \times 10^{-27}$ kg, $q_d = 1.6 \times 10^{-19}$ C

$$\therefore\ \lambda_d = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 2 \times 1.67 \times 10^{-27} \times 1.6 \times 10^{-19} V}}$$

or $\lambda_d = \frac{0.202 \times 10^{-10}}{\sqrt{V}}$ m or $\lambda_d = \frac{0.202}{\sqrt{V}}$ Å

For ~ particles :

$q = 2 \times 1.6 \times 10^{-19}$ C, $m = 4 \times 1.67 \times 10^{-27}$ kg

$$\therefore\ \lambda = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 4 \times 1.67 \times 10^{-27} \times 2 \times 1.6 \times 10^{-19} V}}$$

or $\lambda = \frac{0.101 \times 10^{-10}}{\sqrt{V}}$ m or $\lambda = \frac{0.101}{\sqrt{V}}$ Å

DE BROGLIE WAVELENGTH ASSOCIATED WITH UNCHARGED PARTICLES

Kinetic energy of uncharged particle

$$E = \frac{1}{2}mv^2 = \frac{p^2}{2m}$$

m = mass of particle, v = velocity of particle,
p = momentum of particle.

Velocity of uncharged particle, $v = \sqrt{\frac{2E}{m}}$

Momentum of particle, $p = mv = \sqrt{2mE}$

wavelength associated with the particle,

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$$

Kinetic energy of the particle in terms of its wavelength

$$E = \frac{h^2}{2m\lambda^2} \Rightarrow E = \frac{h^2}{2m\lambda^2 \times 1.6 \times 10^{-19}} \text{ eV}$$

For a neutron, $m = 1.67 \times 10^{-27}$ kg

$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times E}}$ or $\lambda = \frac{0.286 \text{x} 10^{-10}}{\sqrt{E}}$ meter

or $\lambda = \frac{0.286}{\sqrt{E}}$ Å

DAVISSON GERMER EXPERIMENT

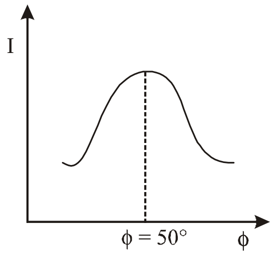
There are three main parts of this experiment
(i) Electron gun (ii) Nickle crystal
(iii) Ionisation chamber (Detector)

Electron gun : Electrons of desired energy are produced in it by the process of thermionic emission.

Nickel crystal diffracts the electrons beam obtained from electron gun.

Ionisation chamber : It detects the electron beam diffracted by the nickle crystal. Nickle crystal behaves like a three dimensional diffraction grating

Curve between the intensity (I) of diffracted electrons and diffracting angle (ϕ)



In this experiment maximum peak is obtained in I – ϕ curve at an angle of diffraction of 50° and acceleration potential 54 volt.

In this experiment the experimental value of De Broglie wavelength associated with electron is obtained as 1.65 Å whereas according to De Broglie theory this wavelength comes out to be 1.66 Å. In this experiment the wave nature of electron is verified due to their diffraction.

Diagram representing the angle of diffraction (ϕ) and glancing angle (θ).

For maxima, path difference = nλ. or $2d\sin\theta = n\lambda$

Here, d = distance between two consecutive crystal plane or interplanar distance, n = order of diffraction

λ = De broglie wavelength associated with electron.

θ = glancing angle, ϕ = angle of diffraction

Relation between θ and ϕ:

$$\phi = 180^\circ - 2\theta \text{ or } \theta = 90^\circ - \frac{\phi}{2}$$

EXPLANATION OF BOHR QUANTISATION CONDITION

According to De Broglie electron revolves round the nucleus in the form of stationary waves (i. e. wave packet) in the similar fashion as stationary waves in a vibrating string. Electron can stay in those circular orbits whose circumference is an integral multiple of De-Broglie wavelength associated with the electron, $2\pi r = n\lambda$.

$$\because \lambda = \frac{h}{mv} \quad \& \quad 2\pi r = n\lambda \qquad \therefore \quad mvr = \frac{nh}{2\pi}$$

This is the Bohr quantisation condition.

Example 34 :

Find the initial momentum of electron if the momentum of electron is changed by P_m and the De Broglie wavelength associated with it changes by 0.50 %.

Sol. $\frac{d\lambda}{\lambda} \times 100 = 0.5 \Rightarrow \frac{d\lambda}{\lambda} = \frac{0.5}{100} = \frac{1}{200}$ and $\Delta P = P_m$

$\because p = \frac{h}{\lambda}$ differentiating

$$\frac{dp}{d\lambda} = -\frac{h}{\lambda^2} = -\frac{h}{\lambda} \times \frac{1}{\lambda} = -\frac{p}{\lambda} \Rightarrow \frac{|dp|}{p} = \frac{d\lambda}{\lambda}$$

$$\therefore \frac{P_m}{p} = \frac{1}{200} \Rightarrow p = 200\, P_m$$

Example 35 :

A deutron is accelerated through a potential of 500 volts. Find the potential through which a singly ionised helium ion is to be accelerated for the same De Broglie wavelength.

Sol. $\lambda = \frac{h}{\sqrt{2mqV}}$ or mV = constant, V = P.d., q is same

$$m_{He} \times V_{He} = m_d V_d$$

or $4V_{He} = 2 \times 500 \Rightarrow V_{He} = 250\text{V}$

TRY IT YOURSELF - 6

Q.1 Calculate the de Broglie wavelength of the electrons accelerated through a potential difference of 56 V.

Q.2 What is the momentum and speed of an electron with kinetic energy of 120 eV.

Q.3 The wavelength of light from the spectral emission line of sodium is 589 nm. Find the kinetic energy at which a neutron, would have the same de Broglie wavelength.

Q.4 What is the de Broglie wavelength of
(a) a bullet of mass 0.040 kg travelling at the speed of 1.0km/s,
(b) a ball of mass 0.060 kg moving at a speed of 1.0 m/s,
(c) a dust particle of mass 1.0×10^{-9} kg drifting with a speed of 2.2 m/s?

Q.5 For what kinetic energy of a neutron will the associated de Broglie wavelength be 1.40×10^{-10}m?

Q.6 Also find the de Broglie wavelength of a neutron, in thermal equilibrium with matter, having an average kinetic energy of (3/2) kT at 300 K.

Q.7 What is the de Broglie wavelength of a nitrogen molecule in air at 300K? Assume that the molecule is moving with the root-mean square speed of molecules at this temperature. (Atomic mass of nitrogen = 14.0076 u)

ANSWERS

(1) 1.64 Å **(2)** 5.91×10^{-24} kg ms^{-1} ; 6.5×10^{6} ms^{-1}
(3) 3.79×10^{-28} J.
(4) (a) 1.66×10^{-35} m, (b) 1.1×10^{-32} m, (c) 3.01×10^{-25} m.
(5) 4.19×10^{-2} eV. **(6)** 1.456 Å
(7) 0.275×10^{-10} m.

ADDITIONAL EXAMPLES

Example 1 :

Find the ratio of the area of orbit of first excited state of electron to the area of orbit of ground level for hydrogen atom.

Sol. $A \propto r^2 \propto n^4$; $\frac{A_2}{A_1} = \left[\frac{2}{1}\right]^4 = \frac{16}{1} = 16:1$

Example 2 :

The activity of a radioactive substance drops to 1/32 of its initial value in 7.5 h. Find the half life.

Sol. Using $\frac{A}{A_0} = \left(\frac{1}{2}\right)^{t/T}$ or $\frac{1}{32} = \left(\frac{1}{2}\right)^{7.5/T}$

or $\left(\frac{1}{2}\right)^5 = \left(\frac{1}{2}\right)^{7.5/T}$ or $5 = \frac{7.5}{T}$ i.e. T = 1.5 hours

Example 3 :

The half life of a radioactive substance is 34.65 minute. If 10^{22} atoms are active at any time then find the activity of substance?

Sol. Activity $A = \frac{-dN}{dt} = \lambda N$

$$A = \frac{0.693}{T} \times N = \frac{0.693}{34.65 \times 60} \times 10^{22} = 3.34 \times 10^{18} \text{ dps}$$

Example 4 :

The mean life of a radioactive material for α and β decay are 1620 years and 520 years. What is the half life of sample.

Sol. There are two channels of decay so $\frac{1}{\tau} = \frac{1}{\tau_\alpha} + \frac{1}{\tau_\beta}$

or $\tau = \frac{\tau_\alpha \tau_\beta}{\tau_\alpha + \tau_\beta} = \frac{1620 \times 520}{1620 + 520} = 394$ years

The half life $T = 0.693\tau = 0.693 \times 394 = 273$ years

Example 5 :

A nucleus breaks into two parts whose velocity is in ratio 2:1. Find the ratio of their radius.

Sol. as per conservation of momentum $m_1v_1 + m_2v_2 = 0$

$\frac{m_1}{m_2} = \frac{v_2}{v_1}$; ratio of radii $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{m_1}{m_2}\right)^{1/3} = \left(\frac{1}{2}\right)^{1/3}$

so $R_1 : R_2 = 1 : 2^{1/3}$

Example 6 :

The binding energy of ${}_{10}Ne^{20}$ is 160.64 MeV. Find the atomic mass.

Sol. Given $m_p = 1.007825$ amu and $m_n = 1.008665$ amu

$BE = \Delta mc^2 = c^2\,[Zm_p + (A - Z)\,m_n - M]$

$M = Zm_p + (A - Z)\,m_n - BE(amu)$

$$M = 10 \times 1.007825 + 10 \times 1.008665 - \frac{160.64}{931.25} = 19.992 \text{ amu.}$$

Example 7 :

Find the ratio of de-Broglie wavelength of molecules of hydrogen & helium which are at 27°C & 127°C respectively.

Sol. de-Broglie wavelength, $\lambda = \frac{h}{\sqrt{3mkT}}$

$$\frac{\lambda_H}{\lambda_{He}} = \frac{h}{\sqrt{3m_H kT_H}} \times \frac{\sqrt{3m_{He}kT_{He}}}{h}$$

$$\sqrt{\frac{m_{He}}{m_H} . \frac{T_{He}}{T_H}} = \sqrt{\frac{4m\,(127+73)}{m\,(27+273)}} = \sqrt{\frac{8}{3}}$$

Example 8 :

The mass defect in a nuclear fusion reaction is 0.3% . What amount of energy is produced when 1kg of substance undergoes fusion.

Sol. Total mass converted to energy $= \frac{0.3}{1000} \times 1 = 3 \times 10^{-3}$ kg

Energy liberated = $\Delta mc^2 = 3 \times 10^{-3} \times (3 \times 10^8)^2$
$= 27 \times 10^{13}$ joule

Example 9 :

The wavelength for K_α line of an element of atomic number 57 is λ. What is the wavelength of K_α line for the element of atomic number 29.

Sol. For K_α emission,

$$\frac{1}{\lambda} \propto (Z-1)^2 \quad \text{so,} \quad \frac{\lambda_1}{\lambda_2} = \frac{(Z_2-1)^2}{(Z_1-1)^2} = \frac{(29-1)^2}{(57-1)^2}$$

$$\Rightarrow \lambda_2 = \frac{56 \times 56\lambda}{28 \times 28} = 4\lambda$$

Example 10 :

A metal surface is illuminated by light of two different wavelengths 248 nm and 310 nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are u_1 and u_2, respectively. If the ratio $u_1 : u_2 = 2 : 1$ and hc = 1240 eV nm, the work function of the metal is nearly

(A) 3.7 eV (B) 3.2 eV (C) 2.8 eV (D) 2.5 eV

Sol. **(A).** $\frac{1}{2}mu_1^2 = \frac{hc}{\lambda_1} - W$; $\frac{1}{2}mu_2^2 = \frac{hc}{\lambda_2} - W$

$$\left(\frac{u_1}{u_2}\right)^2 = \frac{\frac{hc}{\lambda_1} - W}{\frac{hc}{\lambda_2} - W} \; ; \; \frac{4hc}{\lambda_2} - 4W = \frac{hc}{\lambda_1} - W \quad \left(\because \frac{u_1}{u_2} = 2\right)$$

$$\frac{4hc}{\lambda_2} - \frac{hc}{\lambda_1} = 3W \Rightarrow \frac{4 \times 1240}{310} - \frac{1240}{248} = 3W$$

$\Rightarrow 16 - 5 = 3W \Rightarrow 11 = 3W \Rightarrow W = 3.7$ eV

QUESTION BANK

CHAPTER 7 : MODERN PHYSICS

EXERCISE - 1 [LEVEL-1]

Choose one correct response for each question.

PART 1 : THE PHOTON

Q.1 Light of wavelength 5000 Å falls on a sensitive surface. If the surface has received 10^{-7} Joule of energy, then what is the number of photons falling on the surface ?

(A) 25×10^{11} (B) 25×10^{12}
(C) 0.25×10^{11} (D) 2.5×10^{11}

Q.2 An AIR station is broadcasting the waves of wavelength 300 metres. If the radiating power of the transmitter is 10kW, then the number of photons radiated per second is

(A) 1.5×10^{29} (B) 1.5×10^{31}
(C) 1.5×10^{33} (D) 1.5×10^{35}

Q.3 Wavelength of a 1 keV photon is 1.24×10^{-9}m. What is the frequency of 1 MeV photon

(A) 1.24×10^{15} Hz (B) 2.4×10^{20} Hz
(C) 1.24×10^{18} Hz (D) 2.4×10^{23} Hz

Q.4 If we express the energy of a photon in KeV and the wavelength in angstroms, then energy of a photon can be calculated from the relation

(A) $E = 12.4\, h\nu$ (B) $E = 12.4\, h/\lambda$
(C) $E = 12.4/\lambda$ (D) $E = h\nu$

Q.5 The wavelength of a photon is 4000 Å. Calculate its energy.

(A) 49.5×10^{-19} J (B) 495×10^{-19} J
(C) 4.95×10^{-19} K (D) 4.95×10^{-19} J

Q.6 The momentum of the photon of wavelength 5000Å will be

(A) 1.3×10^{-27} kg-m/sec (B) 1.3×10^{-28} kg-m/sec
(C) 4×10^{29} kg-m/sec (D) 4×10^{-18} kg-m/sec

Q.7 Which of the following statements about photon incorrect?

(A) Photons exert no pressure.
(B) Momentum of photon is $h\nu/c$
(C) Rest mass of photon is zero.
(D) Energy of photon is $h\nu$.

Q.8 When intensity of a light beam is increased –

(A) energy of photons present increases.
(B) momentum of photons present increases.
(C) wavelength of photons present increases.
(D) number of photons crossing a unit area per second increases.

PART 2 : EXPERIMENTAL STUDY OF PHOTOELECTRIC EFFECT

Q.9 Slope of $V_0 - \nu$ curve is-
(where V_0 = Stopping potential and ν = frequency)

(A) e (B) h/e
(C) ϕ_0 (D) h

Q.10 When green light is incident on the surface of metal, it emits photo-electrons but there is no such emission with yellow colour light. Which one of the colour can produce emission of photoelectrons

(A) Orange (B) Red
(C) Indigo (D) None of the above

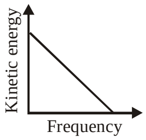
Q.11 The collector plate in an experiment on photoelectric effect is kept vertically above the emitter plate. Light source is put on and a saturation photo current is recorded. An electric field is switched on which has a vertically downward direction

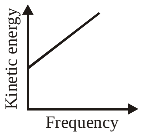
(A) The photo current will increase.
(B) The kinetic energy of the electrons will increase.
(C) The stopping potential will decrease.
(D) The threshold wavelength will increase.

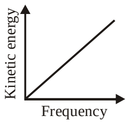
Q.12 For photoelectric emission, tungsten requires light of 2300Å. If light of 1800 Å wavelength is incident then emission

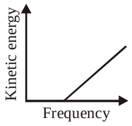
(A) Takes place
(B) Don't take place
(C) May or may not take place
(D) Depends on frequency

Q.13 According to Einstein's photoelectric equation, the graph between the kinetic energy of photoelectrons ejected and the frequency of incident radiation is

(A)


(B)


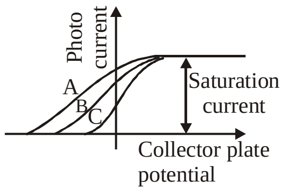
(C)


(D)


Q.14 Which one among the following shows particle nature of light?

(A) Photoelectric effect (B) Interference
(C) Refraction (D) Polarization

Q.15 For the graph of collector plate potential versus photo electric current shown. If 'I' denotes intensity of incident radiation, then



(A) $I_A > I_B > I_C$ (B) $I_A < I_B < I_C$
(C) $I_A = I_B = I_C$ (D) $I_B > I_A$ & $I_B < I_C$

Q.16 In photoelectric effect, stopping potential depends on –

(A) frequency of incident light.
(B) nature of the emitter material.
(C) intensity of incident light.
(D) both (A) and (B).

Q.17 According to wave theory of light,

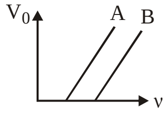
(A) Frequency less than threshold frequency is required for photoemission.

(B) Frequency greater than threshold frequency is required for photoemission.

(C) Frequency equal to that of threshold frequency is required.

(D) A beam of sufficient high intensity is required.

Q.18 The figure shows stopping potential V_0 and frequency ν for two different metallic surfaces A and B. The work function of A, as compared to that of B is –



(A) less
(B) more
(C) equal
(D) nothing can be said

PART 3 : EINSTEIN'S PHOTOELECTRIC EQUATION

Q.19 The work function for the surface of aluminium is 4.2 eV. What will be the wavelength of that incident light for which the stopping potential will be zero.

(A) 2496 Å
(B) 2946×10^{-7} m
(C) 2649 Å
(D) 2946 Å

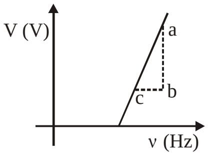
Q.20 If maximum velocity with which an electron can be emitted from a photo cell is 4×10^8 cm/sec, the stopping potential is (Mass of electron = 9×10^{-31} kg)

(A) 30 volt
(B) 45 volt
(C) 59 volt
(D) Information is insufficient

Q.21 A metal surface of work function 1.07 eV is irradiated with light of wavelength 332 nm. The retarding potential required to stop the escape of photo-electrons is

(A) 4.81 eV
(B) 3.74 eV
(C) 2.65 eV
(D) 1.07 eV

Q.22 In a photoelectric experiment, the graph of frequency ν of incident light (in Hz) and stopping potential V (in V) is as shown in the figure. From figure, the value of the Planck's constant is (e is the elementary charge)



(A) $e\dfrac{ab}{bc}$
(B) $e\dfrac{cb}{ab}$
(C) $e\dfrac{ac}{bc}$
(D) $e\dfrac{ac}{ab}$

Q.23 The photoelectric threshold wavelength for silver is λ_0. The energy of the electron ejected from the surface of silver by an incident wavelength λ ($\lambda < \lambda_0$) will be

(A) $hc\,(\lambda_0 - \lambda)$
(B) $\dfrac{hc}{\lambda_0 - \lambda}$
(C) $\dfrac{h}{c}\left(\dfrac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)$
(D) $hc\left(\dfrac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)$

PART 4 : DE-BROGLIE RELATION

Q.24 One electron & one proton is accelerated by equal potential. Ratio in their de-broglie wavelength is-

(A) $\sqrt{\dfrac{m_p}{m_e}}$
(B) $\dfrac{m_e}{m_p}$
(C) $\dfrac{m_p}{m_e}$
(D) 1

Q.25 One electron & one proton have equal energies then ratio of associated de-broglie wavelength will be-

(A) $1 : (1836)^2$
(B) $\sqrt{1836} : 1$
(C) $1836 : 1$
(D) $(1836)^2 : 1$

Q.26 Ratio of wavelength of deuteron & proton accelerated by equal potential-

(A) $1/\sqrt{2}$
(B) $\sqrt{2}/1$
(C) 1/2
(D) 2/1

Q.27 Associated de-broglie wavelength of a electron in nth bohr's orbit is-

(A) $\dfrac{2\pi r}{n}$ Å
(B) $2\pi n$Å
(C) (1/n) Å
(D) $n\lambda$Å

Q.28 The kinetic energy of an electron with de-Broglie wavelength of 0.3 nanometer is

(A) 0.168 eV
(B) 16.8 eV
(C) 1.68 eV
(D) 2.5 eV

Q.29 When the velocity of an electron increases, its de Broglie wavelength

(A) increases
(B) decreases
(C) remains same
(D) may increase or decrease

Q.30 A proton, a neutron, an electron and an α-particle have same energy. Then their de Broglie wavelengths compare as

(A) $\lambda_p = \lambda_n > \lambda_e > \lambda_\alpha$
(B) $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$
(C) $\lambda_e < \lambda_p = \lambda_n > \lambda_\alpha$
(D) $\lambda_e = \lambda_p = \lambda_n = \lambda_\alpha$

Q.31 A particle is dropped from a height H. The de Broglie wavelength of the particle as a function of height is proportional to –

(A) H
(B) $H^{1/2}$
(C) H^0
(D) $H^{-1/2}$

PART 5 : DAVISSON-GERMER EXPERIMENT

Q.32 In Davisson and Germer experiment, the tungsten filament is coated with –

(A) aluminium oxide
(B) barium chloride
(C) titanium oxide
(D) barium oxide

Q.33 In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by –

(A) increasing the potential difference between the anode and filament.
(B) increasing the filament current.
(C) decreasing the filament current.
(D) decreasing the potential difference between the anode and filament.

PART 6 : RUTHERFORD'S MODEL

Q.34 Rutherford's experiments suggested that the size of the nucleus is about

(A) 10^{-14} m to 10^{-12} m
(B) 10^{-15} m to 10^{-13} m
(C) 10^{-15} m to 10^{-14} m
(D) 10^{-15} m to 10^{-12} m

Q.35 For scattering of α-particles Rutherford suggested that

(A) mass of atom and its positive charge were concentrated at centre of atom.
(B) only mass of atom is concentrated at centre of atom.
(C) Only positive charge of atom is concentrated at centre of atom.
(D) Mass of atom is uniformly distributed throughout its volume.

Q.36 In the Geiger-Marsden scattering experiment, in case of head-on collision the impact parameter should be

(A) maximum
(B) minimum
(C) infinite
(D) zero

PART 7 : BOHR'S MODEL

Q.37 Ionisation energy of an electron in ground state of a hydrogen atom is –

(A) 13.6 eV
(B) –13.6 eV
(C) more than 13.6 eV
(D) less than 13.6 eV

Q.38 The radius of hydrogen atom in its ground state is 5.3×10^{-11}m. After collision with an electron it is found to have a radius of 21.2×10^{-11}m. What is the principal quantum number n of the final state of the atom

(A) n = 4
(B) n = 2
(C) n = 16
(D) n = 3

Q.39 The wavelength of radiation emitted is λ_0 when an electron jumps from the third to the second orbit of hydrogen atom. For the electron jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be

(A) $\frac{16}{25}\lambda_0$
(B) $\frac{20}{27}\lambda_0$
(C) $\frac{27}{20}\lambda_0$
(D) $\frac{25}{16}\lambda_0$

Q.40 In the Bohr model of the hydrogen atom, let R, v and E represent the radius of the orbit, the speed of electron and the total energy of the electron respectively. Which quantity is proportional to the quantum number n

(A) R/E
(B) E/v
(C) RE
(D) vR

Q.41 For the Bohr's first orbit of circumference $2\pi r$, the de-Broglie wavelength of revolving electron will be

(A) $2\pi r$
(B) πr
(C) $1/2\pi r$
(D) $1/4\pi r$

Q.42 The radius of first orbit of hydrogen atom is 0.53Å. The radius of its fourth orbit will be-

(A) 0.193 Å
(B) 4.24 Å
(C) 2.12 Å
(D) 8.48 Å

Q.43 In which of the following systems will the radius of first orbit (n = 1) be minimum?

(A) doubly ionized lithium.
(B) singly ionized helium.
(C) deuterium atom.
(D) hydrogen atom.

Q.44 The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. This is because –

(A) of the electrons not being subject to a central force.
(B) of the electrons colliding with each other.
(C) of screening effects.
(D) the force between the nucleus and an electron will no longer be given by coulomb's law.

Q.45 The angular speed of the electron in the n^{th} orbit of Bohr's hydrogen atom is –

(A) directly proportional to n.
(B) inversely proportional to $n^{1/2}$.
(C) inversely proportional to n^2.
(D) inversely proportional to n^3.

Q.46 An electron in a hydrogen atom makes a transition from $n = n_1$ to $n = n_2$. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are –

(A) $n_1 = 4, n_2 = 2$
(B) $n_1 = 8, n_2 = 2$
(C) $n_1 = 8, n_2 = 1$
(D) $n_1 = 6, n_2 = 2$

PART 8 : ATOMIC SPECTRA

Q.47 In a sample of hydrogen like atoms all of which are in ground state, a photon beam containing photons of various energies is passed. In absorption spectrum, five dark lines, are observed. The number of bright lines in the emission spectrum will be (assume that all transitions takes place).

(A) 5
(B) 10
(C) 15
(D) None of these

Q.48 The ratio of the largest to shortest wavelengths in Lyman series of hydrogen spectra is

(A) 25/9
(B) 17/6
(C) 9/5
(D) 4/3

Q.49 The energy of the highest energy photon of Balmer series of hydrogen spectrum is close to

(A) 13.6 eV
(B) 3.4 eV
(C) 1.5 eV
(D) 0.85 eV

Q.50 If ν_1 is the frequency of the series limit of Lyman series, ν_2 is the frequency of the first line of Lyman series and ν_3 is the frequency of the series limit of the Balmer series, then

(A) $\nu_1 - \nu_2 = \nu_3$
(B) $\nu_1 = \nu_2 - \nu_3$
(C) $\frac{1}{\nu_2} = \frac{1}{\nu_1} + \frac{1}{\nu_3}$
(D) $\frac{1}{\nu_1} = \frac{1}{\nu_2} + \frac{1}{\nu_3}$

Q.51 Spectrum of sunlight is an example for
(A) Line absorption spectrum
(B) Continuous emission spectrum
(C) Continuous absorption spectrum
(D) Band emission spectrum

Q.52 Pick out the INCORRECT statement from the following:
(A) Mercury vapour lamp produces line emission spectrum.
(B) Oil flame produces line emission spectrum.
(C) Band spectrum helps us to study molecular structure.
(D) Sunlight spectrum is an example for line absorption spectrum.

Q.53 Which of the following spectral series of hydrogen atom is lying in visible range of electromagnetic wave?
(A) Paschen series (B) Pfund series
(C) Lyman series (D) Balmer series

PART 9 : NUCLEUS

Q.54 Correct order is –
(A) $F_{gravitation} > F_{electrostatic} > F_{nuclear}$
(B) $F_{nuclear} > F_{gravitation} > F_{electrostatic}$
(C) $F_{nuclear} > F_{electrostatic} > F_{gravitation}$
(D) $F_{gravitation} > F_{nuclear} > F_{electrostatic}$

Q.55 Nuclear radius of $_8O^{16}$ is 3×10^{-15} m. Find the density of nuclear matter.
(A) 7.5×10^{17} kg m^{-3} (B) 5.7×10^{17} kg m^{-3}
(C) 2.3×10^{17} kg m^{-3} (D) 1.66×10^{17} kg m^{-3}

Q.56 The ratio of the radii of the nuclei $^{27}_{13}$Al and $_{52}Te^{125}$ is approximately -
(A) 6 : 10 (B) 13 : 52
(C) 40 : 177 (D) 14 : 73

Q.57 The radius of the $_{30}Zn^{64}$ nucleus is nearly (in fm)-
(A) 1.2 (B) 2.4
(C) 3.7 (D) 4.8

Q.58 A nucleus $_ZX^A$ emits 9α-particles and 5β particle. The ratio of total protons and neutrons in the final nucleus is
(A) $\frac{Z-13}{(A-Z-23)}$ (B) $\frac{(Z-18)}{(A-36)}$
(C) $\frac{(Z-13)}{(A-36)}$ (D) $\frac{(Z-13)}{(A-Z-13)}$

Q.59 Determine the ratio of speed of electrons in hydrogen atom in its 3rd & 4th orbit
(A) 1 : 2 (B) 1 : 3
(C) 1 : 4 (D) 4 : 3

Q.60 O_2 molecule consists of two oxygen atoms. In the molecule, nuclear force between the nuclei of the two atoms
(A) is not important because nuclear forces are short-ranged.
(B) is as important as electrostatic force for binding the two atoms.
(C) cancels the repulsive electrostatic force between the nuclei.
(D) is not important because oxygen nucleus have equal number of neutrons & protons.

Q.61 Masses of nuclei of hydrogen, deuterium and tritium are in ratio –
(A) 1 : 2 : 3 (B) 1 : 1 : 1
(C) 1 : 1 : 2 (D) 1 : 2 : 4

Q.62 The ratio of the nuclear radii of the gold isotope $^{197}_{79}$Au and silver isotope $^{107}_{47}$Ag is
(A) 1.23 (B) 0.216
(C) 2.13 (D) 3.46

Q.63 Let m_p be the mass of a proton, m_n the mass of a neutron, M_1 the mass of a $^{20}_{10}$Ne nucleus and M_2 the mass of a $^{40}_{20}$Ca nucleus. Then –
(A) $M_2 = M_1$ (B) $M_2 > 2M_1$
(C) $M_2 < 2M_1$ (D) $M_1 < 10(m_n + m_p)$

Q.64 A force between two protons is same as the force between proton and neutron. The nature of the force is
(A) Weak nuclear force (B) Strong nuclear force
(C) Electrical force (D) Gravitational force

PART 10 : BINDING ENERGY

Q.65 Binding energy per nucleon is
(A) energy required to separate proton from the nucleus.
(B) energy required to separate a neutron from the nucleus.
(C) energy required to separate nucleons of a nucleus.
(D) energy required to separate a proton or a neutron (on an average) from the nucleus.

Q.66 If mass equivalent to one mass of proton is completely converted into energy then determine the energy produced?
(A) 931.49 MeV (B) 731.49 MeV
(C) 911.49 MeV (D) 431.49 MeV

Q.67 If mass equivalent to one mass of electron is completely converted into energy then determine the energy liberated.
(A) 1.51 MeV (B) 0.51 MeV
(C) 3.12 MeV (D) 2.12 MeV

Q.68 If the binding energy of deuterium is 2.23 MeV, then the mass defect will be- (in a.m.u.)
(A) 0.0024 (B) – 0.0024
(C) – 0.0012 (D) 0.0012

Q.69 The mass defect for the nucleus of helium is 0.0303 a.m.u. What is the binding energy per nucleon for helium in MeV
(A) 28 (B) 7
(C) 4 (D) 1

Q.70 If the binding energy per nucleon in Li^7 and He^4 nuclei are respectively 5.60 MeV and 7.06 MeV, then energy of reaction $Li^7 + p \rightarrow 2\ _2He^4$ is
(A) 19.6 MeV (B) 2.4 MeV
(C) 8.4 MeV (D) 17.3 MeV

Q.71 The mass defect in a particular nuclear reaction is 0.3 grams. The amount of energy liberated in kilowatt hours is (Velocity of light = 3 × 10^8 m/s)
(A) 1.5×10^6 (B) 2.5×10^6
(C) 3×10^6 (D) 7.5×10^6

Q.72 The mass of ${}^{7}_{3}\text{Li}$ is 0.042 amu less than the sum of masses of its constituents. The binding energy per nucleon is –
(A) 5.586 MeV (B) 10.522 MeV
(C) 2.433 MeV (D) 3.739 MeV

PART 11 : NUCLEAR ENERGY

Q.73 How much mass has to be converted into energy to produce electric power of 500 MW for one hour?
(A) 2×10^{-5} kg (B) 1×10^{-5} kg
(C) 3×10^{-5} kg (D) 4×10^{-5} kg

Q.74 Commonly used moderators are
I. water. II. heavy water (D_2O)
III. graphite IV. sodium chloride (NaCl).
(A) I, II and III (B) I and II
(C) I, II and IV (D) All of these

Q.75 Fast neutrons can easily be slowed down by
(A) the use of lead shielding.
(B) passing them through water.
(C) elastic collisions with heavy nuclei.
(D) applying a strong electric field.

Q.76 From fission reaction of ${}^{235}_{92}\text{U}$, on an average number of neutrons (per fission) released is –
(A) 1 (B) 2
(C) 3 (D) 2.5

PART 12 : RADIOACTIVITY

Q.77 SI unit for activity is –
(A) Curie (B) Rutherford
(C) Pascal (D) Becquerel

Q.78 The half life of a radioactive substance is 20 s, the time taken for the sample to decay by 7/8th of its initial value is
(A) 20 s (B) 40 s
(C) 60 s (D) 80 s

Q.79 For a radioactive sample half lift $T_{1/2}$ and disintegration constant λ are related as
(A) $T_{1/2} = \ln 2 \, . \, \lambda$ (B) $T_{1/2} = \dfrac{\ln 2}{\lambda}$
(C) $T_{1/2} \times \ln 2 = \lambda$ (D) None of these

Q.80 If $t_{1/2}$ is the half life of a substance then $t_{3/4}$ is the time in which substance
(A) Decays (3/4)th (B) Remains (3/4)th
(C) Decays (1/2) (D) Remains (1/2)

Q.81 The half-life period of radium is 1600 years. Its average life time will be
(A) 3200 years (B) 4800 years
(C) 2319 years (D) 4217 years

Q.82 Three α-particles and one β-particle decaying takes place in series from an isotope ${}_{88}\text{Ra}^{236}$. Finally the isotope obtained will be
(A) ${}_{84}X^{220}$ (B) ${}_{86}X^{222}$
(C) ${}_{83}X^{224}$ (D) ${}_{83}X^{215}$

Q.83 The counting rate observed from a radioactive source at t=0 second was 1600 counts per second and at t=8 seconds it was 100 counts per second. The counting rate observed, as counts per second at t=6 seconds, will be
(A) 400 (B) 300
(C) 200 (D) 150

Q.84 A radio isotope has a half life of 75 years. The fraction of the atoms of this material that would decay in 150 years will be
(A) 66.6% (B) 85.5%
(C) 62.5% (D) 75%

Q.85 An atomic nucleus ${}_{90}\text{Th}^{232}$ emits several α and β radiations and finally reduces to ${}_{82}\text{Pb}^{208}$. It must have emitted
(A) 4α and 2β (B) 6α and 4β
(C) 8α and 24β (D) 4α and 16β

Q.86 In a mean life of a radioactive sample
(A) About 1/3 of substance disintegrates
(B) About 2/3 of the substance disintegrates
(C) About 90% of the substance disintegrates
(D) Almost all the substance disintegrates

Q.87 The radioactivity of an element becomes 1/64th of its original value in 60 sec. Then the half life period is
(A) 5 sec (B) 10 sec
(C) 20 sec (D) 30 sec

Q.88 A radioactive material has a half life of 10 days. What fraction of the material would remain after 30 days
(A) 0.5 (B) 0.25
(C) 0.125 (D) 0.33

Q.89 Two radioactive nuclei A and B are taken with their disintegration constant λ_A and λ_B and initially N_A and N_B number of nuclei are taken then the time after which their undisintegrated nuclei are same is
(A) $\dfrac{\lambda_A \lambda_B}{(\lambda_A - \lambda_B)} \ln\left(\dfrac{N_B}{N_A}\right)$ (B) $\dfrac{1}{(\lambda_A + \lambda_B)} \ln\left(\dfrac{N_B}{N_A}\right)$
(C) $\dfrac{1}{(\lambda_B - \lambda_A)} \ln\left(\dfrac{N_B}{N_A}\right)$ (D) $\dfrac{1}{(\lambda_A - \lambda_B)} \ln\left(\dfrac{N_B}{N_A}\right)$

Q.90 Consider α and β particles and γ-rays each having an energy of 0.5 MeV. In the increasing order of penetrating power, the radiation are respectively
(A) α, β, γ (B) α, γ, β
(C) β, γ, α (D) γ, β, α

Q.91 In a nuclear reactor, moderators slow down the neutrons which come out in a fission process. The moderator used have light nuclei. Heavy nuclei will not serve the purpose because

(A) they will break up.
(B) elastic collision of neutrons with heavy nuclei will not slow them down.
(C) the net weight of the reactor would be unbearably high.
(D) substances with heavy nuclei do not occur in liquid or gaseous state at room temperature.

Q.92 When a nucleus in an atom undergoes a radioactive decay, the electronic energy levels of the atom
(A) do not change for any type of radioactivity.
(B) change for α and β radioactivity but not for γ-radioactivity.
(C) change for α-radioactivity but not for others.
(D) change for β-radioactivity but not for others.

Q.93 Complete the series $^6He \rightarrow e^+ + {}^6Li^+$
(A) neutrino (B) antineutrino
(C) proton (D) neutron

EXERCISE - 2 (LEVEL-2)

Choose one correct response for each question.

Q.1 Energy of a α-particle, having de Broglie wavelength of 0.004 Å.
(A) 1275 eV (B) 1200 KeV
(C) 1200 MeV (D) 1200 GeV

Q.2 De-broglie wavelength of a electron is 10 Å then velocity will be-
(A) 7.2×10^7 m/s (B) 7.2×10^6 m/s
(C) 7.2×10^5 m/s (D) 7.2×10^4 m/s

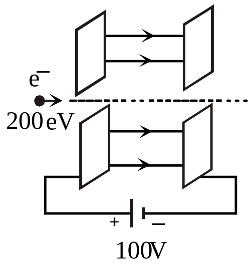
Q.3 De-broglie wavelength of a rotating electron around a nucleus of hydrogen atom at the fundamental energy level is-
(A) 0.3 Å (B) 3.3 Å
(C) 6.62 Å (D) 10 Å

Q.4 From rest a electron is accelerated between two such points which has potential 20 & 40 volts respectively. Associated de Broglie wavelength of electron is-
(A) 0.75 Å (B) 7.5 Å
(C) 2.75 Å (D) 2.75 m

Q.5 The de-broglie wavelength of an electron is 0.2Å. Calculate the potential difference required to retard it to rest-
(A) 3.76×10^{-3} V (B) 3.76×10^3 V
(C) 3.76×10^3 eV (D) 376.5 V

Q.6 An α-particle and a singly ionized $_4Be^8$ atom are accelerated through the same potential difference. Ratio of de-broglie wavelength-
(A) 1 : 2 (B) 2 : 1
(C) 4 : 1 (D) 1 : 1

Q.7 Two large parallel plates are connected with the terminal of 100 V power supply. These plates have a fine hole at the centre. An electron having energy 200 eV is so directed that it passes through the holes. When it comes out it's de-Broglie wavelength is



(A) 1.23 Å (B) 1.75 Å
(C) 2 Å (D) None of these

Q.8 The ratio of momenta of an electron and an α-particle which are accelerated from rest by a potential difference of 100 V
(A) 1 (B) $\sqrt{\frac{2m_e}{m_\alpha}}$
(C) $\sqrt{\frac{m_e}{m_\alpha}}$ (D) $\sqrt{\frac{m_e}{2m_\alpha}}$

Q.9 The de-Broglie wavelength of a particle moving with a velocity 2.25×10^8 m/s is equal to the wavelength of photon. The ratio of kinetic energy of the particle to the energy of the photon is (velocity of light is 3×10^8 m/s)
(A) 1/8 (B) 3/8
(C) 5/8 (D) 7/8

Q.10 When ultraviolet light of energy 6.2 eV incidents on a aluminium surface, it emits photo electrons. If work function for aluminium surface is 4.2 eV, then kinetic energy of emitted electrons is-
(A) 3.2×10^{-19} J (B) 3.2×10^{-17} J
(C) 3.2×10^{-16} J (D) 3.2×10^{-11} J

Q.11 If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is X%. Find the value of (X – 70)
(A) 1 (B) 2
(C) 3 (D) 5

Q.12 Threshold wavelength for photoelectric effect on sodium is 5000 Å. Its work function is
(A) 15 J (B) 16×10^{-14}J
(C) 4×10^{-19} J (D) 4×10^{-18} J

Q.13 Mercury violet light (λ = 4558Å) is falling on a photosensitive material (ϕ_0 = 2.5eV). The speed of the ejected electrons is in m/s, about
(A) 3×10^5 (B) 2.65×10^5
(C) 4×10^4 (D) 3.65×10^7

Q.14 Light of frequency 8×10^{15} Hz is incident on a substance of photoelectric work function 6.125eV. The maximum kinetic energy of the emitted photoelectrons is
(A) 17eV (B) 22eV
(C) 27eV (D) 37eV

Q.15 Ultraviolet light of wavelength 280 nm is used in an experiment on photo electric effect with lithium (ϕ = 2.5 eV) cathode. Stopping potential is
(A) 1 .9 eV (B) 1.9 V
(C) 4.4 eV (D) 4.4 V

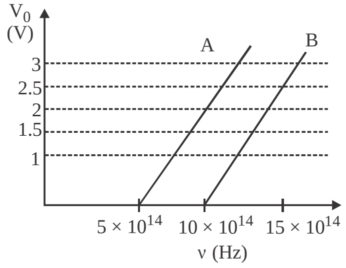
Q.16 A monochromatic source of light operating at 200 W emits 4×10^{20} photons per second. Find the wavelength of light.

(A) 400 nm (B) 200 n
(C) 4×10^{-10} Å (D) None

Q.17 Find the number of photons emitted per second by a 25 watt source of monochromatic light of wavelength 6000Å.

(A) 7.54×10^{19} (B) 6.54×10^{19}
(C) 7.54×10^{16} (D) 8.54×10^{11}

Q.18 A student performs an experiment on photoelectric effect using two materials A and B. A plot of stopping potential (V_0) vs frequency (ν) is as shown in the figure.



The value of h obtained from the experiment for both A and B respectively is (Given electric charge of an electron $= 1.6 \times 10^{-19}$ C)

(A) 3.2×10^{-34} J s, 4×10^{-34} J s
(B) 6.4×10^{-34} J s, 8×10^{-34} J s
(C) 1.2×10^{-34} J s, 3.2×10^{-34} J s
(D) 4.2×10^{-34} J s, 5×10^{-34} J s

Q.19 An electron is moving with an initial velocity $\vec{v} = v_0\hat{i}$ and is in a magnetic field $\vec{B} = B_0\hat{j}$. Then it's de Broglie wavelength –

(A) remains constant.
(B) increases with time.
(C) decreases with time.
(D) increases and decreases periodically.

Q.20 'n' photons of wavelength 'λ' are absorbed by a black body of mass 'm'. The momentum gained by the body is

(A) $\frac{mnh}{\lambda}$ (B) $\frac{nh}{m\lambda}$
(C) $\frac{nh}{\lambda}$ (D) $\frac{h}{m\lambda}$

Q.21 The additional energy that should be given to an electron to reduce its de-Broglie wavelength from 1 nm to 0.5 nm

(A) 2 times the initial kinetic energy
(B) 3 times the initial kinetic energy
(C) 0.5 times the initial kinetic energy
(D) 4 times the initial kinetic energy

Q.22 Maximum velocity of the photoelectron emitted by a metal is 1.8×10^6 m/s. Take the value of specific charge of the electron is 1.8×10^{11} C kg^{-1}. Then the stopping potential in volt is –

(A) 1 (B) 3
(C) 9 (D) 6

Q.23 λ_1 and λ_2 are used to illuminate the slits. β_1 and β_2 are the corresponding fringe widths. The wavelength λ_1 can produce photoelectric effect when incident on a metal. But the wavelength λ_2 cannot produce photoelectric effect. The correct relation between β_1 and β_2 is –

(A) $\beta_1 < \beta_2$ (B) $\beta_1 = \beta_2$
(C) $\beta_1 > \beta_2$ (D) $\beta_1 \geq \beta_2$

Q.24 In a photoelectric experiment, it is found that the maximum kinetic energy of photoelectrons is tripled when the wavelength of incident light is changed from λ/2 to λ/4. The work function of the metal is $\frac{nhc}{\lambda}$, where n is

(A) 1 (B) 2
(C) 3 (D) 4

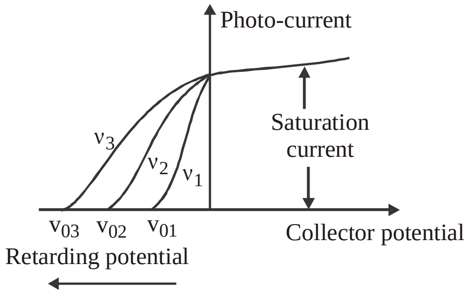
Q.25 Find the de-Broglie wavelength of an electron with kinetic energy of 120 eV.

(A) 112 pm (B) 95 pm
(C) 124 pm (D) 102 pm

Q.26 When a monochromatic 3W source is at 0.3m from a photoelectric cell, the cut-off voltage and saturation current are respectively 0.3V and 3mA. If the power of the source is reduced to 1W and its distance from the cell is reduced to 0.1m then –

(A) stopping potential will be 0.1V
(B) saturation potential will be 3mA
(C) stopping potential will be 0.9V
(D) saturation current will be 9mA

Q.27 The variation of photo-current with collector potential for different frequencies of incident radiation ν_1, ν_2 and ν_3 is as shown in the graph, then



(A) $\nu_3 = \frac{\nu_1 + \nu_2}{2}$ (B) $\nu_1 < \nu_2 < \nu_3$
(C) $\nu_1 > \nu_2 > \nu_3$ (D) $\nu_1 = \nu_2 = \nu_3$

Q.28 A metal begins emitting photoelectrons with green light. It will also give photoemission with

(A) blue light (B) yellow light
(C) orange light (D) red light

Q.29 Polychromatic light described at a place by the equation

$$E = 100 [\sin (0.5\pi\times10^{15}t) + \cos (\pi\times10^{15}t) + \sin (2\pi\times10^{15}t)]$$

where E is in V/m and t in sec, falls on a metal surface having work function 2.0 eV. The maximum kinetic energy of the photoelectron is

(A) zero (B) 1 eV
(C) 2 eV (D) 3 eV

Q.30 If c is the velocity of electromagnetic radiation, e is the charge of an electron, m is the mass of an electron and h is the Planck's constant, then the combination of these universal constants that is dimensionless, is

(A) $me^2/(hc)$ (B) $ch/(me)$
(C) mc^2/h (D) none

Q.31 A beam of fast moving electrons having cross-sectional area A falls normally on a flat surface. The electrons are absorbed by the surface and the average pressure exerted by the electrons on this surface is found to be P. If the electrons are moving with a speed v, then the effective current through any cross-section of the electron beam is

(A) $APe/(mv)$ (B) $APe/(mv^2)$
(C) $APv/(me)$ (D) $APm/(eV)$

Q.32 Photons are incident from vacuum on a transparent material with a refractive index n for a given wavelength. Determine the momentum of the incident photon, if its wavelength in the material is equal to λ.

(A) nh/λ (B) h/λ
(C) $h/n\lambda$ (D) $h/\lambda(n+1)$

Q.33 A beam of α-particles of velocity 2.1×10^7 m/s is scattered by a gold (z = 79) foil. Find out the distance of closest approach of the α-particle to the gold nucleus. The value of charge/mass for α-particle is 4.8×10^7 c/kg.

(A) 2.5×10^{-14}m (B) 1.5×10^{-14}m
(C) 5×10^{-12}m (D) 3×10^{-11}m

Q.34 The ratio between total acceleration of the electron in singly ionized helium atom and hydrogen atom (both in ground state) is

(A) 1 (B) 8
(C) 4 (D) 16

Q.35 Which sample contains greater number of nuclei:
a 5.00- μCi sample of ^{240}Pu (half-life 6560y)
or a 4.45-μCi sample of ^{243}Am (half-life 7370y)

(A) ^{240}Pu (B) ^{243}Am
(C) Equal in both (D) None of these

Q.36 The energy required to knock out the electron in the third orbit of a hydrogen atom is equal to

(A) 13.6 eV (B) $+\frac{13.6}{9}$ eV
(C) $-\frac{13.6}{3}$ eV (D) $-\frac{3}{13.6}$ eV

Q.37 In which of the following process the number of protons in the nucleus increases –

(A) α-decay (B) β^- decay
(C) β^+ decay (D) k-capture

Q.38 An electron jumps from the 4th orbit to the 2nd orbit of hydrogen atom. Given Rydberg's constant $R = 10^5$ cm^{-1}. The frequency in Hz of the emitted radiation will be

(A) $\frac{3}{16} \times 10^5$ (B) $\frac{3}{16} \times 10^{15}$
(C) $\frac{9}{16} \times 10^{15}$ (D) $\frac{3}{4} \times 10^{15}$

Q.39 A hydrogen atom (ionisation potential 13.6 eV) makes a transition from third excited state to first excited state. The energy of the photon emitted in the process is

(A) 1.89 eV (B) 2.55 eV
(C) 12.09 eV (D) 12.75 eV

Q.40 The wavelength of the first line of Balmer series is 6563Å. The Rydberg constant for hydrogen is about

(A) 1.09×10^7 per m (B) 1.09×10^8 per m
(C) 1.09×10^9 per m (D) 1.09×10^5 per m

Q.41 The weight based ratio of U^{238} and Pb^{226} in a sample of rock is 4 : 3 . If the half life of U^{238} is 4.5×10^9 years, then the age of rock is –

(A) 9.0×10^9 years (B) 6.3×10^9 years
(C) 4.5×10^9 years (D) 3.78×10^9 years

Q.42 A nucleus with mass number 220 initially at rest emits an α-particle. If the Q value of the reaction is 5.5MeV, the KE of the α particle is

(A) 4.4 MeV (B) 5.4 MeV
(C) 5.6 MeV (D) 6.5 MeV

Q.43 The wavelength of the first line of Lyman series is 1215Å, the wavelength of first line of Balmer series will be –

(A) 4545 Å (B) 5295 Å
(C) 6561 Å (D) 6750 Å

Q.44 Tritium is an isotope of hydrogen whose nucleus Triton contains 2 neutrons and 1 proton. Free neutrons decay into $p + e^- + \bar{\nu}$. If one of the neutrons in Triton decays, it would transform into He^3 nucleus. This does not happen. This is because

(A) Triton energy is less than that of a He^3 nucleus.
(B) the electron created in the beta decay process cannot remain in the nucleus.
(C) both the neutrons in triton have a decay simultaneously resulting in a nucleus with 3 protons, which is not a He^3 nucleus.
(D) because free neutrons decay due to external perturbations which is absent in a triton nucleus.

Q.45 A fraction f_1 of a radioactive sample decays in one mean life, and a fraction f_2 decays in one half life. Then

(A) $f_1 > f_2$ (B) $f_1 < f_2$
(C) $f_1 = f_2$ (D) None of these

Q.46 Radon has 3.8 days as its half–life. How much radon will be left out of 15 mg mass after 38 days?

(A) 1.05 mg (B) 0.015 mg
(C) 0.231 mg (D) 0.50 mg

Q.47 For the ground state, the electron in the H-atom has an angular momentum = $\hbar$, according to the simple Bohr model. Angular momentum is a vector and hence there will be infinitely many orbits with the vector pointing in all possible directions. In actuality, this is not true,

(A) because Bohr model gives incorrect values of angular momentum.
(B) because only one of these would have a minimum energy.
(C) angular momentum must be in the direction of spin of electron.
(D) because electrons go around only in horizontal orbits.

Q.48 The energy required to excite an electron in hydrogen atom to its first excited state is

(A) 8.5 eV
(B) 10.2 eV
(C) 12.7 eV
(D) 13.6 eV

Q.49 A spectral line results from the transition n = 2 to n = 1 in the single electron system given below. Which one of these will produce the shortest wavelength emission ?

(A) H
(B) He^{+}
(C) Li^{++}
(D) Dueterium atom

Q.50 The wavelength of the first line of the Lyman series of a ten times ionized Na atom (Z = 11) is nearest to

(A) 0.1 Å
(B) 10 Å
(C) 100Å
(D) 1000 Å

Q.51 Which of the following statement is correct in connection with hydrogen spectrum

(A) The longest wavelength in the Balmer series is longer than the longest wavelength in Lyman series.
(B) The shortest wavelength in the Balmer series is shorter than the shortest wavelength in the Lyman series.
(C) The longest wavelength in both Balmer and Lyman series are equal.
(D) The longest wavelength in Balmer series is shorter than the longest wavelength in the Lyman series.

Q.52 N^{th} level of Li^{2+} has the same energy as the ground state energy of the hydrogen atom. If r_N and r_1 be the radius of the N^{th} Bohr orbit of Li^{2+} and first orbit radius of H atom respectively, then the ratio (r_N/r_i) is

(A) 9
(B) 1/9
(C) 3
(D) None

Q.53 In a hydrogen like atom, energy required to excite the electron from its first excited state to second excited state is 7.55 eV. The energy required to remove the electron from its ground state is

(A) 72.6 eV
(B) 67.9 eV
(C) 58.6 eV
(D) 54.4 eV

Q.54 The ratio of the binding energies of the hydrogen atom in the first and the second excited states is

(A) 1/4
(B) 4
(C) 4/9
(D) 9/4

Q.55 An α-particle and a free electron, both initially at rest combine to form a He^{+} ion in its ground state with the emission of a single photon. the energy of the photon is

(A) 54.4 eV
(B) 27.2 eV
(C) 13.6 eV
(D) 40.8 eV

Q.56 An electron orbiting around the nucleus of an atom

(A) has a magnetic dipole moment.
(B) exerts an electric force on the nucleus equal to that on it by the nucleus.
(C) does produce a magnetic induction at the nucleus.
(D) all of these

Q.57 A radioactive sample S_1 having the activity A_1 has twice the number of nuclei as another sample S_2 of activity A_2. If $A_2 = 2A_1$, then the ratio of half life of S_1 to the half life of S_2 is –

(A) 4
(B) 2
(C) 0.25
(D) 0.75

Q.58 When a neutron is disintegrated to give a β-particle –

(A) a neutrino alone is emitted
(B) a proton and neutrino are emitted
(C) a proton alone is emitted
(D) a proton and an antineutrino are emitted

Q.59 When an electron jumps from the orbit n = 2 to n = 4, then wavelength of the radiations absorbed will be – (R is Rydberg's constant).

(A) 3R/16
(B) 5R/16
(C) 16/5R
(D) 16/3R

Q.60 The ratio of minimum wavelength of Lyman and Balmer series will be –

(A) 10
(B) 5
(C) 0.25
(D) 1.25

Q.61 The fraction of the initial number of radioactive nuclei which remain undecayed after half of a half-life of the radioactive sample is –

(A) $1/\sqrt{2}$
(B) 1/2
(C) $1/2\sqrt{2}$
(D) 1/4

Q.62 1 curie represents

(A) 1 disintegration per second
(B) 10^6 disintegrations per second
(C) 3.7×10^{10} disintegrations per second
(D) 3.7×10^{7} disintegrations per second

Q.63 The ratio of the magnetic dipole moment to the angular momentum of the electron in the 1st orbit of hydrogen atom is –

(A) e/m
(B) 2m/e
(C) m/e
(D) e/2m

Q.64 If n is the orbit number of the electron in a hydrogen atom, the correct statement among the following is

(A) hydrogen emits infrared rays for the electron transition from n = ∞ to n = 1.
(B) electron energy is zero for n = 1
(C) electron energy varies as n^2
(D) electron energy increases as n increases

Q.65 The radius of $_{29}Cu^{64}$ nucleus in Fermi is (Given $R_0 = 1.2 \times 10^{-15}$ m)

(A) 1.2
(B) 7.7
(C) 9.6
(D) 4.8

Q.66 In a radioactive decay, an element $_{Z}X^{A}$ emits four α-particles, three β-particles and eight gamma photons. The atomic number and mass number of the resulting final nucleus are –

(A) Z – 5, A – 13
(B) Z – 5, A – 16
(C) Z – 8, A – 13
(D) Z – 11, A – 16

Q.67 A radioactive nucleus has specific binding energy 'E_1'. It emits an α-particle. The resulting nucleus has specific binding energy 'E_2'. Then –

(A) $E_2 < E_1$
(B) $E_2 > E_1$
(C) $E_2 = 0$
(D) $E_2 = E_1$

Q.68 In hydrogen atom, electron excites from ground state to higher energy state and its orbit velocity is reduced to $1/3^{\text{rd}}$ of its initial value. The radius of the orbit in the ground state is R. The radius of the orbit in that higher energy state is –

(A) 3R	(B) 27R
(C) 9R	(D) 2R

Q.69 Decay constants of two radio-active samples A and B are 15x and 3x respectively. The have equal number of initial nuclei. The ratio of the number of nuclei left in A and B after time 1/6x is –

(A) e^2	(B) e^{-1}
(C) e^{-2}	(D) e

Q.70 Mass numbers of the elements A, B, C and D are 30, 60, 90 and 120 respectively. The specific binding energy of them are 5 MeV, 8.5 MeV, 8 MeV and 7 MeV respectively. Then, in which of the following reaction/s energy is released?

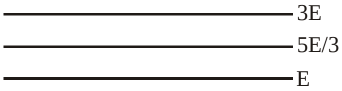
(a) $D \rightarrow 2B$ (b) $C \rightarrow B + A$ (c) $B \rightarrow 2A$

(A) in (b), (c)	(B) in (a), (c)
(C) in (a), (b) and (c)	(D) only in (a)

Q.71 The ionisation energy of an electron in the ground state of helium atom is 24.6 eV. The energy required to remove both the electron is –

(A) 51.8 eV	(B) 79 eV
(C) 38.2 eV	(D) 49.2 eV

Q.72 The figure shows the energy level of certain atom. When the electron deexcites from 3E to E, an electromagnetic wave of wavelength λ is emitted. What is the wavelength of the electromagnetic wave emitted when the electron deexcites from 5E/3 to E?



(A) 3λ	(B) 2λ
(C) 5λ	(D) 3λ/5

Q.73 Pick out the correct statements from the following:

(a) Electron emission during β-decay is always accompanied by neutrino.

(b) Nuclear force is charge independent.

(c) Fusion is the chief source of stellar energy.

(A) (a), (b) correct	(B) (a), (c) are correct
(C) only (a) is correct	(D) (b), (c) are correct

Q.74 A nucleus $_ZX^A$ emits an α-particle with velocity v. The recoil speed of the daughter nucleus is

(A) $\dfrac{A-4}{4v}$	(B) $\dfrac{4v}{A-4}$
(C) v	(D) v/4

Q.75 A radioactive substance emits 100 beta particles in the first 2 seconds and 50 beta particles in the next 2 seconds. The mean life of the sample is –

(A) 4 seconds	(B) 2 seconds
(C) (2/0.693) seconds	(D) 2 × 0.693 seconds

Q.76 In the sun about 4 billion kg of matter is converted to energy each second. The power output of the sun in watt is

(A) 3.6×10^{26}	(B) 0.36×10^{26}
(C) 36×10^{26}	(D) 0.036×10^{26}

Q.77 What is the energy of the electron revolving in third orbit expressed in eV?

(A) 1.51 eV	(B) 3.4 eV
(C) 4.53 eV	(D) 4 eV

Q.78 A radioactive decay can from an isotope of the original nucleus with the emission of particles –

(A) one α and one β	(B) one α four β
(C) four α and one β	(D) one α and two β

Q.79 A nucleus at rest splits into two nuclear parts having radii in the ratio 1: 2. Their velocities are in the ratio

(A) 4 : 1	(B) 8 : 1
(C) 2 : 1	(D) 6 : 1

Q.80 If an electron in hydrogen atom jumps from an orbit of level n = 3 to an orbit of level n = 2, the emitted radiation has a frequency

(R = Rydberg constant., C = velocity of light)

(A) 8RC/9	(B) 3RC/27
(C) 5RC/36	(D) RC/25

Q.81 Total energy of electron in an excited state of hydrogen atom is –3.4 eV. The kinetic and potential energy of electron in this state

(A) K = + 10.2 eV ; U = –13.6 eV

(B) K = –6.8 eV ; U = + 3.4 eV

(C) K = 3.4 eV ; U = – 6.8 eV

(D) K = –3.4 eV ; U = –6.8 eV

Q.82 A radioactive sample of half - life 10 days contains 1000x nuclei. Number of original nuclei present after 5 days is

(A) 250 x	(B) 500 x
(C) 750 x	(D) 707 x

Q.83 There are two radioactive substances A and B. Decay constant of B is two times that of A. Initially, both have equal number of nuclei. After n half lives of A, rate of disintegration of both are equal. The value of n is

(A) 4	(B) 2
(C) 1	(D) 5

Q.84 After 280 days, the activity of a radioactive sample is 6000 dps. The activity reduces to 3000dps after another 140 days. The initial activity of the sample in dps is

(A) 6000	(B) 9000
(C) 3000	(D) 24000

Q.85 If a star can convert all the He nuclei completely into oxygen nuclei. The energy released per oxygen nuclei is [Mass of the nucleus is 4.0026 amu and mass of oxygen nucleus is 15.9994amu]

(A) 7.6 MeV	(B) 56.12 MeV
(C) 10.24 MeV	(D) 23.4 MeV

Q.86 The largest wavelength in the ultraviolet region of the hydrogen spectrum is 122 nm. The smallest wavelength in the infrared region of the hydrogen spectrum (to the nearest integer) is

(A) 802 nm	(B) 823 nm
(C) 1882 nm	(D) 1648 nm

Q.87 In the options given below, let E denote the rest mass energy of a nucleus and n a neutron. The correct option is

(A) $E\left({}^{236}_{92}U\right) > E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$

(B) $E\left({}^{236}_{92}U\right) < E\left({}^{137}_{53}I\right) + E\left({}^{97}_{39}Y\right) + 2E(n)$

(C) $E\left({}^{236}_{92}U\right) < E\left({}^{140}_{56}Ba\right) + E\left({}^{94}_{36}Kr\right) + 2E(n)$

(D) $E\left({}^{236}_{92}U\right) = E\left({}^{140}_{56}Ba\right) + E\left({}^{94}_{36}Kr\right) + 2E(n)$

Q.88 For a radioactive sample the counting rate changes from 6520 counts/minute to 3260 counts/minute in 2 minutes. Determine the decay constant.

(A) 1.78×10^{-2} per sec
(B) 0.78×10^{-3} per sec
(C) 2.78×10^{-6} per sec
(D) 5.78×10^{-3} per sec

Q.89 What is the decay constant of a radioactive substance whose half life is 5 hours

(A) 1.85×10^{-5} per sec
(B) 0.85×10^{-5} per sec
(C) 3.85×10^{-5} per sec
(D) 38.5×10^{-5} per sec

EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)

NOTE : The answer to each question is a NUMERICAL VALUE.

Q.1 Magnetic field at the centre (at nucleus) of hydrogen like atoms (atomic no. = Z) due to motion of electron in n^{th} orbit is proportional to $\frac{z^x}{n^y}$. Find the value of x + y.

Q.2 In Coolidge tube experiment, if applied voltage is increased to three times, the short wavelength limit of continuous X-ray spectrum shifts by 20 pm. What is the initial voltage (in kV) applied to the tube ?

Q.3 In certain experiment it has been found that the ratio of the decay current in a L-R circuit to the activity of a radioactive sample remains constant with time. The time constant ofL-R circuit is 0.4 sec., the average life of radioactive sample is x/10 sec. Find the value of x.

Q.4 The probability of a radioactive atom to survive 5 times longer than its half life period is 2^{-x}. Find the value of x.

Q.5 When a hydrogen atom emits a photon in going from n = 5 to n = 1 state, find its recoil speed (in m/s).
(Mass of H-atom = 1.67×10^{-27} kg)

Q.6 Polonium (${}_{84}Po^{210}$) emits α-particles and is converted into lead (${}_{82}Pb^{206}$). This reaction is used for producing electric power. Polonium has half life 138.6 days. Assuming an efficiency of 10% for the thermoelectric machine, calculate the amount of polonium (in gm) required to produce 1.2×10^7 J of electric energy per day at the end of 693 days. Masses of nuclei are
Po^{210} =209.98264amu, Pb^{206} = 205.97440 amu,
He^4 = 4.00260 amu, 1 amu = 931 MeV/c^2,
Avagoadro's number = 6×10^{23} per mol.

Q.7 In a slow reaction, heat is being evolved at a rate about 10mW in a liquid. If the heat were being generated by the decay of ${}^{32}P$, a radioactive isotope of phosphorus that has half-life of 14 days and emits only beta-particles with a mean energy of 700KeV, estimate the number of ${}^{32}P$ atoms in the liquid. Express your answer in form of $A \times 10^{15}$. Round off A to nearest integer.
[Take : ln 2 = 0.7]

Q.8 The activity of a freshly prepared radioactive sample is 10^{10} disintegrations per second, whose mean life is 10^9 s. The mass of an atom of this radioisotope is 10^{-25} kg. The mass (in mg) of the radioactive sample is

Q.9 A silver sphere of radius 1 cm and work function 4.7 eV is suspended from an insulating thread in freespace. It is under continuous illumination of 200 nm wavelength light. As photoelectrons are emitted, the sphere gets charged and acquires a potential. The maximum number of photoelectrons emitted from the sphere is $A \times 10^Z$ (where 1 < A < 10). The value of Z is –

Q.10 The work functions of Silver and Sodium are 4.6 and 2.3 eV, respectively. The ratio of the slope of the stopping potential versus frequency plot for Silver to that of Sodium is –

Q.11 A freshly prepared sample of a radioisotope of half-life 1386 s has activity 10^3 disintegrations per second. Given that ln 2 = 0.693, the fraction of the initial number of nuclei (expressed in nearest integer percentage) that will decay in the first 80 s after preparation of the sample is –

Q.12 Consider a hydrogen atom with its electron in the nth orbital. An electromagnetic radiation of wavelength 90 nm is used to ionize the atom. If the kinetic energy of the ejected electron is 10.4 eV, then the value of n is
(hc = 1242 eV nm)

Q.13 A nuclear power planet supplying electrical power to a village uses a radioactive material of half life T years as the fuel. The amount of fuel at the beginning is such that the total power requirement of the village is 12.5% of the electrical power available from the plant at that time. If the plant is able to meet the total power needs of the village for a maximum period of nT years, then the value of n is–

Q.14 For a radioactive material, its activity A and rate of change of its activity R are defined as $A = \frac{-dN}{dt}$ and $R = \frac{-dA}{dt}$, where N (t) is the number of nuclei at time t. Two radioactive sources P (mean life τ) and Q (mean life 2τ) have the same activity at t = 0. Their rates of change of activities at t = 2 are RP and RQ, respectively. If $\frac{R_P}{R_Q} = \frac{n}{e}$, then the value of n is :

Q.15 An electron in an excited state of Li^{2+} ions has angular momentum 3h/2π. The de-Broglie wavelength of the electron in this state is $p\pi a_0$ (where a_0 is the Bohr radius). The value of p is –

Q.16 A hydrogen atom in its ground state is irradiated by light of wavelength 970 Å . Taking hc / e = 1.237×10^{-6} eV m and the ground state energy of hydrogen atom as –13.6eV , the number of lines present in the emission spectrum is________.

Q.17 The isotope ${}^{12}_{5}B$ having a mass 12.014 u undergoes β-decay to ${}^{12}_{6}C$. ${}^{12}_{6}C$ has an excited state of the nucleus (${}^{12}_{6}C^*$) at 4.041 MeV above its ground state. If ${}^{12}_{5}B$ decays to ${}^{12}_{6}C^*$, the maximum kinetic energy of the β - particle in units of MeV is________. (1u = 931.5 MeV/c^2 , where c is the speed of light in vacuum)

EXERCISE - 4 [PREVIOUS YEARS JEE MAIN QUESTIONS]

Q.1 13.6 eV energy is required to ionize the hydrogen atom, then the energy required to remove an electron from n = 2 is – **[AIEEE-2002]**

(A) 10.2 eV (B) 0 eV

(C) 3.4 eV (D) 6.8 eV

Q.2 Formation of covalent bonds in compounds exhibits –

(A) Wave nature of electron **[AIEEE-2002]**

(B) Particle nature of electron

(C) Both wave and particle nature of electron

(D) None of these

Q.3 The work functions of potassium and sodium are 4.5eV and 2.3eV respectively. The approximate ratio of their threshold wavelength will be - **[AIEEE-2002]**

(A) 1 : 2 (B) 2 : 1

(C) 1 : 3 (D) 3 : 1

Q.4 In N_0 is the original mass of the substance of half-life period $t_{1/2}$ = 5 years, then the amount of substance left after 15 years is– **[AIEEE-2002]**

(A) $\frac{N_0}{8}$ (B) $\frac{N_0}{16}$

(C) $\frac{N_0}{2}$ (D) $\frac{N_0}{4}$

Q.5 At a specific instant emission of radioactive compound is deflected in a magnetic field. The compound can emit

(A) Electrons (B) Protons **[AIEEE-2002]**

(C) He^{2+} (D) Neutrons

Q.6 A radioactive sample at any instant has its disintegration rate 5000 disintegrations per minute. After 5 minutes, the rate is 1250 disintegrations per minute. Then, the decay constant (per minute) is – **[AIEEE-2003]**

(A) 0.2 ln 2 (B) 0.1 In 2

(C) 0.8 In 2 (D) 0.4 In 2

Q.7 Which of the following cannot be emitted by radioactive substances during their decay ? **[AIEEE-2003]**

(A) Neutrinos (B) Helium nuclei

(C) Electrons (D) Protons

Q.8 Which of the following radiations has the least wavelength **[AIEEE-2003]**

(A) β-rays (B) α-rays

(C) X-rays (D) γ -rays

Q.9 When a U^{238} nucleus originally at rest, decay by emitting an alpha particle having a speed 'u' the recoil speed of the residual nucleus is – **[AIEEE-2003]**

(A) $-\frac{4u}{234}$ (B) $\frac{4u}{234}$

(C) $-\frac{4u}{238}$ (D) $\frac{4u}{238}$

Q.10 A nucleus with Z =92 emits the following in a sequence : $\alpha, \beta^-, \beta^-, \alpha, \alpha, \alpha, \alpha, \alpha, \beta^-, \beta^-, \alpha, \beta^+, \beta^+, \alpha$ The Z of the resulting nucleus is – **[AIEEE-2003]**

(A) 78 (B) 82

(C) 74 (D) 76

Q.11 Two identical photocathodes receive light of frequencies f_1 and f_2 . If the velocities of the photo electrons (of mass m) coming out are respectively v_1 and v_2, then – **[AIEEE-2003]**

(A) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$ (B) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1+f_2)$

(C) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$ (D) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1-f_2)$

Q.12 The wavelengths involved in the spectrum of deuterium $({}_1^2D)$ are slightly different from that of hydrogen spectrum, because – **[AIEEE-2003]**

(A) The nuclear forces are different in the two cases.

(B) The masses of the two nuclei are different.

(C) The attraction between the electron and the nucleus is different in the two cases.

(D) The size of the two nuclei are different.

Q.13 Which of the following atoms has the lowest ionization potential ? **[AIEEE-2003]**

(A) ${}_{55}^{133}Cs$ (B) ${}_{18}^{40}Ar$

(C) ${}_8^{16}O$ (D) ${}_7^{14}N$

Q.14 If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is – **[AIEEE-2003]**

(A) 13.6 eV (B) 3.4 eV

(C) 122.4 eV (D) 30.6 eV

Q.15 An α-particle of energy 5 MeV is scattered through 180° by a fixed uranium nucleus. The distance of closest approach is of the order of – **[AIEEE-2004]**

(A) 10^{-12} cm (B) 10^{-10} cm

(C) 1Å (D) 10^{-15} cm

Q.16 In the nuclear fusion reaction ${}_1^2H + {}_1^3H \rightarrow {}_2^4H + n$, given that the repulsive potential energy between the two nuclei is $\sim 7.7 \times 10^{-14}$ J, the temperature at which the gases must be heated to initiate the reaction is nearly – (Boltzman constant : $K = 1.38 \times 10^{-23}$ J/k)**[AIEEE-2003]**

(A) 10^5 K (B) 10^3 K

(C) 10^9 K (D) 10^7 K

Q.17 A nucleus disintegrates into two nuclear parts which have their velocities in the ratio of 2 : 1. The ratio of their nuclear sizes will be – **[AIEEE-2004]**

(A) $3^{1/2} : 1$ (B) $1 : 2^{1/3}$

(C) $2^{1/3} : 1$ (D) $1 : 3^{1/2}$

Q.18 The binding energy per nucleon of deuteron $({}_1^2H)$ and helium nucleus $({}_2^4He)$ is 1.1 MeV and 7 MeV respectively. If two deuteron nuclei react to form a single helium nucleus, then the energy released is– **[AIEEE-2004]**

(A) 23.6 MeV (B) 26.9 MeV

(C) 13.9 MeV (D) 19.2 MeV

Q.19 A radiation of energy E falls normally on a perfectly reflecting surface. The momentum transferred to the surface is – **[AIEEE-2004]**
(A) E/c (B) 2E/c
(C) E/c (D) E/c^2

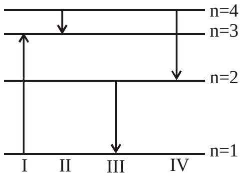
Q.20 According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photo electrons from a metal **Vs** the frequency, of the incident radiation gives a straight line whose slope – **[AIEEE-2004]**
(A) depends both on the intensity of the radiation and the metal used.
(B) depends on the intensity of the radiation.
(C) depends on the nature of the metal used.
(D) is the same for all metals and independent of the intensity of the radiation.

Q.21 The work function of a substance is 4.0 eV. The longest wavelength of light that can cause photoelectron emission from this substance is approximately –
(A) 310 nm (B) 400 nm **[AIEEE-2004]**
(C) 540 nm (D) 220 nm

Q.22 A photocell is illuminated by a small bright source placed 1m away. When the same source of light is placed 1/2 m away, the number of electrons emitted by photocathode would – **[AIEEE-2005]**
(A) decrease by a factor of 4 (B) increase by a factor of 4
(C) decrease by a factor of 2 (D) increase by a factor of 2

Q.23 If the kinetic energy of a free election doubles, its deBroglie wavelength changes by the factor
(A) 1/2 (B) 2 **[AIEEE-2005]**
(C) $1/\sqrt{2}$ (D) $\sqrt{2}$

Q.24 The diagram shows the energy levels for an electron in a certain atom. Which transition shown represents the emission of a photon with the most energy **[AIEEE-2005]**



(A) III (B) IV
(C) I (D) II

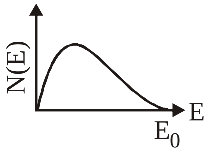
Q.25 If radius of the $^{27}_{13}\text{Al}$ nucleus is estimated to be 3.6 Fermi then the radius of $^{125}_{52}\text{Te}$ nucleus be nearly
(A) 6 fermi (B) 8 fermi **[AIEEE-2005]**
(C) 4 fermi (D) 5 fermi

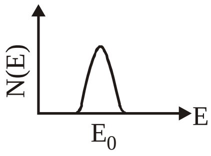
Q.26 A nuclear transformation is denoted by X(n, α) $^{7}_{3}\text{Li}$. Which of the following is the nucleus of element of X ?
(A) $^{12}C_6$ (B) $^{10}_{5}\text{B}$ **[AIEEE-2005]**
(C) $^{9}_{5}\text{B}$ (D) $^{11}_{4}\text{Be}$

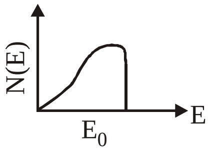
Q.27 The intensity of gamma radiation from a given source is I. On passing through 36 mm of lead, it is reduced to I/8. The thickness of lead which will reduce the intensity to I/2 will be **[AIEEE-2005]**
(A) 6 mm (B) 9 mm
(C) 18 mm (D) 12 mm

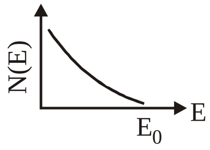
Q.28 Starting with a sample of pure ^{66}Cu, 7/8 of it decays into Zn in 15 minutes. The corresponding half-life is
(A) 10 min (B) 15 min **[AIEEE-2005]**
(C) 5 min (D) 7½ min

Q.29 The energy spectrum of β-particles [number N(E) as a function of β-energy E] emitted from a radioactive source is – **[AIEEE 2006]**

(A) 

(B) 

(C) 

(D) 

Q.30 The 'rad' is the correct unit used to report the measurement of – **[AIEEE 2006]**
(A) the biological effect of radiation.
(B) the rate of decay of a radioactive sourced.
(C) the ability of a beam of gamma ray photons to produce ions in a target.
(D) the energy delivered by radiation to a target.

Q.31 When $_3\text{Li}^7$ nuclei are bombarded by protons, and the resultant nuclei are $_4\text{Be}^8$, the emitted particles wil be – **[AIEEE 2006]**
(A) gamma photons (B) neutrons
(C) alpha particles (D) beta particles

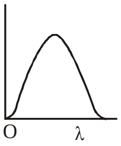
Q.32 An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to –
(A) 1/v^4 (B) 1/Ze **[AIEEE 2006]**
(C) v^2 (D) 1/m

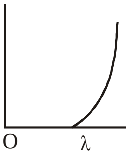
Q.33 If the binding energy per nucleon in $^{7}_{3}\text{Li}$ and $^{4}_{2}\text{He}$ nuclei are 5.60 MeV and 7.06 MeV respectively, then in the reaction $p + {}^{7}_{3}\text{Li} \rightarrow 2\,{}^{4}_{2}\text{He}$ energy of proton must be – **[AIEEE 2006]**
(A) 1.46 MeV (B) 39.2 MeV
(C) 28.24 MeV (D) 17.28 MeV

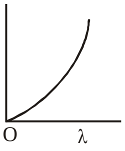
Q.34 The threshold frequency for a metallic surface corresponds to an energy of 6.2 eV and the stopping potential for a radiation incident on this surface is 5 V. The incident radiation lies in – **[AIEEE 2006]**
(A) visible region (B) X-ray region
(C) ultra-violet region (D) infra-red region

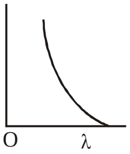
Q.35 The time taken by a photoelectron to come out after the photon strikes is approximately – **[AIEEE 2006]**
(A) 10^{-16} s (B) 10^{-1} s
(C) 10^{-4} s (D) 10^{-10} s

Q.36 The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows – **[AIEEE 2006]**

(A)


(B)


(C)


(D)


Q.37 Which of the following transitions in hydrogen atoms emit photons of highest frequency ? **[AIEEE-2007]**
(A) n = 2 to n = 6 (B) n = 6 to n = 2
(C) n = 2 to n =1 (D) n = 1 to n = 2

Q.38 Photon of frequency v has a momentum associated with it. If c is the velocity of light, the momentum is -
(A) v /c (B) h v c **[AIEEE-2007]**
(C) h v/c^2 (D) h v /c

Q.39 If M_0 is the mass of an oxygen isotope $_8O^{17}$, Mp and M_N are the masses of a proton and a neutron respectively, the nuclear binding energy of the isotope is **[AIEEE-2007]**
(A) $(M_0 - 8M_P)\,C^2$ (B) $(8M_P + 9M_N - M_O)\,C^2$
(C) M_0C^2 (D) $(M_0 - 17\,M_N)\,C^2$

Q.40 In gamma ray emission from a nucleus **[AIEEE-2007]**
(A) both the neutron number and the proton number change.
(B) there is no change in the proton number and the neutron number.
(C) only the neutron number changes
(D) only the proton number changes

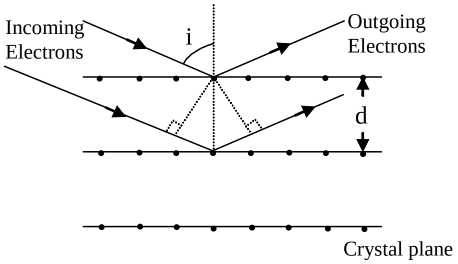
Q.41 The half-life period of a radio-active element X is same as the mean life time of another radio-active element Y. Initially they have the same number of atoms. Then
(A) X will decay faster than Y **[AIEEE 2007]**
(B) Y will decay faster than X
(C) X and Y have same decay rate initially
(D) X and Y decay at same rate always

Q.42 Suppose an electron is attracted towards the origin by a force (k/r) where 'k' is a constant and 'r' is the distance of the electron from the origin. By applying Bohr model to this system, the radius of the n^th^ orbital of the electron is found to be 'r_n' and the kinetic energy of the electron to be 'T_n'. Then which of the following is true? **[AIEEE-2008]**

(A) T_n independent of n, $r_n \propto n$ (B) $T_n \propto \frac{1}{n}$, $r_n \propto n$
(C) $T_n \propto \frac{1}{n}$, $r_n \propto n^2$ (D) $T_n \propto \frac{1}{n^2}$, $r_n \propto n^2$

For Q.43-Q.45

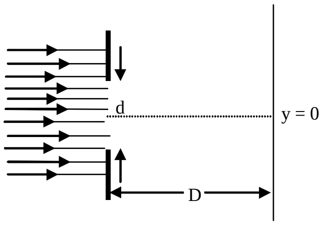
Wave property of electrons implies that they will show diffraction effects. Davisson and Germer demonstrated this by diffracting electrons from crystals. The law governing the diffraction from a crystal is obtained by requiring that electron waves reflected from the planes of atoms in a crystal interfere constructively (see figure),



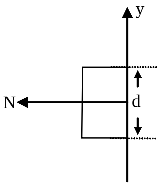
Q. 43 If a strong diffraction peak is observed when electrons are incident at an angle 'i' from the normal to the crystal planes with distance 'd' between them (see figure) de Broglie wavelength λ_{dB} of electrons can be calculated by the relationship (n is an integer). **[AIEEE-2008]**
(A) $2d \cos i = n\,\lambda_{dB}$ (B) $2d \sin i = n\,\lambda_{dB}$
(C) $d \cos i = n\,\lambda_{dB}$ (D) $d \sin i = n\,\lambda_{dB}$

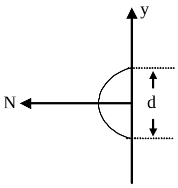
Q.44 Electrons accelerated by potential V are diffracted from a crystal. If d = 1Å and i = 30°, V should be about
($h = 6.6 \times 10^{-34}$Js, $m_e = 9.1 \times 10^{-31}$ kg., $e = 1.6 \times 10^{-19}$ C)
(A) 50 V (B) 500 V **[AIEEE-2008]**
(C) 1000 V (D) 2000V

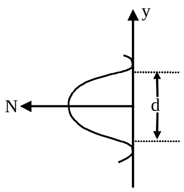
Q.45 In an experiment, electrons are made to pass through a narrow slit of width 'd' comparable to their de Broglie wavelength. They are detected on a screen at a distance 'D' from the slit (see figure).

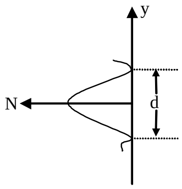


Which of the following graphs can be expected to represent the number of electrons 'N' detected as a function of the detector position 'y' (y = 0 corresponds to the middle of the slit) ? **[AIEEE-2008]**

(A)


(B)


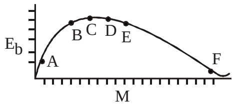
(C) 

(D) 

Q.46 **Statement-1 :** Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion.
Statement-2 : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z. **[AIEEE-2008]**
(A) Statement-1 is true, Statement-2 is true; Statement-2 is a correct explanation for Statement-1.
(B) Statment-1 is true, Statement-2 is true; Statement-2 is not a correct explanation for Statement-1.
(C) Statement-1 is true, Statement-2 is false.
(D) Statement-1 is false, Statement-2 is true.

Q.47 The transition from the state n = 4 to n = 3 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from - **[AIEEE 2009]**
(A) $2 \to 1$ (B) $3 \to 2$
(C) $4 \to 2$ (D) $5 \to 4$

Q.48 A plot of binding energy per nucleon E_b, against the nuclear mass M; A, B, C, D, E, F correspond to different nuclei. Consider four reactions :



(i) $A + B \to C + \varepsilon$ (ii) $C \to A + B + \varepsilon$
(iii) $D + E \to F + \varepsilon$ and (iv) $F \to D + E + \varepsilon$
Where ε is the energy released ? In which reactions is ε positive. **[AIEEE 2009]**
(A) (i) and (iv) (B) (i) and (iii)
(C) (ii) and (iv) (D) (ii) and (iii)

Q.49 The surface of a metal is illuminated with the light of 400nm. The kinetic energy of the ejected photoelectrons was found to be 1.68 eV. The work function of the metal is (hc = 1240 eV. nm) **[AIEEE-2009]**
(A) 3.09 eV (B) 1.41 eV
(C) 1.51 eV (D) 1.68 eV

Q.50 **Statement-1** : When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max}. When the ultraviolet light is replaced by Xrays, both V_0 and K_{max} increase. **[AIEEE 2010]**
Statement-2 : Photoelectrons are emitted with speeds ranging from zero to a maximum value because of the range of frequencies present in the incident light.
(A) Statement-1 is true, Statement-2 is true; Statement-2 is the correct explanation of Statement-1.
(B) Statement-1 is true, Statement-2 is true; Statement-2 is not the correct explanation of Statement-1.
(C) Statement-1 is false, Statement-2 is true.
(D) Statement-1 is true, Statement-2 is false.

For Q.51-Q.52
A nucleus of mass M + Δm is at rest and decays into two daughter nuclei of equal mass M/2 each.
Speed of light is c. **[AIEEE 2010]**

Q.51 The binding energy per nucleon for the parent nucleus is E_1 and that for the daughter nuclei is E_2. Then
(A) $E_2 = 2E_1$ (B) $E_1 > E_2$
(C) $E_2 > E_1$ (D) $E_1 = 2E_2$

Q.52 The speed of daughter nuclei is –
(A) $c\dfrac{\Delta m}{M + \Delta m}$ (B) $c\sqrt{\dfrac{2\Delta m}{M}}$
(C) $c\sqrt{\dfrac{\Delta m}{M}}$ (D) $c\sqrt{\dfrac{\Delta m}{M + \Delta m}}$

Q.53 A radioactive nucleus (initial mass number A and atomic number Z) emits 3 α-particles and 2 positrons. The ratio of number of neutrons to that of protons in the final nucleus will be – **[AIEEE 2010]**
(A) $\dfrac{A - Z - 8}{Z - 4}$ (B) $\dfrac{A - Z - 4}{Z - 8}$
(C) $\dfrac{A - Z - 12}{Z - 4}$ (D) $\dfrac{A - Z - 4}{Z - 2}$

Q.54 If a source of power 4 kW produces 10^{20} photons/second, the radiation belong to a part of the spectrum called **[AIEEE 2010]**
(A) X-rays (B) ultraviolet rays
(C) microwaves (D) γ-rays

Q.55 The half life of a radioactive substance is 20 minutes. The approximate time interval $(t_2 - t_1)$ between the time t_2 when 2/3 of it has decayed and time t_1 when 1/3 of it had decayed is : **[AIEEE 2011]**
(A) 7 min (B) 14 min (C) 20 min
(D) 28 min

Q.56 Energy required for the electron excitation in Li^{++} from the first to the third Bohr orbit is : **[AIEEE 2011]**
(A) 12.1 eV (B) 36.3 eV
(C) 108.8 eV (D) 122.4 eV

Q.57 **Statement-1 :** A metallic surface is irradiated by a monochromatic light of frequency $\nu > \nu_0$ (the threshold frequency). The maximum kinetic energy and the stopping potential are K_{max} and V_0 respectively. If the frequency incident on the surface is doubled, both the K_{max} and V_0 are also doubled. **[AIEEE 2011]**
Statement-2 : The maximum kinetic energy and the stopping potential of photoelectrons emitted from a surface are linearly dependent on the frequency of incident light.
(A) Statement-1 is true, statement-2 is false.
(B) Statement-1 is true, Statement-2 is true, Statement-2 is the correct explanation of Statement-1.
(C) Statement-1 is true, Statement-2 is true, Statement-2 is not the correct explanation of Statement-1.
(D) Statement-1 is false, Statement-2 is true.

Q.58 Hydrogen atom is excieted from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be – **[AIEEE 2012]**

(A) 2 (B) 3
(C) 5 (D) 6

Q.59 **Statement 1 :** Davisson-Germer experiment established the wave nature of electrons. **[AIEEE 2012]**

Statement 2 : If electrons have wave nature, they can interfere and show diffraction.

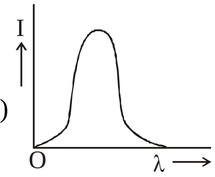
(A) Statement 1 is false, Statement 2 is true.
(B) Statement 1 is true, Statement 2 is false.
(C) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation for statement 1.
(D) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.

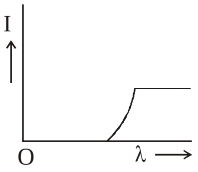
Q.60 Assume that a neutron breaks into a proton and an electron. The energy released during this process is –

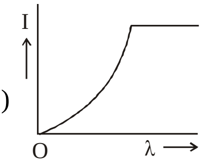
(Mass of neutron = 1.6725×10^{-27} kg,
Mass of proton = 1.6725×10^{-27} kg,
Mass of electron = 9×10^{-31} kg) **[AIEEE 2012]**

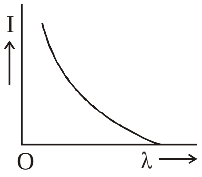
(A) 0.73 MeV (B) 7.10 MeV
(C) 6.30 MeV (D) 5.4 MeV

Q.61 The anode voltage of a photocell is kept fixed. The wavelength λ of the light falling on the cathode is gradually changed. The plate current I of the photocell varies as follows : **[JEE MAIN 2013]**

(A)


(B)


(C)


(D)


Q.62 In a hydrogen like atom electron make transition from an energy level with quantum number n to another with quantum number (n – 1). If n >> 1, the frequency of radiation emitted is proportional to – **[JEE MAIN 2013]**

(A) $1/n$ (B) $1/n^2$
(C) $1/n^{3/2}$ (D) $1/n^3$

Q.63 Hydrogen ($_1H^1$), Deuterium ($_1H^2$), singly ionised Helium $(_2He^4)^+$ and doubly ionised lithium $(_3Li^6)^{++}$ all have one electron around the nucleus. Consider an electron transition from n = 2 to n = 1. If the wave lengths of emitted radiation are $\lambda_1, \lambda_2, \lambda_3$ and λ_4 respectively then approximately which one of the following is correct? **[JEE MAIN 2014]**

(A) $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$ (2) $\lambda_1 = 2\lambda_2 = 3\lambda_3 = 4\lambda_4$
(C) $4\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$ (4) $\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$

Q.64 The radiation corresponding to 3 → 2 transition of hydrogen atom falls on a metal surface to produce photoelectrons. These electrons are made to enter a magnetic field of 3×10^{-4}T. If the radius of the largest circular path followed by these electrons is 10.0 mm, the work function of the metal is close to **[JEE MAIN 2014]**

(A) 0.8 eV (B) 1.6 eV
(C) 1.8 eV (D) 1.1 eV

Q.65 As an electron makes a transition from an excited state to the ground state of a hydrogen-like atom/ion –

(A) Kinetic energy, potential energy & total energy decrease.
(B) Kinetic energy decreases, potential energy increases but total energy remains same. **[JEE MAIN 2015]**
(C) Kinetic energy and total energy decrease but potential energy increases.
(D) Its kinetic energy increases but potential energy and total energy decrease.

Q.66 Match List-I (Fundamental Experiment) with List-II (its conclusion) and select the correct option from the choices given below the list: **[JEE MAIN 2015]**

List -I	**List-II**
(a) Franck-Hertz experiment	(i) Particle nature of light
(b) Photo-electric experiment	(ii) Discrete energy levels of atom
(c) Davison-Germer experiment	(iii) Wave nature of electron
	(iv) Structure of atom

(A) (a) - (ii) (b) - (iv) (c) - (iii) (B) (a) - (ii) (b) - (i) (c) - (iii)
(C) (a) - (iv) (b) - (iii) (c) - (ii) (D) (a)- (i) (b) - (iv) (c) - (iii)

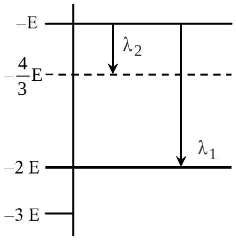
Q.67 Half-lives of two radioactive elements A and B are 20 minutes and 40 minutes, respectively. Initially the samples have equal number of nuclei. After 80 minutes, the ratio of decayed numbers of A and B nuclei will be : **[JEE MAIN 2016]**

(A) 4 : 1 (B) 1 : 4
(C) 5 : 4 (D) 1 : 16

Q.68 Radiation of wavelength λ, is incident on a photocell. The fastest emitted electron has speed v. If the wavelength is changed to 3λ/4, the speed of the fastest emitted electron will be – **[JEE MAIN 2016]**

(A) $< v\,(4/3)^{1/2}$ (B) $= v\,(4/3)^{1/2}$
(C) $< v\,(3/4)^{1/2}$ (D) $> v\,(3/4)^{1/2}$

Q.69 Some energy levels of a molecule are shown in the figure. The ratio of the wavelengths $r_1 = \lambda_1 / \lambda_2$ is given by: **[JEE MAIN 2017]**



(A) r = 2/3 (B) r = 3/4
(C) r = 1/3 (D) r = 4/3

Q.70 A radioactive nucleus A with a half life T, decays into a nucleus B. At t = 0, there is no nucleus B. At sometime t, the ratio of the number of B to that of A is 0.3. Then, t is given by: **[JEE MAIN 2017]**

(A) $t = T\frac{\log 1.3}{\log 2}$ (B) $t = T\log(1.3)$

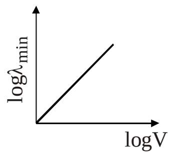
(C) $t = \frac{T}{\log(1.3)}$ (D) $t = \frac{T}{2}\frac{\log}{\log 1.3}$

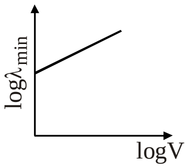
Q.71 A particle A of mass m and initial velocity v collides with a particle B of mass m/2 which is at rest. The collision is head on, and elastic. The ratio of the de-Broglie wavelengths λ_A to λ_B after the collision is: **[JEE MAIN 2017]**

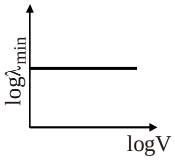
(A) $\frac{\lambda_A}{\lambda_B} = 2$ (B) $\frac{\lambda_A}{\lambda_B} = \frac{2}{3}$

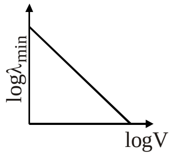
(C) $\frac{\lambda_A}{\lambda_B} = \frac{1}{2}$ (D) $\frac{\lambda_A}{\lambda_B} = \frac{1}{3}$

Q.72 An electron beam is accelerated by a potential difference V to hit a metallic target to produce X-rays. It produces continuous as well as characteristic X-rays. If λ_{min} is the smallest possible wavelength of Xray in the spectrum, the variation of $\log \lambda_{min}$ with log V is correctly represented in: **[JEE MAIN 2017]**

(A)


(B)


(C)


(D)


Q.73 If the series limit frequency of the Lyman series is v_L, then the series limit frequency of the Pfund series is – **[JEE MAIN 2018]**

(A) $v_L/16$ (B) $v_L/25$

(C) $25\,v_L$ (D) $16v_L$

Q.74 An electron from various excited states of hydrogen atom emit radiation to come to the ground state. Let λ_n, λ_g be the de Broglie wavelength of the electron in the nth state and the ground state respectively. let Λ_n be the wavelength of the emitted photon in the transition from the nth state to the ground state. For large n, (A, B are constants) **[JEE MAIN 2018]**

(A) $\Lambda_n^2 \approx A + B\lambda_n^2$ (B) $\Lambda_n^2 \approx \lambda$

(C) $\Lambda_n \approx A + \frac{B}{\lambda_n^2}$ (D) $\Lambda_n \approx A + B\lambda_n$

Q.75 A sample of radioactive material A, that has an activity of 10 mCi (1 Ci = 3.7×10^{10} decays/s), has twice the number of nuclei as another sample of a different radioactive material B which has an activity of 20 mCi. The correct choices for half lives of A and B would then be respectively : **[JEE MAIN 2019 (JAN)]**

(A) 20 days and 5 days
(B) 20 days and 10 days
(C) 5 days and 10 days
(D) 10 days and 40 days

Q.76 Surface of certain metal is first illuminated with light of wavelength λ_1 = 350 nm and then, by light of wavelength λ_2 = 540 nm. It is found that the maximum speed of the photo electrons in the two cases differ by a factor of 2. The work function of the metal (in eV) is close to :

(Energy of photon = $\frac{1240}{\lambda\text{ (in nm)}}$eV)

[JEE MAIN 2019 (JAN)]

(A) 1.8 (B) 1.4

(C) 2.5 (D) 5.6

Q.77 Radiation coming from transitions n = 2 to n = 1 of hydrogen atoms fall on He^+ ions in n = 1 and n = 2 states. The possible transition of helium ions as they absorb energy from the radiation is : **[JEE MAIN 2019 (APRIL)]**

(A) $n = 1 \rightarrow n = 4$ (B) $n = 2 \rightarrow n = 4$

(C) $n = 2 \rightarrow n = 5$ (D) $n = 2 \rightarrow n = 3$

Q.78 Two particles move at right angle to each other. Their de-Broglie wavelengths are λ_1 and λ_2 respectively. The particles suffer perfectly inelastic collision. The de-Broglie wavelength λ, of the final particle, is given by : **[JEE MAIN 2019 (APRIL)]**

(A) $\lambda = \frac{\lambda_1 + \lambda_2}{2}$ (B) $\frac{2}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

(C) $\lambda = \sqrt{\lambda_1\lambda_2}$ (D) $\frac{1}{\lambda^2} = \frac{1}{\lambda_1^2} + \frac{1}{\lambda_2^2}$

Q.79 The ratio of mass densities of nuclei of ^{40}Ca and ^{16}O is close to : **[JEE MAIN 2019 (APRIL)]**

(A) 1 (B) 2 (C) 0.1 (D) 5

Q.80 A nucleus A, with a finite de-broglie wavelength λ_A, undergoes spontaneous fission into two nuclei B and C of equal mass. B flies in the same direction as that of A, while C flies in the opposite direction with a velocity equal to half of that of B. The de-Broglie wavelengths λ_B and λ_C of B and C are respectively : **[JEE MAIN 2019 (APRIL)]**

(A) $2\lambda_A, \lambda_A$ (B) $\lambda_A, 2\lambda_A$

(C) $\lambda_A, \lambda_A/2$ (D) $\lambda_A/2, \lambda_A$

Q.81 The time period of revolution of electron in its ground state orbit in a hydrogen atom is 1.6×10^{-16} s. The frequency of revolution of the electron in its first excited state (in s^{-1}) is: **[JEE MAIN 2020 (JAN)]**

(A) 7.8×10^{14} (B) 7.8×10^{16}

(C) 3.7×10^{14} (D) 3.7×10^{16}

Q.82 On a photosensitive metal of area 1 cm^2 and work function 2eV, light of intensity 6.4×10^{-5} W/cm^2 and wavelength 310 nm is incident normally. If 1 out of every 10^3 photons are successful, then number of photoelectrons emitted in one second is 10^x. Find x

[JEE MAIN 2020 (JAN)]

Q.83 Activity of a substance changes from 700 s^{-1} to 500 s^{-1} in 30 minute. Find its half-life in minutes.

[JEE MAIN 2020 (JAN)]

(A) 66 (B) 62

(C) 56 (D) 50

Q.84 An electron & a photon have same energy E. Find the ratio of de Broglie wavelength of electron to wavelength of photon. Given mass of electron is m and speed of light is C. **[JEE MAIN 2020 (JAN)]**

(A) $\frac{1}{C}\left(\frac{E}{2m}\right)^{1/2}$ (B) $\left(\frac{E}{m}\right)^{1/2}C$

(C) $\frac{\sqrt{2mE}}{C}$ (D) $\left(\frac{E}{2m}\right)^{1/2}$

Q.85 When photon of energy 4.0 eV strikes the surface of a metal A, the ejected photoelectrons have maximum kinetic energy T_A eV end de-Broglie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal B by photon of energy 4.50 eV is $T_B = (T_A - 1.5)$ eV. If the de-Broglie wavelength of these photoelectrons $\lambda_B = 2\lambda_A$, then the work function of metal B is : **[JEE MAIN 2020 (JAN)]**

(A) 3 eV (B) 2 eV

(C) 4 eV (D) 1.5 eV

Q.86 The graph which depicts the results of Rutherform gold foil experiment with α-particales is :

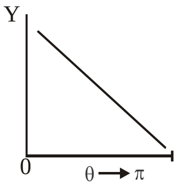
θ : Scattering angle

Y : Number of scattered α-particles detected

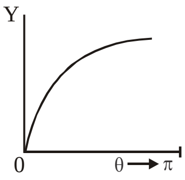
(Plots are schematic and not to scale)

[JEE MAIN 2020 (JAN)]

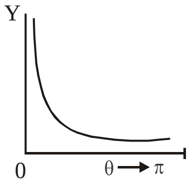
(A)



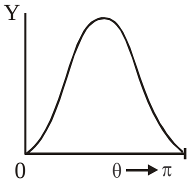
(B)



(C)



(D)



Q.87 An electron (mass m) with initial velocity

$\vec{v} = v_0\hat{i} + v_0\hat{j}$ is in an electric field $\vec{E} = -E_0\hat{k}$.

If λ_0 is initial de-Broglie wavelength of electron, its de-Broglie wave length at time t is given by :

[JEE MAIN 2020 (JAN)]

(A) $\frac{\lambda_0\sqrt{2}}{\sqrt{1+\frac{e^2E^2t^2}{m^2v_0^2}}}$ (B) $\frac{\lambda_0}{\sqrt{2+\frac{e^2E^2t^2}{m^2v_0^2}}}$

(C) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E^2t^2}{2m^2v_0^2}}}$ (D) $\frac{\lambda_0}{\sqrt{1+\frac{e^2E_0^2t^2}{m^2v_0^2}}}$

Q.88 The first member of the Balmer series of hydrogen atom has a wavelength of 6561 Å. The wavelength of the second member of the Balmer series (in nm) is:

[JEE MAIN 2020 (JAN)]

Q.89 The energy required to ionise a hydrogen like ion in its ground state is 9 Rydbergs. What is the wavelength of the radiation emitted when the electron in this ion jumps from the second excited state to the ground state ?

[JEE MAIN 2020 (JAN)]

(A) 35.8 nm (B) 24.2 nm

(C) 8.6 nm (D) 11.4 nm

EXERCISE - 5 [PREVIOUS YEARS AIPMT / NEET QUESTIONS]

PART - A (DUAL NATURE OF MATTER AND RADIATION)

Q.1 The work functions for metals A, B and C are respectively 1.92eV, 2.0eV and 5eV. According to Einstein's equation, the metals which will emit photoelectrons for a radiation of wavelength 4100Å is/are – **[AIPMT 2005]**

(A) none (B) A only
(C) A and B only (D) all three metals

Q.2 A photosensitive metallic surface has work function, $h\nu_0$. If photons of energy $2h\nu_0$ fall on this surface, the electrons come out with a maximum velocity of 4×10^6 m/s. When the photon energy is increased to $5\,h\nu_0$, then maximum velocity of photoelectrons will be – **[AIPMT 2005]**

(A) 2×10^7 m/s (B) 2×10^6 m/s
(C) 8×10^6 m/s (D) 8×10^5 m/s

Q.3 A photo-cell employs photoelectric effect to convert – **[AIPMT 2006]**

(A) change in the intensity of illumination into a change in photoelectric current.
(B) change in the intensity of illumination into a change in the work function of the photocathode.
(C) change in the frequency of light into a change in the electric current.
(D) change in the frequency of light into a change in electric voltage.

Q.4 In a discharge tube ionization of enclosed gas is produced due to collisions between – **[AIPMT 2006]**

(A) negative electrons and neutral atoms/molecules.
(B) photons and neutral atoms/molecules.
(C) neutral gas atoms/molecules.
(D) positive ions and neutral atoms/molecules.

Q.5 The momentum of a photon of energy 1MeV in kg m/s, will be – **[AIPMT 2006]**

(A) 7×10^{-24} (B) 10^{-22}
(C) 5×10^{-22} (D) 0.33×10^6

Q.6 Monochromatic light of frequency 6.0×10^{14}Hz is produced by a laser. The power emitted is 2×10^{-3}W. The number of photons emitted, on the average, by the sources per second is – **[AIPMT 2007]**

(A) 5×10^{16} (B) 5×10^{17}
(C) 5×10^{14} (D) 5×10^{15}

Q.7 A 5 watt source emits monochromatic light of wavelength 5000Å. When placed 0.5m away, it liberates photoelectrons from a photosensitive metallic surface. When the source is moved to a distance of 1.0m, the number of photoelectrons liberated will be reduced by a factor of – **[AIPMT 2007]**

(A) 8 (B) 16
(C) 2 (D) 4

Q.8 The work function of a surface of a photosensitive material is 6.2 eV. The wavelength of the incident radiation for which the stopping potential is 5 V lies in the – **[AIPMT 2008]**

(A) X-ray region (B) Ultraviolet region
(C) Visible region (D) Infrared region

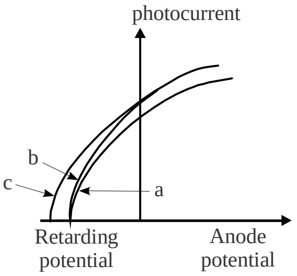
Q.9 A particle of mass 1 mg has the same wavelength as an electron moving with a velocity of 3×10^6 m/s. The velocity of the particle is – **[AIPMT 2008]**

(A) 2.7×10^{-21} m/s (B) 2.7×10^{-18} m/s
(C) 9×10^{-2} m/s (D) 3×10^{-31} m/s
(Mass of electron = 9.1×10^{-31} kg)

Q.10 The number of photo electrons emitted for light of a frequency ν (higher than the threshold frequency ν_0) is proportional to **[AIPMT 2009]**

(A) Threshold frequency (ν_0) (B) Intensity of light
(C) Frequency of light (ν) (D) $\nu - \nu_0$

Q.11 The Figure shows a plot of photo current versus anode potential for a photo sensitive surface for three different radiations. Which one of the following is a correct statement? **[AIPMT 2009]**



(A) Curves (a) and (b) represent incident radiations of same frequency but of different intensities.
(B) Curves (b) and (c) represent incident radiations of different frequencies and different intensities.
(C) Curves (b) and (c) represent incident radiations of same frequency having same intensity.
(D) Curves (a) and (b) represent incident radiations of different frequencies and different intensities.

Q.12 Monochromatic light of wavelength 667 nm is produced by a helium neon laser. The power emitted is 9 mW. The number of photons arriving per sec. on the average at a target irradiated by this beam is: **[AIPMT 2009]**

(A) 3×10^{16} (B) 9×10^{15}
(C) 3×10^{19} (D) 9×10^{17}

Q.13 A source S_1 is producing 10^{15} photons per second of wavelength 5000Å. Another source S_2 is producing 1.02×10^{15} photons per second of wavelength 5100Å. Then (power of S_2) / (power of S_1) is equal to **[AIPMT 2010 (PRE)]**

(A) 1.00 (B) 1.02
(C) 1.04 (D) 0.98

Q.14 In photoelectric emission process from a metal of work function 1.8eV, the kinetic energy of most energetic electrons is 0.5eV. The corresponding stopping potential is – **[AIPMT 2011 (PRE)]**

(A) 2.3 V (B) 1.8 V
(C) 1.3 V (D) 0.5 V

Q.15 Electrons used in an electron microscope are accelerated by a voltage of 25 kV. If the voltage is increased to 100kV then the de-Broglie wavelength associated with the electrons would **[AIPMT 2011 (PRE)]**

(A) Increases by 4 times
(B) Increases by 2 times
(C) Decreases by 2 times
(D) Decreases by 4 times

Q.16 Light of two different frequencies whose photons have energies 1eV and 2.5eV respectively illuminate a metallic surface whose work function is 0.5 eV successively. Ratio of maximum speeds of emitted electrons will be **[AIPMT 2011 (PRE)]**

(A) 1 : 5 (B) 1 : 4
(C) 1 : 2 (D) 1 : 1

Q.17 In the Davisson and Germer experiment, the velocity of e^- emitted from the electron gun can be increased by – **[AIPMT 2011 (PRE)]**

(A) Decreasing the potential difference between the anode and filament.
(B) Increasing the potential difference between the anode and filament.
(C) Increasing the filament current.
(D) Decreasing the filament current.

Q.18 Photoelectric emission occurs only when the incident light has more than a certain minimum – **[AIPMT 2011 (PRE)]**

(A) Frequency (B) Power
(C) Wavelength (D) Intensity

Q.19 The threshold frequency for a photosensitive metal is 3.3×10^{14} Hz. If light of frequency 8.2×10^{14} Hz is incident on this metal, the cut-off voltage for the photoelectric emission is nearly **[AIPMT 2011 (MAINS)]**

(A) 2V (B) 3V
(C) 5V (D) 1V

Q.20 An electron in the hydrogen atom jumps from excited state n to the ground state. The wavelength so emitted illuminates a photosensitive material having work function 2.75eV. If the stopping potential of the photoelectron is 10 V, the value of n is – **[AIPMT 2011 (MAINS)]**

(A) 3 (B) 4
(C) 5 (D) 2

Q.21 A 200 W sodium street lamp emits yellow light of wavelength 0.6 μm. Assuming it to be 25% efficient in converting electrical energy to light, the number of photons of yellow light it emits per second is – **[AIPMT 2012 (PRE)]**

(A) 1.5×10^{20} (B) 6×10^{18}
(C) 62×10^{20} (D) 3×10^{19}

Q.22 Monochromatic radiation emitted when electron on hydrogen atom jumps from first excited to the ground state irradiates a photosensitive material. The stopping potential is measured to be 3.57V. The threshold frequency of the materials is : **[AIPMT 2012 (PRE)]**

(A) 4×10^{15} Hz (B) 5×10^{15} Hz
(C) 1.6×10^{15} Hz (D) 2.5×10^{15} Hz

Q.23 If the momentum of electron is changed by P, then the de Broglie wavelength associated with it changes by 0.5%. The initial momentum of electron will be – **[AIPMT 2012 (MAINS)]**

(A) 200 P (B) 400 P
(C) P/200 (D) 100 P

Q.24 Two radiations of photons energies 1eV and 2.5eV, successively illuminate a photo sensitive metallic surface of work function 0.5 eV. The ratio of the maximum speeds of the emitted electrons is : **[AIPMT 2012 (MAINS)]**

(A) 1 : 4 (B) 1 : 2
(C) 1 : 1 (D) 1 : 5

Q.25 The wavelength λ_e of an electron and λ_P of a photon of same energy E are related by – **[NEET 2013]**

(A) $\lambda_P \propto \frac{1}{\sqrt{\lambda_e}}$ (B) $\lambda_P \propto \lambda_e^2$

(C) $\lambda_P \propto \lambda_e$ (D) $\lambda_P \propto \sqrt{\lambda_e}$

Q.26 For photoelectric emission from certain metal the cutoff frequency is ν. If radiation of frequency 2ν impinges on the metal plate, the maximum possible velocity of the emitted electron will be (m is the electron mass) – **[NEET 2013]**

(A) $2\sqrt{h\nu/m}$ (B) $\sqrt{h\nu/2m}$
(C) $\sqrt{h\nu/m}$ (D) $\sqrt{2h\nu/m}$

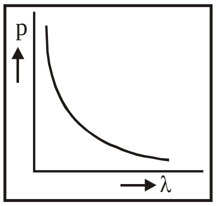
Q.27 When the energy of the incident radiation is increased by 20%, the kinetic energy of the photoelectrons emitted from a metal surface increased from 0.5eV to 0.8eV. The work function of the metal is – **[AIPMT 2014]**

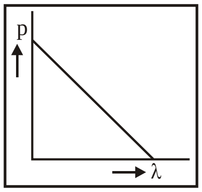
(A) 0.65 eV (B) 1.0 eV
(C) 1.3 eV (D) 1.5 eV

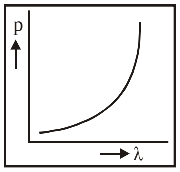
Q.28 If the kinetic energy of the particle is increased to 16 times its previous value, the percentage change in the de-Broglie wavelength of the particle is – **[AIPMT 2014]**

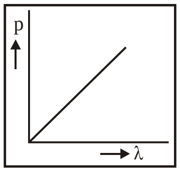
(A) 25 (B) 75
(C) 60 (D) 50

Q.29 Which of the following figures represent the variation of particle momentum & the associated de-Broglie wavelength – **[AIPMT 2015]**

(A)


(B)


(C)


(D)


Q.30 A certain metallic surface is illuminated with monochromatic light of wavelength λ. The stopping potential for photo-electric current for this light is $3V_0$. If the same surface is illuminated with light of wavelength 2λ. The stopping potential is V_0, the threshold wavelength for this surface for photo-electric effect is

(A) 4λ (B) $\lambda/4$ **[AIPMT 2015]**
(C) $\lambda/6$ (D) 6λ

Q.31 Light of wavelength 500 nm is incident on a metal with work function 2.28 eV. The de Broglie wavelength of the emitted electron is – **[RE-AIPMT 2015]**

(A) $\le 2.8 \times 10^{-12}$m (B) $< 2.8 \times 10^{-10}$m
(C) $< 2.8 \times 10^{-9}$ m (D) $\ge 2.8 \times 10^{-9}$ m

Q.32 A photoelectric surface is illuminated successively by monochromatic light of wavelength λ and $\lambda/2$. If the maximum kinetic energy of the emitted photoelectrons in the second case is 3 times that in the first case, the work function of the surface of the material is :
(h = Plank's constant, c = speed of light)
[RE-AIPMT 2015]

(A) $hc/3\lambda$ (B) $hc/2\lambda$
(C) hc/λ (D) $2hc/\lambda$

Q.33 An electron of mass m and a photon have same energy E. The ratio of de-Broglie wavelengths associated with them is (c being velocity of light)**[NEET 2016 PHASE 1]**

(A) $\frac{1}{c}\left(\frac{E}{2m}\right)^{1/2}$ (B) $\left(\frac{E}{2m}\right)^{1/2}$
(C) $c\,(2mE)^{1/2}$ (D) $\frac{1}{c}\left(\frac{2m}{E}\right)^{1/2}$

Q.34 When a metallic surface is illuminated with radiation of wavelength λ, the stopping potential is V. If the same surface is illuminated with radiation of wavelength 2λ, the stopping potential is V/4. The threshold wavelength for the metallic surface is **[NEET 2016 PHASE 1]**

(A) 4λ (B) 5λ
(C) $(5/2)\,\lambda$ (D) 3λ

Q.35 Electrons of mass m with de-Broglie wavelength λ fall on the target in an X-ray tube. The cutoff wavelength (λ_0) of the emitted X-ray is **[NEET 2016 PHASE 2]**

(A) $\lambda_0 = \frac{2mc\lambda^2}{h}$ (B) $\lambda_0 = \frac{2h}{mc}$
(C) $\lambda_0 = \frac{2m^2c^2\lambda^3}{h^2}$ (D) $\lambda_0 = \lambda$

Q.36 Photons with energy 5 eV are incident on a cathode C in a photoelectric cell. The maximum energy of emitted photoelectrons is 2 eV. When photons of energy 6 eV are incident on C, no photoelectrons will reach the anode A, if the stopping potential of A relative to C is
[NEET 2016 PHASE 2]

(A) +3 V (B) +4 V
(C) –1 V (D) –3 V

Q.37 The de-Broglie wavelength of a neutron in thermal equilibrium with heavy water at a temperature T (Kelvin) and mass m, is – **[NEET 2017]**

(A) $\frac{h}{\sqrt{3mkT}}$ (B) $\frac{2h}{\sqrt{3mkT}}$ (C) $\frac{2h}{\sqrt{mkT}}$ (D) $\frac{h}{\sqrt{mkT}}$

Q.38 The photoelectric threshold wavelength of silver is 3250×10^{-10} m. The velocity of the electron ejected from a silver surface by ultraviolet light of wavelength 2536×10^{-10} m is – **[NEET 2017]**
(Given $h = 4.14\times 10^{-15}$ eVs & $c = 3 \times 10^8$ m/s)

(A) $\approx 0.6 \times 10^6\ \text{ms}^{-1}$ (B) $\approx 61 \times 10^3\ \text{ms}^{-1}$
(C) $\approx 0.3 \times 10^6\ \text{ms}^{-1}$ (D) $\approx 6 \times 10^7\ \text{ms}^{-1}$

Q.39 An electron of mass m with an initial velocity $\vec{V} = V_0\hat{i}\ (V_0 > 0)$ enters an electric field $\vec{E} = -E_0\hat{i}\ (E_0 = \text{constant} > 0)$ at t = 0. If λ_0 is its de-Broglie wavelength initially, then its de-Broglie wavelength at time t is **[NEET 2018]**

(A) $\lambda_0 t$ (B) $\lambda_0\left(1+\frac{eE_0}{mV_0}t\right)$
(C) $\frac{\lambda_0}{\left(1+\frac{eE_0}{mV_0}t\right)}$ (D) λ_0

Q.40 When the light of frequency $2\nu_0$ (where ν_0 is threshold frequency), is incident on a metal plate, the maximum velocity of electrons emitted is v_1. When the frequency of the incident radiation is increased to $5\nu_0$, the maximum velocity of electrons emitted from the same plate is v_2. The ratio of v_1 to v_2 is **[NEET 2018]**

(A) 4 : 1 (B) 1 : 4
(C) 1 : 2 (D) 2 : 1

Q.41 An electron is accelerated through a potential difference of 10,000 V. Its de Broglie wavelength is, (nearly) : ($m_e = 9 \times 10^{-31}$ kg) **[NEET 2019]**

(A) 12.2×10^{-13} m (B) 12.2×10^{-12} m
(C) 12.2×10^{-14} m (D) 12.2 nm

PART-B (ATOMS AND NUCLEI)

Q.1 The total energy of an electron in the first excited state of hydrogen atom is about –3.4 eV. Its kinetic energy in this state is – **[AIPMT 2005]**

(A) 3.4eV (B) 6.8eV
(C) –3.4eV (D) – 6.8eV

Q.2 In the reaction, ${}^{2}_{1}H + {}^{3}_{1}H \longrightarrow {}^{4}_{1}He + {}^{1}_{0}n$, if the binding energies of ${}^{2}_{1}H$, ${}^{3}_{1}H$ & ${}^{4}_{2}He$ are respectively, a, b and c (in MeV), then the energy (in MeV) released in this reaction is – **[AIPMT 2005]**

(A) a + b + c (B) a + b – c
(C) c – a – b (D) c + a – b

Q.3 The nuclei of which one of the following pairs of nuclei are isotones – **[AIPMT 2005]**

(A) ${}_{34}Se^{74}$, ${}_{31}Ga^{71}$ (B) ${}_{38}Sr^{84}$, ${}_{38}Sr^{86}$
(C) ${}_{42}Mo^{92}$, ${}_{40}Zr^{92}$ (D) ${}_{20}Ca^{40}$, ${}_{16}S^{32}$

Q.4 Fission of nuclei is possible because the binding energy per nucleon in them – **[AIPMT 2005]**

(A) increases with mass number at low mass numbers.
(B) decreases with mass number at low mass numbers.
(C) increases with mass number at high mass numbers.
(D) decreases with mass number at high mass numbers.

Q.5 In any fission process, the ratio

$\dfrac{\text{mass of fission products}}{\text{mass of parent nucleus}}$ is – **[AIPMT 2005]**

(A) equal to 1
(B) greater than 1
(C) less than 1
(D) depends on the mass of the parent nucleus

Q.6 Ionization potential of hydrogen atom is 13.6eV. Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1eV. According to Bohr's theory, the spectral lines emitted by hydrogen will be

(A) three (B) four **[AIPMT 2006]**
(C) one (D) two

Q.7 The binding energy of deuteron is 2.2MeV and that of ${}^{4}_{2}\text{He}$ is 28 MeV. If two deuterons are fused to form one ${}^{4}_{2}\text{He}$, then the energy released is – **[AIPMT 2006]**

(A) 23.6 MeV (B) 19.2 MeV
(C) 30.2 MeV (D) 25.8 MeV

Q.8 In a radioactive material the activity at time t_1 is R_1 and at a later time t_2, it is R_2. If the decay constant of the material is λ, then **[AIPMT 2006]**

(A) $R_1 = R_2 e^{\lambda(t_1-t_2)}$ (B) $R_1 = R_2 e^{(t_2/t_1)}$
(C) $R_1 = R_2$ (D) $R_2 = R_1 e^{-\lambda(t_2-t_1)}$

Q.9 The radius of germanium (Ge) nuclide is measured to be twice the radius of ${}^{9}_{4}\text{Be}$. The number of nucleons in Ge are – **[AIPMT 2006]**

(A) 74 (B) 75
(C) 72 (D) 73

Q.10 The total energy of electron in the ground state of hydrogen atom is –13.6eV. The kinetic energy of an electron in the first excited state is – **[AIPMT 2007]**

(A) 6.8eV (B) 13.6eV
(C) 1.7eV (D) 3.4eV

Q.11 In a radioactive decay process, the negatively charged emitted β-particles are – **[AIPMT 2007]**

(A) the electrons produced as a result of the decay of neutrons inside the nucleus.
(B) the electrons produced as a result of collisions between atoms.
(C) the electron orbiting around the nucleus.
(D) the electron present inside the nucleus.

Q.12 A nucleus ${}^{A}_{Z}X$ has mass represented by M (A, Z). If M_p and M_n denote the mass of proton and neutron respectively and B.E. the binding energy in MeV, then **[AIPMT 2007]**

(A) B.E. = $[ZM_p + (A-Z)M_n - M(A, Z)]c^2$
(B) B.E. = $[ZM_p + ZM_n - M(A, Z)]c^2$
(C) B.E. = $M(A, Z) - ZMp - (A-Z)Mn$
(D) B.E. = $[M(A, Z) - ZM_p - (A-Z)M_n]c^2$

Q.13 If the nucleus ${}^{27}_{13}\text{Al}$ has nuclear radius of about 3.5fm, then ${}^{125}_{32}\text{Te}$ would have its radius approximately as –

(A) 9.5fm (B) 12.0fm **[AIPMT 2007]**
(C) 4.8fm (D) 6.0fm

Q.14 Two radioactive substances A and B have decay constants 5λ and λ respectively. At t = 0 they have the same number of nuclei. The ratio of number of nuclei of A to those of B will be $(1/e)^2$ after a time interval

(A) 4λ (B) 2λ **[AIPMT 2007]**
(C) 1/2λ (D) 1/4λ

Q.15 The ground state energy of hydrogen atom is –13.6eV. When its electron is in the first excited state, its excitation energy is **[AIPMT 2008]**

(A) 0 (B) 3.4 eV
(C) 6.8 eV (D) 10.2 eV

Q.16 Two radioactive materials X_1 and X_2 have decay constants 5λ and λ repetitively. If initially they have the same number of nuclei, then the ratio of the number of nuclei of X_1 to that X_2 will be 1/e after a time

(A) e/λ (B) λ **[AIPMT 2008]**
(C) λ/2 (D) 1/4λ

Q.17 In a Rutherford scattering experiment when a projectile of charge z_1 and mass M_1 approaches a target nucleus of charge z_2 and mass M_2, the distance of closest approach is r_0. The energy of the projectile is:

(A) directly proportional to $z_1\,z_2$ **[AIPMT 2009]**
(B) inversely proportional to z_1
(C) directly proportional to mass M_1
(D) directly proportional to $M_1 \times M_2$

Q.18 The ionization energy of the electron in the hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between: **[AIPMT 2009]**

(A) n = 3 to n = 1 states (B) n = 2 to n = 1 states
(C) n = 4 to n = 3 states (D) n = 3 to n = 2 states

Q.19 The number of beta particles emitted by a radioactive substance is twice the number of alpha particles emitted by it. The resulting daughter is an: **[AIPMT 2009]**

(A) isomer of parent (B) isotone of parent
(C) isotope of parent (D) isobar of parent

Q.20 In the nuclear decay given below:

$${}^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y \longrightarrow {}^{A-4}_{Z-1}B^{*} \longrightarrow {}^{A-4}_{Z-1}B\ ,$$

the particles emitted in the sequence are: **[AIPMT 2009]**

(A) γ, β, α (B) β, γ, α
(C) α, β, γ (D) β, α, γ

Q.21 The energy of a hydrogen atom in the ground state is –13.6 eV. The energy of a He^+ ion in the first excited state will be **[AIPMT (PRE) 2010]**
(A) – 13.6 eV (B) – 27.2 eV
(C) – 54.4 eV (D) – 6.8 eV

Q.22 The activity of a radioactive sample is measured as N_0 counts per minute at t = 0 and N_0/e counts per minute at t = 5 minutes. The time (in min) at which the activity reduces to half its value is **[AIPMT (PRE) 2010]**
(A) $\log_e \frac{2}{5}$ (B) $\frac{5}{\log_e 2}$
(C) $5 \log_{10} 2$ (D) $5 \log_e 2$

Q.23 The mass of a ^7_3Li nucleus is 0.042u less than the sum of the masses of all its nucleons. The binding energy per nucleon of ^7_3Li nucleus is nearly **[AIPMT (PRE) 2010]**
(A) 46 MeV (B) 5.6 MeV
(C) 3.9 MeV (D) 23 MeV

Q.24 A radioactive nucleus of mass M emits a photon of frequency ν and the nucleus recoils. The recoil energy will be **[AIPMT (PRE) 2011]**
(A) hν (B) $Mc^2 – h\nu$
(C) $h^2\nu^2/2Mc^2$ (D) zero

Q.25 The wavelength of the first line of Lyman series for hydrogen atom is equal to that of the second line of Balmer series for a hydrogen like ion. The atomic number Z of hydrogen like ion is **[AIPMT (PRE) 2011]**
(A) 2 (B) 3
(C) 4 (D) 1

Q.26 The half life of a radioactive isotope X is 50 years. It decays to another element Y which is stable. The two elements X and Y were found to be in the ratio of 1 : 15 in a sample of a given rock. The age of the rock was estimated to be **[AIPMT (PRE) 2011]**
(A) 100 years (B) 150 years
(C) 200 years (D) 250 years

Q.27 Fusion reaction takes place at high temperature because **[AIPMT (PRE) 2011]**
(A) Molecules break up at high temperature.
(B) Nuclei break up at high temperature.
(C) Atoms get ionised at high temperature.
(D) Kinetic energy is high enough to overcome the coulomb repulsion between nuclei.

Q.28 A nucleus ^m_nX emits one α particle and two β particles. The resulting nucleus is – **[AIPMT (PRE) 2011]**
(A) $^{m-4}_{n-2}Y$ (B) $^{m-6}_{n-4}Z$
(C) $^{m-6}_{n}Z$ (D) $^{m-4}_{n}X$

Q.29 Two radioactive nuclei P and Q, in a given sample decay into a stable nuclei R. At time t = 0, number of P species are 4 N_0 and that of Q are N_0. Half-life of P (for conversion to R) is 1 minute where as that of Q is 2 minutes. Initially there are no nuclei of R present in the sample. When number of nuclei of P and Q are equal, the number of nuclei of R present in the sample would be - **[AIPMT (MAINS) 2011]**
(A) $3N_0$ (B) $9N_0/2$
(C) $5N_0/2$ (D) $2N_0$

Q.30 Out of the following which one is not a possible energy for a photon to be emitted by hydrogen atom according to Bohr's atomic model? **[AIPMT (MAINS) 2011]**
(A) 1.9 eV (B) 11.1 eV
(C) 13.6 eV (D) 0.65 eV

Q.31 Electron in hydrogen atom first jumps from third excited state to second excited state and then from second excited to the first excited state. The ratio of the wavelength $\lambda_1 : \lambda_2$ emitted in the two cases is **[AIPMT (PRE) 2012]**
(A) 7/5 (B) 27/20
(C) 27/5 (D) 20/7

Q.32 A mixture consists of two radioactive materials A_1 and A_2 with half lives of 20s and 10s respectively. Initially the mixture has 40 g of A_1 and 160 g of A_2. The amount of the two in the mixture will become equal after : **[AIPMT (PRE) 2012]**
(A) 60 s (B) 80 s
(C) 20 s (D) 40 s

Q.33 An electron of a stationary hydrogen atom passes from the fifth energy level to the ground level. The velocity that the atom acquired as a result of photon emission will be : **[AIPMT (PRE) 2012]**
(A) $\frac{24hR}{25m}$ (B) $\frac{25hR}{24m}$ (C) $\frac{25m}{24hR}$ (D) $\frac{24m}{25hR}$
(m is the mass of the $e^–$, R, Rydberg const.&h Planck's constant)

Q.34 The transition from the state n = 3 to n = 1 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from : **[AIPMT (MAINS) 2012]**
(A) 2 → 1 (B) 3 → 2 (C) 4 → 2 (D) 4 → 3

Q.35 The half life of a radioactive nucleus is 50 days. The time interval $(t_2 – t_1)$ between the time t_2 when 2/3 of it has decayed and the time t_1 when 1/3 of it had decayed is : **[AIPMT (MAINS) 2012]**
(A) 30 days (B) 50 days
(C) 60 days (D) 15 days

Q.36 A certain mass of hydrogen is changed to Helium by the process of fusion. The mass defect in fusion reaction is 0.02866 u. The energy liberated per u is : (Given 1u = 931 MeV) **[NEET 2013]**
(A) 13.35 MeV (B) 2.67 MeV
(C) 26.7 MeV (D) 6.675 MeV

Q.37 The half life of a radioactive isotope 'X' is 20 years. It decays to another element 'Y' which is stable. The two elements 'X' and 'Y' were found to be in the ratio 1 : 7 in a sample of a given rock. The age of the rock is estimated to be – **[NEET 2013]**
(A) 100 years (B) 40 years
(C) 60 years (D) 80 years

Q.38 Ratio of longest wavelengths corresponding to Lyman and Balmer series in hydrogen spectrum is **[NEET 2013]**

(A) 9/31 (B) 5/27
(C) 3/23 (D) 7/29

Q.39 Hydrogen atom in ground state is excited by a monochromatic radiation of λ = 975 Å. Number of spectral lines in the resulting spectrum emitted will be –

(A) 3 (B) 2 **[AIPMT 2014]**
(C) 6 (D) 10

Q.40 The binding energy per nucleon of $^{7}_{3}\text{Li}$ and $^{4}_{2}\text{He}$ nuclei are 5.60 MeV & 7.06 MeV, respectively. In the nuclear reaction $^{7}_{3}\text{Li}+{}^{1}_{1}\text{H}\rightarrow{}^{4}_{2}\text{He}+{}^{4}_{2}\text{He}+\text{Q}$, the value of energy Q released is – **[AIPMT 2014]**

(A) 19.6 MeV (B) –2.4 MeV
(C) 8.4 MeV (D) 17.3 MeV

Q.41 A radio isotope X with a half life 1.4×10^9 years decays to Y which is stable. A sample of the rock from a cave was found to contain X and Y in the ratio 1 : 7. The age of the rock is **[AIPMT 2014]**

(A) 1.96×10^9 years (B) 3.92×10^9 years
(C) 4.20×10^9 years (D) 8.40×10^9 years

Q.42 If radius of the $^{17}_{12}\text{Al}$ nucles is taken to be R_{Al}, then the radius of $^{125}_{53}\text{Te}$ nucleus is nearly : **[AIPMT 2015]**

(A) $\frac{5}{3}R_{Al}$ (B) $\frac{3}{5}R_{Al}$

(C) $\left(\frac{13}{53}\right)^{1/3} R_{Al}$ (D) $\left(\frac{53}{13}\right)^{1/3} R_{Al}$

Q.43 Consider 3rd orbit of He^+ (Helium), using non-relativistic approach, the speed of electron in this orbit will be – [Given K = 9×10^9 constant, Z = 2 and h (Plank's constant) = 6.6×10^{-34} J s] **[AIPMT 2015]**

(A) 1.46×10^6 m/s (B) 0.73×10^6 m/s
(C) 3.0×10^8 m/s (D) 2.92×10^6 m/s

Q.44 In the spectrum of hydrogen, the ratio of the longest wavelength in the Lyman series to the longest wavelength in the Balmer series is : **[RE-AIPMT 2015]**

(A) 5/27 (B) 4/9
(C) 9/4 (D) 27/5

Q.45 A nucleus of uranium decays at rest into nuclei of thorium and helium. Then – **[RE-AIPMT 2015]**

(A) The helium nucleus has less kinetic energy than the thorium nucleus.
(B) The helium has more kinetic energy than the thorium nucleus.
(C) The helium nucleus has less momentum than the thorium nucleus.
(D) The helium nucleus has more momentum than the thorium nucleus.

Q.46 Given the value of Rydberg constant is 10^7 m^{-1}, the wave number of the last line of the Balmer series in hydrogen spectrum will be **[NEET 2016 PHASE 1]**

(A) 0.025×10^4 m^{-1} (B) 0.5×10^7 m^{-1}
(C) 0.25×10^7 m^{-1} (D) 2.5×10^7 m^{-1}

Q.47 If an electron in a hydrogen atom jumps from the 3rd orbit to the 2nd orbit, it emits a photon of wavelength λ. When it jumps from the 4th orbit to the 3rd orbit, the corresponding wavelength of the photon will be **[NEET 2016 PHASE 2]**

(A) (16/25) λ (B) (9/16) λ
(C) (20/7) λ (D) (20/13) λ

Q.48 The half-life of a radioactive substance is 30 minutes. The time (in minutes) taken between 40% decay and 85% decay of the same radioactive substance is **[NEET 2016 PHASE 2]**

(A) 15 (B) 30
(C) 45 (D) 60

Q.49 Radioactive material 'A' has decay constant 8λ and material 'B' has decay constant λ. Initially they have same number of nuclei. After what time, the ratio of number of nuclei of material 'B' to that 'A' will be 1/e ?

(A) 1/7λ (A) 1/8λ **[NEET 2017]**
(C) 1/9λ (A) 1/λ

Q.50 The ratio of wavelengths of the last line of Balmer series and the last line of Lyman series is – **[NEET 2017]**

(A) 1 (B) 4
(C) 0.5 (D) 2

Q.51 The ratio of kinetic energy to the total energy of an electron in a Bohr orbit of the hydrogen atom, is

(A) 2 : –1 (B) 1 : –1 **[NEET 2018]**
(C) 1 : 1 (D) 1 : –2

Q.52 For a radioactive material, half-life is 10 minutes. If initially there are 600 number of nuclei, the time taken (in minutes) for the disintegration of 450 nuclei is **[NEET 2018]**

(A) 30 (B) 10
(C) 20 (D) 15

Q.53 The total energy of an electron in an atom in an orbit is –3.4 eV. Its kinetic and potential energies are, respectively: **[NEET 2019]**

(A) –3.4 eV, –3.4 eV (B) –3.4 eV, –6.8 eV
(C) 3.4 eV, –6.8 eV (D) 3.4 eV, 3.4 eV

Q.54 α-particle consists of : **[NEET 2019]**

(A) 2 protons and 2 neutrons only.
(B) 2 electrons, 2 protons and 2 neutrons.
(C) 2 electrons and 4 protons only.
(D) 2 protons only.

ANSWER KEY

EXERCISE - 1

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	D	B	B	C	D	A	A	D	B	C	B	A	D	A	C	D	D	A	D	B	C	A	D	A	B
Q	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
A	A	A	B	B	B	D	D	A	C	A	B	A	B	B	D	A	D	A	A	D	A	C	D	B	A
Q	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
A	A	B	D	C	C	A	D	A	D	A	A	A	D	B	D	A	B	A	B	D	D	A	A	A	B
Q	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**	**90**	**91**	**92**	**93**							
A	D	D	C	B	A	C	C	C	D	B	B	B	C	C	A	B	B	A							

EXERCISE - 2

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	A	C	B	C	B	D	A	D	B	A	D	C	B	C	B	A	A	B	A	C	B	C	A	A	A
Q	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
A	D	B	A	C	D	A	C	A	B	C	B	B	C	B	A	D	B	C	A	A	B	A	B	C	B
Q	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
A	A	C	D	D	A	D	A	D	D	C	A	C	D	D	D	B	B	C	C	D	B	A	D	B	C
Q	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**											
A	B	A	D	B	C	C	D	C	C	C	B	A	D	C											

EXERCISE - 3

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
A	8	41	4	5	4	320	154	1	7	1	4	2	3	2	2	6	9

EXERCISE - 4

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	C	A	A	A	A	D	D	D	B	A	D	B	A	D	A	C	B	A	B	D	A	B	C	A	A
Q	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
A	B	D	C	A	D	A	D	D	C	D	D	C	D	B	B	B	A	A	A	C	A	D	A	B	D
Q	**51**	**52**	**53**	**54**	**55**	**56**	**57**	**58**	**59**	**60**	**61**	**62**	**63**	**64**	**65**	**66**	**67**	**68**	**69**	**70**	**71**	**72**	**73**	**74**	**75**
A	C	B	B	A	C	C	D	D	C	A	D	D	A	D	D	B	C	D	C	A	A	D	B	C	A
Q	**76**	**77**	**78**	**79**	**80**	**81**	**82**	**83**	**84**	**85**	**86**	**87**	**88**	**89**											
A	A	B	D	A	D	A	11	B	A	C	C	C	486	D											

EXERCISE - 5 (PART-A)

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	C	C	A	A	C	D	D	A	B	B	A	A	A	D	C	C	B	A	A	B	A	C	A	B	B
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41									
A	D	B	B	A	A	D	B	A	D	A	D	A	A	C	C	B									

EXERCISE - 5 (PART-B)

A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Q	A	C	A	D	C	A	A	D	C	D	A	A	D	C	D	D	A	C	C	D	A	D	B	C	A
A	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Q	C	D	D	B	B	D	D	A	D	B	D	C	D	C	D	C	A	A	A	B	C	C	D	A	B
A	51	52	53	54																					
	B	C	C	A																					

MODERN PHYSICS

TRY IT YOURSELF - 1

(1) **(C).** Energy of any level $\propto Z^2$, which is greatest for Li^{2+}]

(2) **(B).** $\frac{1}{\lambda} = RZ^2\left(1-\frac{1}{4}\right)$

(3) **(A).** λ longest $\Rightarrow E_{min}$
For Balmer λ longest is for $n = 2 \to 3$
For Lyman λ longest is for $n = 1 \to 2$
$\Rightarrow$ λ longest Balmer > λ longest Lyman

(4) **(C).** $E = \frac{E_0Z^2}{n^2} = E_0 \Rightarrow n = Z = 3$,

For Lithium $r = \frac{r_0n^2}{Z} = \frac{r_0.3^2}{3} = 3r_0$

(5) **(D).** $13.6Z^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right) = 7.55 \Rightarrow Z = 2$,

$\therefore$ $E = 13.6 \times Z^2 = 54.4$ eV

(6) **(D).** Binding Energy $= -ME \propto n^2$,
for 1st excited state n = 2,
and for 2nd excited state, n =3.

(7) **(A).** He^+ being a hydrogen like atom,

$E = 13.6\, z^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$, $n_1 = 1, n_2 = \infty$]

(8) **(ABCD).**

$$\frac{mv^2}{r} = \frac{kZe^2}{r^2} \Rightarrow \frac{mv^2}{2} = \frac{kZe^2}{2r} ,$$

$$M.E. = \frac{mv^2}{2} - \frac{Ze^2}{r} = \frac{-Ze^2}{2r} \propto \frac{1}{r}$$

(9) **(C).** $\Delta\lambda = \lambda_1 - \lambda_2 = \frac{1}{R\left[\frac{1}{(2)^2}-\frac{1}{(3)^2}\right]z^2} - \frac{1}{R[1-0]z^2}$

On solving , $R = \frac{31}{5}\frac{1}{\Delta\lambda \cdot Z^2}$

(10) **(D).**

TRY IT YOURSELF - 2

(1) **(A).** $\frac{hc}{\lambda} = \phi + c\,.\,(3v_0)$ in case I

$\frac{hc}{2\lambda} = \phi + c.\, v_0$ in case II

where $\frac{hc}{\lambda_0} = \phi$ (λ_0 – threshold wavelength)

(2) **(C).** Let A be the work function of metal.

$$\frac{hc}{\lambda_1} = A + \frac{mv_1^2}{2} \;;\; \frac{hc}{\lambda_2} = A + \frac{mv_2^2}{2}$$

$$hc\left[\frac{1}{\lambda_1}-\frac{1}{\lambda_2}\right] = \frac{m}{2}\left(v_1^2 - v_2^2\right) = \frac{m}{2}\left[4v_2^2 - v_2^2\right] = \frac{3mv_2^2}{2}$$

$$\frac{mv_2^2}{2} = \frac{hc}{3}\left[\frac{1}{\lambda_1}-\frac{1}{\lambda_2}\right]$$

$$A = \frac{hc}{\lambda_2} - \frac{mv_2^2}{2} = \frac{hc}{\lambda_2} - \frac{hc}{3}\left[\frac{1}{\lambda_1}-\frac{1}{\lambda_2}\right]$$

$$= \frac{4hc}{3\lambda_2} - \frac{hc}{3\lambda_1} = -\frac{hc}{3}\left[\frac{1}{\lambda_1}-\frac{4}{\lambda_2}\right]$$

$$= \frac{6.62\times10^{-34}\times3\times10^{8}}{3}\left[\frac{4}{450\times10^{-9}}-\frac{1}{350\times10^{-9}}\right]$$

$\therefore$ $A = 3.93 \times 10^{-19}$ J.]

(3) **(A).** $(freq)_{\text{blue light}} > (freq)_{\text{green light}}$

(4) **(C).** Most energetic photon frequency

$$= \frac{2\pi\times10^{15}}{2\pi} = 10^{15}\,Hz$$

$h\nu - \phi = K_{max}$

$$\frac{6.4\times10^{-34}\times10^{15}}{1.6\times10^{-19}} - 2eV = K_{max}$$

$K_{max} = 2eV$

(5) **(D).** $h \to ML^2T^{-1}$
$c \to LT^{-1}$
$e \to IT$
$m \to M$

(6) **(A).** Let n be the average no. of electrons per unit volume, present in the beam of electrons, then impulse-momentum theorem gives
$(nAv)(mv) = F,\ P = F/A \Rightarrow n = P/(mv^2)$

$\therefore$ $i = nAve = \frac{APe}{mv}$

(7) **(C).** $\lambda = \frac{h}{p} = \frac{\lambda_0}{n} = \frac{h}{p_0n}$; $p_0 = \frac{p}{n}$

(8) **(D).** $\lambda = \frac{hc}{E} = \frac{1240}{1.1}$ nm ≈ 1100 nm ⇒ infra red.

(9) **(BCD).**

(10) **(B).**

TRY IT YOURSELF - 3

(1) **(B).**

(2) **(D).**

(3) **(CD).**

(4) **(C).**

(5) **(AD).** $N_A = N_0 e^{-3\lambda_A} \Rightarrow N_B = N_0 e^{-3\lambda_B}$

$N_A = 3N_B \Rightarrow e^{-3\lambda_A} = 3e^{-3\lambda_B}$

$e^{3(\lambda_B - \lambda_A)} = 3$

$R_A = \lambda_A \times 3N_0 \Rightarrow R_B = \lambda_B \times N_0 \Rightarrow \frac{R_A}{R_B} = \frac{3\lambda_A}{\lambda_B}$

(6) **(A).**

(7) **(A).**

(8) **(A).**

(9) **(B).** Activity of 1 liter after 3 half life = $\frac{1200}{2^3}$

$\therefore$ Activity of ΔV will be = $\frac{1200}{2^3}\Delta V = 120$

$\Rightarrow \Delta V = 0.8$ litres.

(10) **(C).** $N_0 e^{-\lambda t} = 2\,(N_0 e^{-\lambda_2 t})$

$\Rightarrow e^{-\lambda_1 t} = 2e^{-\lambda_2 t}$

$\Rightarrow e^{-(\lambda_1 - \lambda_2)t} = 2 \Rightarrow (\lambda_2 - \lambda_1)\,t = \ln 2$

$\Rightarrow \left(\frac{\ln 2}{t_2} - \frac{\ln 2}{t_1}\right) t = \ln 2 \Rightarrow t = \left(\frac{t_1 t_2}{t_1 - t_2}\right) = 6$ years.

TRY IT YOURSELF - 4

(1) **(A).**

(2) **(C).**

(3) **(A).**

(4) **(C).**

(5) **(B).** $Q = -2 \times 1 - 7 \times 5.5 + 8 \times 7 = 56 - 2 - 38.5 = 15.5$

(6) **(D).**

(7) **(C).**

(8) **(D).**

(9) **(A).**

(10) **(B).**

(11) **(AC).** . $\frac{P^2}{2m_\alpha} + \frac{P^2}{2m_{th}} = Q \Rightarrow P = \left(\frac{2m_\alpha m_{th} Q}{m_\alpha + m_{th}}\right)^{1/2}$

and $\frac{K.E_\alpha}{K.E_{th}} = \frac{m_{th}}{m_\alpha} = \frac{234}{4}$

TRY IT YOURSELF - 5

(1) **(D).**

(2) **(C).**

(3) **(BC).**

(4) **(B).**

(5) **(D).** Moseley's Law $\sqrt{f} = a\,(z - b)$

$\Rightarrow \lambda \propto (z - b)^{-2}$ for k_α line $b = 1$

(6) **(B).**

(7) **(D).** $eV = \frac{hc}{\lambda} \Rightarrow V = \frac{12400}{\lambda\,(\text{in Å})}$

(8) **(D).** $\lambda_{cutoff} = \frac{hc}{eV} = \frac{12400}{40000} = 0.31\text{Å}$

Wavelength less than 0.31 Å wll be absent.

(9) **(A).**

(10) **(A).**

(11) **(C).**

(12) **(B).**

TRY IT YOURSELF - 6

(1) Wavelength $\lambda = \frac{12.27}{\sqrt{V}}\text{Å} = \frac{12.27}{\sqrt{56}}\text{Å} = 1.64\text{Å}$

(2) Momentum $p = \sqrt{2mE}$

$= \sqrt{2 \times 9.1 \times 10^{-31} \times 1.92 \times 10^{-17}} = \sqrt{3.49 \times 10^{-47}}$

$= 5.91 \times 10^{-24}$ kg ms^{-1}

Speed $v = \frac{p}{m} = \frac{5.91 \times 10^{-24}}{9.1 \times 10^{-31}} = 6.5 \times 10^6$ ms^{-1}

(3) For a neutron,

$$E = \frac{h^2}{2m_n\lambda^2} = \frac{(6.626 \times 10^{-34})^2}{2 \times 1.67 \times 10^{-27} \times (589 \times 10^{-9})^2}$$

$= 3.79 \times 10^{-28}$ J.

(4) (a) Here, m = 0.040 kg and v = 1.0 km/s = 1000 m/s

$\therefore \lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{0.040 \times 1000} = 1.66 \times 10^{-35}$ m

(b) Here, m = 0.060 kg and v = 1.0 m/s

$\therefore \lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{0.060 \times 1.0} = 1.1 \times 10^{-32}$ m.

(c) Here, $m = 1.0 \times 10^{-9}$ kg and v = 2.2 m/s

$\therefore \lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{1.0 \times 10^{-19} \times 2.2} = 3.01 \times 10^{-25}$ m.

(5) Here $\lambda = 1.40 \times 10^{-10}$ m

Also, $h = 6.63 \times 10^{-34}$ Js and $m = 1.67 \times 10^{-27}$ kg

$\therefore \lambda = \frac{h}{\sqrt{2mE}} \Rightarrow E = \frac{h^2}{2m\lambda^2}$

$$\therefore \quad E = \frac{(6.63\times10^{-34})^2}{2\times1.67\times10^{-27}\times(1.4\times10^{-10})^2}$$

$$= 6.7\times10^{-21}\text{ J} = \frac{6.7\times10^{-27}}{1.6\times10^{-19}}\text{ eV}$$

$$= 4.19\times10^{-2}\text{ eV.}$$

(6) Since $E = \frac{3}{2}kT$

$$\therefore \quad \lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{3mkT}}$$

Here $k = 1.38\times10^{-23}\text{ JK}^{-1}$ and $T = 300\text{ K}$

$$\therefore \quad \lambda = \frac{(6.63\times10^{-34})}{\sqrt{3\times1.67\times10^{-27}\times1.38\times10^{-23}\times300}}$$

$$= 1.456\times10^{-10}\text{ m} = 1.456\text{ Å}$$

(7) For nitrogen,

$\therefore$ RMS velocity, $v = \sqrt{\frac{3kT}{m}}$

$\therefore$ de Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{3mkT}}$

$$= \frac{6.63\times10^{-34}}{\sqrt{3\times28.0152\times1.66\times10^{-27}\times1.38\times10^{-23}\times300}}$$

$(\therefore m = 2\times14.0076 = 28.0152)$

or $\lambda = 0.275\times10^{-10}\text{ m.}$

CHAPTER- 7 :
MODERN PHYSICS
EXERCISE-1

(1) **(D).** Let the energy of one photon = hc/λ,

∴ Energy of n photons E = nhc/λ

$$\because \quad 10^{-7} = \frac{n \times 6.6 \times 10^{-34} \times 3 \times 10^{8}}{5000 \times 10^{-10}}$$

$$n = \frac{5000 \times 10^{-10} \times 10^{-7}}{19.8 \times 10^{-26}} = 0.25 \times 10^{12} = 2.5 \times 10^{11}$$

(2) **(B).** $P = \frac{W}{t} = \frac{nhc}{\lambda t} \Rightarrow \left(\frac{n}{t}\right) = \frac{P\lambda}{hc}$

$$= \frac{10 \times 10^{3} \times 300}{6.6 \times 10^{-34} \times 3 \times 10^{8}} = 1.5 \times 10^{31}$$

(3) **(B).** $E = h\nu \Rightarrow \nu = \frac{E}{h} = \frac{1 \times 10^{6} \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = 2.4 \times 10^{20}$ Hz

(4) **(C).** Energy of photon

$$E = \frac{hc}{\lambda}\ (\text{Joules}) = \frac{hc}{e\lambda}(\text{eV})$$

$$\Rightarrow \underset{(\text{eV})}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{1.6 \times 10^{-19} \times \lambda} = \frac{12375}{\lambda(\text{Å})}$$

$$\Rightarrow E\ (\text{keV}) = \frac{12.37}{\lambda\ (\text{Å})} \approx \frac{12.4}{\lambda}$$

(5) **(D).** $E = \frac{hc}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{4000 \times 10^{-10}} = 4.95 \times 10^{-19}$ J

(6) **(A).** $p = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{(5000 \times 10^{-10})} = 1.3 \times 10^{-27}$ kg-m / s

(7) **(A).** Photons move with velocity of light and have energy hν. Therefore, they also exert pressure.

(8) **(D).** Intensity of a light beam = Number of photons falling on a unit area in 1s.

(9) **(B).** Relation between $V_0 - \nu$; $V_0 = \frac{h\nu}{e} - \frac{h\nu_0}{e}$

Put it in the form of $y = mx - c$,

Here $V_0 = y, \nu = x, \frac{h\nu_0}{e} = c$

$$\therefore \quad y = \left(\frac{h}{e}\right) x - c \quad \therefore m = \frac{h}{e}$$

(10) **(C).** Wave length of green light is threshold wave length. Hence for emission of electron, wave length of incident light < wavelength of green light.

(11) **(B).** In electric field photoelectron will experience force and accelerate opposite to the field so it's K.E. increases (i.e. stopping potential will increase), no change in photoelectric current, and threshold wavelength.

(12) **(A).** In tungsten, photoemission take place with a light of wavelength 2300 Å. As emission of electron is inversely proportional to wavelength, all the wavelengths smaller then 2300 Å will cause emission of electrons.

(13) **(D).** The maximum kinetic energy of photoelectron ejected is given by : K.E. = $h\nu - \phi_0 = h\nu - h\nu_0$ where work function depends on the type of material. If the frequency of incident radiation is greater than ν_0 only then the ejection of photoelectrons start. After that as frequency increases kinetic energy also increases.

(14) **(A).** Particle nature of light was established by photoelectric effect.

(15) **(C).** Intensities will be equal as the saturation current is same. To study the variation of photocurrent with collector plate potential at different frequencies, intensity is kept same.

(16) **(D).** The stopping potential depends on frequency of incident light and the nature of the emitter material. For a given frequency of incident light, it is independent of its intensity.

(17) **(D).** According to wave theory we will require beam of sufficient high intensity.

(18) **(A).** The value of threshold frequency ν_0 for A is less than that for B, hence $\phi_A < \phi_B$.

(19) **(D).** If the incident light be of threshold wavelength (λ_0), then the stopping potential shall be zero. Thus

$$\lambda_0 = \frac{hc}{\phi} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{4.2 \times 1.6 \times 10^{-19}}$$

$$\lambda_0 = 2.946 \times 10^{-7}\ \text{m} = 2946\ \text{Å}$$

(20) **(B).** $v_{max} = 4 \times 10^{8}$ cm/sec $= 4 \times 10^{6}$ m/sec.

$$\therefore \quad K_{max} = \frac{1}{2} m v_{max}^{2} = \frac{1}{2} \times 9 \times 10^{-31} \times (4 \times 10^{6})^{2}$$

$$= 7.2 \times 10^{-18}\ \text{J} = 45\ \text{eV}.$$

Hence, stopping potential

$$|V_0| = \frac{K_{max}}{e} = \frac{45\,\text{eV}}{e} = 45\ \text{volt}$$

(21) **(C).** Energy of incident light

$$E\,(\text{eV}) = \frac{12375}{3320} = 3.72\,\text{eV} \qquad (332\ \text{nm} = 3320\ \text{Å})$$

According to the relation $E = W_0 + eV_0$

$$\Rightarrow V_0 = \frac{(E - W_0)}{e} = \frac{3.72\,\text{eV} - 1.07\,\text{eV}}{e}$$

$$= 2.65\ \text{volt}$$

(22) **(A).** According to Einstein's photoelectric equation,

$h\nu = (K.E)_{max} + \phi_0$

where ϕ_0 is the work function, ν is the incident frequency and h is the Planck's constant.

Also, $(K.E.)_{max} = eV$

where e is the elementary charge, V is the stopping potential $eV = h\nu - \phi_0$; $V = \frac{h}{e}\nu - \frac{\phi_0}{e}$

Hence, the graph between V and ν is a straight line and slope of this graph is given by

Slope = h/e ..... (1)

From the graph in the question

$$\text{Slope} = \frac{ab}{bc} \qquad ..... (2)$$

From (1) and (2), we get, $h = e\frac{ab}{bc}$

(23) **(D).** According to Einstein's photoelectric equation

$$K = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)$$

(24) **(A).** $\because \lambda \propto \frac{1}{\sqrt{m}} \Rightarrow \lambda_e \propto \frac{1}{\sqrt{m_e}}$,

$$\lambda_p \propto \frac{1}{\sqrt{m_p}} \qquad \therefore \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}}$$

(25) **(B).** $\lambda \propto \frac{1}{\sqrt{m}}$, $\frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} = \sqrt{\frac{1836}{1}}$

(26) **(A).** $\lambda_p = \frac{h}{\sqrt{2m_p e_p V}} \Rightarrow \lambda_d = \frac{h}{\sqrt{2m_d e_d V}}$

$$\therefore \frac{\lambda_d}{\lambda_p} = \sqrt{\frac{m_p e_p}{m_d e_d}} \quad \because m_d = 2m_p,$$

$$e_d = e_p \Rightarrow \frac{\lambda_d}{\lambda_p} = \sqrt{\frac{m_p e_p}{2m_p e_p}} = \frac{1}{\sqrt{2}}$$

(27) **(A).** $\because 2\pi r = n\lambda \Rightarrow \lambda = \frac{2\pi r}{n}$ Å

(28) **(B).** $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow E = \frac{h^2}{2m\lambda^2}$

$$= \frac{(6.6\times10^{-34})^2}{2\times9.1\times10^{-31}\times(0.3\times10^{-9})^2}$$

$$= 2.65\times10^{-18}\,\text{J} = 16.8\text{ eV}$$

(29) **(B).** The de Broglie wavelength is given by

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

So, if the velocity of the electron increases, the de Broglie wavelength decreases.

(30) **(B).** Kinetic energy of particle, $K = \frac{1}{2}mv^2$

or $mv = \sqrt{2mK}$

de Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK}}$

For the given value of K, $\lambda \propto \frac{1}{\sqrt{m}}$

$$\lambda_p : \lambda_n : \lambda_e : \lambda_\alpha = \frac{1}{\sqrt{m_p}} : \frac{1}{\sqrt{m_n}} : \frac{1}{\sqrt{m_e}} : \frac{1}{\sqrt{m_\alpha}}$$

Since $m_p = m_n$; hence $\lambda_p = \lambda_n$
As $m_\alpha > m_p$ therefore $\lambda_\alpha < \lambda_p$
As $m_e < m_n$ therefore $\lambda_e > \lambda_n$
Hence $\lambda_\alpha < \lambda_p = \lambda_n < \lambda_e$

(31) **(D).** Velocity acquired by a particle while falling from a height H is $v = \sqrt{2gH}$ ...... (1)

As $\lambda = \frac{h}{mv} = \frac{h}{m\sqrt{2gH}}$ [Using eq. (1)]

or $\lambda \propto 1/\sqrt{H}$

(32) **(D).** In Davisson and Germer experiment, the tungsten filament is coated with barium oxide.

(33) **(A).** In the Davisson and Germer experiment, the velocity of electrons emitted from the electron gun can be increased by increasing the potential difference between the anode and filament.

(34) (C)

(35) (A)

(36) **(B).** At minimum impact parameter α-particles rebound back ($\theta \approx \pi$) and suffers large scattering.

(37) **(A).** Ionisation energy of an H-atom in ground state is 13.6 eV.

(38) **(B).** $r \propto n^2$ i.e. $\frac{r_f}{r_i} = \left(\frac{n_f}{n_i}\right)^2 \Rightarrow \frac{21.2\times10^{-11}}{5.3\times10^{-11}} = \left(\frac{n}{1}\right)^2$

$\Rightarrow n^2 = 4 \Rightarrow n = 2$

(39) **(B).** $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\Rightarrow \frac{1}{\lambda_{3\to2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] = \frac{5R}{36}$$

and $\frac{1}{\lambda_{4\to2}} = R\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = \frac{3R}{16}$

$$\therefore \frac{\lambda_{4\to2}}{\lambda_{3\to2}} = \frac{20}{27} \Rightarrow \lambda_{4\to2} = \frac{20}{27}\lambda_0$$

(40) **(D).** $R \propto n^2$; $v \propto 1/n$; $E \propto 1/n^2$

$$\frac{R}{E} \propto n^4 \;;\; \frac{E}{v} \propto \frac{1}{n} \;;\; RE \propto n^0 \;;\; vR \propto n$$

(41) **(A).** $mvr = \frac{nh}{2\pi}$ According to Bohr's theory

$\Rightarrow 2\pi r = n\left(\frac{h}{mv}\right) = n\lambda$ for n = 1, $\lambda = 2\pi r$

(42) **(D).** $r_n = 0.53\, n^2$, n = 4

$\Rightarrow r_4 = 0.53 \times 16 \Rightarrow r_4 = 8.48$ Å

(43) **(A).** Radius of first orbit, $r \propto \frac{1}{Z}$,

For doubly ionized lithium, Z (= 3) will be maximum, hence for doubly ionized lithium, r will be minimum.

(44) **(A).** In atoms with many electrons, electrons are not being subjected to one single central force.

(45) **(D).** $\omega = \frac{v}{r}$. Further $v \propto \frac{1}{n}$ and $r \propto n^2$,

Hence, $\omega \propto (1/n^3)$

(46) **(A).** In the n^{th} orbit, let r_n = radius and v_n = speed of electron.

Time period, $T_n = \frac{2\pi r_n}{v_n} \propto \frac{r_n}{v_n}$

Now, $r_n \propto n^2$ and $v_n \propto \frac{1}{n}$ $\therefore \frac{r_n}{v_n} \propto n^3$ or $T_n \propto n^3$

Here, $8 = \left(\frac{n_1}{n_2}\right)^3$ or $\frac{n_1}{n_2} = 2$ or $n_1 = 2n_2$

(47) **(C).** Number of lines in absorption spectrum = (n – 1)

$\Rightarrow 5 = n - 1 \Rightarrow n = 6$

$\therefore$ Number of bright lines in the emission spectrum

$= \frac{n\,(n-1)}{2} = \frac{6\,(6-1)}{2} = 15$.

(48) **(D).** For Lyman series

$$\frac{1}{\lambda_{max}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}R \text{ and}$$

$$\frac{1}{\lambda_{min}} = R\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = \frac{R}{1} \Rightarrow \frac{\lambda_{max}}{\lambda_{min}} = \frac{4}{3}$$

(49) **(B).** $E = 13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$.

For highest energy in Balmer series n_1=2 and $n_2 = \infty$

$$\Rightarrow E = 13.6\left[\frac{1}{(2)^2} - \frac{1}{(\infty)^2}\right] = 3.4\,\text{eV}$$

(50) **(A).** For Lyman series

$\nu = Rc\left[\frac{1}{1^2} - \frac{1}{n^2}\right]$, where n = 2, 3, 4,

For the series limit of Lyman series, n = ∞

$$\therefore \nu_1 = Rc\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = Rc \qquad \text{... (1)}$$

For the first line of Lyman series, n = 2

$$\therefore \nu_2 = Rc\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}Rc \qquad \text{... (2)}$$

For Balmer series

$\nu = Rc\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$, where n = 3, 4, 5....

For the series limit of Balmer series, n = ∞

$$\therefore \nu_3 = Rc\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = \frac{Rc}{4} \qquad \text{... (3)}$$

From equations (1), (2) and (3), we get

$\nu_1 = \nu_2 + \nu_3$ or $\nu_1 - \nu_2 = \nu_3$

(51) **(A).** Spectrum of sunlight is an example for line absorption spectrum

(52) **(B).** Oil flame produces continuous emission spectrum.

(53) **(D).** Balmer series : visible region

(54) **(C).** $F_{nuclear} > F_{electrostatic} > F_{gravitation}$

The nuclear force is much stronger, than the Coulomb force acting between charges or the gravitational forces between masses. The nuclear binding force has to dominate over the coulomb repulsive force between protons inside the nucleus.

This happens only because the nuclear force is much stronger than the coulomb force. The gravitational force is much weaker, than even Coulomb force.

(55) **(C).** Use ρ = Mass/volume

$$= \frac{1.66 \times 10^{-27} \times 16}{(4/3)\pi(3 \times 10^{-15})^3} = 2.35 \times 10^{17}\ \text{kg m}^{-3}$$

(56) **(A).** $\frac{R_{Al}}{R_{Te}} = \frac{(27)^{1/3}}{(125)^{1/3}} = \frac{3}{5} = \frac{6}{10}$

(57) **(D).** $R = R_0 A^{1/3} = 1.2 \times 10^{-15} \times (64)^{1/3}$

$= 1.2 \times 10^{-15} \times 4 = 4.8$ fm

(58) **(A).** ${}_{Z}X^{A} \xrightarrow{9\alpha,} {}_{Z-18}X^{A-36} \xrightarrow{5\beta} {}_{Z-13}X^{A-36}$

Number of protons = (Z – 13)

Number of neutrons

= (A – 36) – (Z – 13) = (A – Z – 23)

$$\therefore \frac{P}{N} = \frac{(Z-13)}{(A-Z-23)}$$

(59) **(D).** $\because v \propto \frac{z}{n}$ $\qquad \therefore \frac{v_3}{v_4} = \frac{4}{3}$

(60) **(A).** In the given oxygen molecule, nuclear force between the nuclei of two atoms is not important because nuclear forces being short ranged are confined only within one particular nucleus. The distance between the nuclei of two atoms is large. So nuclear forces between two nuclei is not effective.

(61) **(A).** Since, the nuclei of deuterium and tritium are isotopes of hydrogen, they must contain only one proton each.

But the masses of the nuclei of hydrogen, deuterium and tritium are in the ratio of 1 : 2 : 3, because of presence of neutral matter in deuterium and tritium nuclei.

(62) **(A).** Here, $A_1 = 197$ and $A_2 = 107$

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{197}{107}\right)^{1/3} = 1.225$$

(63) **(D).** Due to mass defect, the rest mass of a nucleus is always less than the sum of the rest masses of its constituent nucleons.

$^{20}_{10}\text{Ne}$ nucleus consists of 10 protons and 10 neutrons. $\therefore\ M_1 < 10\,(m_p + m_n)$

(64) **(B).** A force between two protons is same as the force between proton and neutron. The nature of the force is strong nuclear force.

(65) **(D).** Binding energy per nucleon is the average energy per nucleon needed to separate a nucleus into its individual nucleons.

(66) **(A).** $E = mc^2 = (1.66 \times 10^{-27})\,(3 \times 10^8)^2\ \text{J} = 1.49 \times 10^{-10}\ \text{J}$

$$= \frac{1.49 \times 10^{-10}}{1.6 \times 10^{-13}}\ \text{MeV} = 931.49\ \text{MeV}$$

(67) **(B).** $E = mc^2 = (9.1 \times 10^{-31})\,(3 \times 10^8)^2\ \text{J} = 0.51\ \text{MeV}$

(68) **(A).** $\because\ \Delta E = \Delta m \times 931\ \text{MeV}$

$$\Rightarrow\quad \Delta m = \frac{\Delta E}{931} = \frac{2.23}{931} = 0.0024\ \text{a.m.u.}$$

(69) **(B).** $\dfrac{\text{Binding energy}}{\text{Nucleon}} = \dfrac{0.0303 \times 931}{4} \approx 7$

(70) **(D).** B.E. of $\text{Li}^7 = 7 \times 5.6 = 39.20\ \text{MeV}$

and $\text{He}^4 = 4 \times 7.06 = 28.24\ \text{MeV}$

Hence binding energy of $2\text{He}^4 = 56.48\ \text{MeV}$

Energy of reaction $= 56.48 - 39.20 = 17.28\ \text{MeV}$.

(71) **(D).** $E = \Delta m.c^2 = \dfrac{0.3}{1000} \times (3 \times 10^8)^2 = 2.7 \times 10^{13}\ \text{J}$

$$= \frac{2.7 \times 10^{13}}{3.6 \times 10^6} = 7.5 \times 10^6\ \text{kWh}$$

(72) **(A).** Binding energy, E_b, of ^7_3Li

$= \Delta m \times 931\ \text{MeV} = 0.042 \times 931\ \text{MeV}$

Binding energy per nucleon $= \dfrac{0.042 \times 931}{7}$

$= 5.586\ \text{MeV}$

(73) **(A).** Here, $P = 500\ \text{MW} = 5 \times 10^8\ \text{W}$, $t = 1\ \text{h} = 3600\ \text{s}$

Energy produced,

$E = P \times t = 5 \times 10^8 \times 3600 = 18 \times 10^{11}\ \text{J}$

As $E = mc^2$

$$\therefore\quad m = \frac{E}{c^2} = \frac{18 \times 10^{11}}{(3 \times 10^8)^2} = \frac{18 \times 10^{11}}{9 \times 10^{16}} = 2 \times 10^{-5}\ \text{kg}$$

(74) **(A).** The moderators commonly used are water, heavy water (D_2O) and graphite.

D_2O, naturally occurs in sea water.

(75) **(B).** Fast neutrons can be easily slowed by passing them through water which contains a large number of protons of comparable masses.

(76) **(D).** When $^{235}_{92}\text{U}$ undergoes a fission after bombarded by a neutron, it is also releases an extra neutron. This extra neutron is then available for initiating fission of another $^{235}_{92}\text{U}$ nucleus.

In fact, on an average, 2½ neutrons per fission of uranium nucleus are released. The fact that more neutrons are produced in fission than are consumed raises the possibility of a chain reaction with each neutron that is produced triggering another fission.

(77) **(D).** 1 unit for activity (decay rate is Becquerel)

1 becquerel = 1 Bq = 1 decay per second

An older unit, the curie, is still in common use.

1 curie = 1 Ci = 3.7×10^{10} Bq (decays per second)

(78) **(C).** After three half lives, the fraction of undecayed nuclei $= (1/2)^3 = 1/8$

$\therefore$ Time taken for the sample to decay by $(1 - 1/8)^{\text{th}}$ or $(7/8)^{\text{th}}$ of initial value.

$= 3T_{1/2} = 3 \times 20 = 60\ \text{s}$

(79) **(B).** To relate $T_{1/2}$ to the disintegration constant λ, we put $N = (1/2)\,N_0$ and $t = T_{1/2}$ in equation,

$$\log \frac{N}{N_0} = -\lambda\, t$$

and solve for $T_{1/2}$ we find $T_{1/2} = \dfrac{\ln 2}{\lambda} = \dfrac{0.693}{\lambda}$

(80) **(A).** You must remember that $t_{1/2}$ is time in which substance decays half. Hence in $t_{3/4}$ time substance decays $3/4^{\text{th}}$.

(81) **(C).** Mean life, $\dfrac{1}{\lambda} = \dfrac{1600}{0.693} = 2308 \approx 2319\ \text{yr}$

(82) **(C).** $n_\alpha = \dfrac{A - A'}{4}$ and $n_\beta = 2n_\alpha - Z + Z'$

$\Rightarrow\quad A' = A - 4n_\alpha = 236 - 4 \times 3 = 224$

$Z' = (n_\beta - 2n_\alpha + Z) = (1 - 2 \times 3 + 88) = 83$

(83) **(C).** $A = A_0 \left(\dfrac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow 100 = 1600 \left(\dfrac{1}{2}\right)^{\frac{8}{T_{1/2}}}$

$\Rightarrow\ T_{1/2} = 2$ sec. Again at $t = 6$ sec,

$$A = 1600 \left(\frac{1}{2}\right)^{6/2} = 200\ \text{counts/sec}$$

(84) **(D).** Number of half lives in 150 years

$$n = \frac{150}{75} = 2$$

Fraction of the atom of decayed

$$= 1 - \left(\frac{1}{2}\right)^n = 1 - \left(\frac{1}{2}\right)^2 = \frac{3}{4} = 0.75$$

$\Rightarrow$ Percentage decay = 75%

(85) **(B).** $n_\alpha = \frac{A - A'}{4} = \frac{232 - 208}{4} = 6$

$$n_\beta = 2n_\alpha - Z + Z' = 2 \times 6 - 90 + 82 = 4$$

(86) **(B).** By using $N = N_0 e^{-\lambda t}$ and $t = \tau = \frac{1}{\lambda}$

Substance remains $= N = \frac{N_0}{e} = 0.37 N_0 \simeq \frac{N_0}{3}$

$\therefore$ Substance disintegrated $= N_0 - \frac{N_0}{3} = \frac{2N_0}{3}$

(87) **(B).** $A = A_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{1}{64} = \left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}}$

$$\Rightarrow \left(\frac{1}{2}\right)^6 = \left(\frac{1}{2}\right)^{\frac{60}{T_{1/2}}} \Rightarrow T_{1/2} = 10\,\text{sec}$$

(88) **(C).** $N = N_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}} \Rightarrow \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{30}{10}} = \frac{1}{8} = 0.125$

(89) **(C).** $N_A e^{-\lambda_A t} = N_B e^{-\lambda_B t}$

or $e^{(\lambda_B - \lambda_A)t} = (N_B / N_A)$

$\therefore$ $t = \frac{1}{\lambda_B - \lambda_A} \ln\left(\frac{N_B}{N_A}\right)$

(90) **(A).** For given energy, the radiations in the increasing order of penetrating power are : $\alpha < \beta < \gamma$

(91) **(B).** During an elastic collision between two particles, the maximum kinetic energy is transferred from one particle to the other when they have the same mass. Therefore, heavy nuclei will not serve the purpose because elastic collision of neutrons with heavy nuclei will not slow them down.

(92) **(B).** As an alpha particle carries 2 units of positive charge, and a beta particle carries one unit of negative charge and γ particle carries no charge, therefore electronic energy levels of the atom change for α and β radioactivity, but not for γ-radioactivity.

(93) **(A).** ${}^6He \to e^+ + {}^6Li + \nu$

A neutrino is emitted alongwith a positron in β^+ decay.

EXERCISE-2

(1) **(A).** $\lambda_\alpha = \frac{0.101}{\sqrt{V}}$ Å, $\sqrt{V} = \frac{0.101}{0.004}$

$$\sqrt{V} = 25.25\,V, V = 637\,V$$

$$E_\alpha = q_\alpha \times V_\alpha = 1275\,eV$$

(2) **(C).** $\lambda = \frac{h}{mv} \Rightarrow v = \frac{h}{m\lambda}$,

$$v = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 10 \times 10^{-10}} = 7.2 \times 10^5\,m/s$$

(3) **(B).** $\lambda = \frac{h}{\sqrt{2mE_1}}$ $\quad \because E_1 = -13.6\,eV$

$$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 13.6 \times 1.6 \times 10^{-19}}}$$

$\Rightarrow$ $\lambda = 3.3 \times 10^{-10}\,m = 3.3$ Å

(4) **(C).** $\lambda = \frac{12.27}{\sqrt{V}}$ Å $\Rightarrow V = 40 – 20 = 20$ Volt

$\Rightarrow$ $\lambda = \frac{12.27}{\sqrt{20}}$ Å $= 2.75$ Å

(5) **(B).** $V = \frac{150.6}{\lambda_e^2}$ volt, to determine the p.d. through which it was accelerated to achieve the given de-broglie wavelength. Then the same p.d. will retard it to rest. Thus,

$$V = \frac{150.6}{0.2 \times 0.2} = 3765\,\text{Volt} = 3.76\,kV$$

(6) **(D).** $\frac{\lambda_\alpha}{\lambda_{Be}} = \sqrt{\frac{m_{Be} q_{Be}}{m_\alpha q_\alpha}} = \sqrt{\frac{8}{4} \times \frac{1}{2}} = 1$

$$\lambda_\alpha : \lambda_{Be} = 1 : 1$$

(7) **(A).** Energy of the electron, when it comes out from the second plate

$= 200\,eV - 100\,eV = 100\,eV$

Accelerating potential difference = 100 V

$$\lambda_{Electron} = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{100}} = 1.23\text{Å}$$

(8) **(D).** Momentum p = mv and $v = \sqrt{\frac{2QV}{m}}$

$\Rightarrow$ $p = \sqrt{2QmV} \Rightarrow p \propto \sqrt{Qm}$

$\Rightarrow$ $\frac{p_e}{p_\alpha} = \sqrt{\frac{e \times m_e}{2e \times m_\alpha}} = \sqrt{\frac{m_e}{2m_\alpha}}$

(9) **(B).** $K_{particle} = \frac{1}{2}mv^2$ also $\lambda = \frac{h}{mv}$

$$K_{particle} = \frac{1}{2}\left(\frac{h}{\lambda v}\right).v^2 = \frac{vh}{2\lambda} \qquad ...(i)$$

$$K_{photon} = \frac{hc}{\lambda} \qquad ...(ii)$$

$$\therefore \frac{K_{particle}}{K_{photon}} = \frac{v}{2c} = \frac{2.25\times10^8}{2\times3\times10^8} = \frac{3}{8}$$

(10) **(A).** $E_k = E - \phi_0 = 6.2 - 4.2 = 2.0\text{ eV}$,
$E_k = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}\text{ J}$

(11) **(D).** $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ $\qquad (\because p = \sqrt{2mE})$

$$\lambda' = \frac{h}{\sqrt{2m\,(16E)}} = \frac{\lambda}{4} = 0.25\lambda \text{ ; \% change} = 75\%$$

(12) **(C).** $W_0 = \frac{hc}{\lambda_0} = \frac{6.625\times10^{-34}\times3\times10^8}{5000\times10^{-10}}\text{J} = 4\times10^{-19}\text{ J}$

(13) **(B).** By using $E = W_0 + \frac{1}{2}mv_{max}^2$

where $E = \frac{12375}{4558} = 2.71\text{ eV}$

$$\Rightarrow 2.71\text{ eV} = 2.5\text{ eV} + \frac{1}{2}\times9.1\times10^{-31}\times v_{max}^2$$

$$\Rightarrow 0.21\times1.6\times10^{-19} = \frac{1}{2}\times9.1\times10^{-31}\times v_{max}^2$$

$$\Rightarrow v_{max} = 2.65\times10^5\text{ m/s}$$

(14) **(C).** $E = h\nu = 6.6\times10^{-34}\times8\times10^{15}$

$= 5.28\times10^{-18}\text{ J} = 33\text{eV}$

$E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0$

$= 33 - 6.125 = 27\text{eV}$

(15) **(B).** The maximum kinetic energy is

$$K_{max} = \frac{hc}{\lambda} - \phi = \frac{1242\text{ eV}-\text{nm}}{280\quad\text{nm}} - 2.5\text{ eV}$$

$= 4.4\text{ eV} - 2.5\text{ eV} = 1.9\text{ eV}$

Stopping potential V is given by $eV = K_{max}$

$$V = \frac{K_{max}}{e} = \frac{1.9}{e}\text{eV} = 1.9\text{ V}$$

(16) **(A).** The energy of each photon $= \frac{200}{4\times10^{20}} = 5 \times 10^{-19}\text{ J}$

Wavelength $\lambda = \frac{hc}{E} = \frac{(6.63\times10^{-34})\times(3\times10^8)}{5\times10^{-19}}$

$\Rightarrow \lambda = 4.0\times10^{-7} = 400\text{ nm}$

(17) **(A).** Energy of one photon

$$E = h\nu = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^8}{6000\times10^{-10}} = 3.315\times10^{-19}\text{ J}$$

No of photons emitted per second

$$= \frac{\text{total energy emitted per second}}{\text{energy of the photon}} = \frac{P}{E}$$

$$= \frac{25}{3.315}\times10^{19} = 7.54\times10^{19}$$

(18) **(B).** For metal A, Slope $= \frac{h}{e} = \frac{2-0}{(10-5)\times10^{14}}$

or $h = \frac{2\times e}{5\times10^{14}} = \frac{2\times1.6\times10^{-19}}{5\times10^{14}} = 6.4\times10^{-34}\text{ J s}$

For metal B, Slope $= \frac{h}{e} = \frac{2.5-0}{(15-10)\times10^{14}}$

$$h = \frac{2.5\times e}{5\times10^{14}} = \frac{2.5\times1.6\times10^{-19}}{5\times10^{14}} = 8\times10^{-34}\text{ J s}$$

(19) **(A).** $\vec{v} = v_0\hat{i}$, $\vec{B} = B_0\hat{j}$.

Force on moving electron due to magnetic field is

$$\vec{F} = -e(\vec{v}\times\vec{B}) = -e(v_0\hat{i}\times B_0\hat{j}) = -ev_0B_0\hat{k}$$

As this force is perpendicular to $\vec{v}$ and $\vec{B}$, so the magnitude of $\vec{v}$ will not change. i.e, momentum (= mv) will remain constant in magnitude. Therefore, de Broglie wavelength, $\lambda\left(=\frac{h}{mv}\right)$ remains constant.

(20) **(C).** $p = \frac{nh\nu}{C} = \frac{nh}{C}\left(\frac{C}{\lambda}\right) = \frac{nh}{\lambda}$

(21) **(B).** $\lambda = \frac{h}{\sqrt{2mE_k}}$. If E_K is increased 4 times then λ becomes half.

$\therefore$ Additional KE supplied $= 4E_K - E_K = 3E_K$

(22) **(C).** $eV_0 = \frac{1}{2}mv^2 \Rightarrow V_0\frac{e}{m} = \frac{v^2}{2}$

$$V_0\times1.8\times10^{11} = \frac{1.8\times1.8\times10^{12}}{2}$$

$$V_0 = \frac{1.8\times10}{2} = 9\text{V}$$

(23) **(A).** $\beta \propto \lambda$. But, $\lambda_1 < \lambda_2$; $\beta_1 < \beta_2$
Because λ_1 produces photoelectric effect.

(24) **(A).** Let E be max. kinetic energy of photoelectrons when wavelength of incident light is $\lambda/2$. It becomes 3E when wavelength $\lambda/4$.

Let ϕ be work function of the metal.

$$E = \frac{2hc}{\lambda} - \phi \ldots (1) \quad 3E = \frac{4hc}{\lambda} - \phi \ldots (2)$$

eq. (1) × 3 – eq. (2)

$$0 = \frac{2hc}{\lambda} - 2\phi \quad \text{or} \quad \phi = \frac{hc}{\lambda}, \quad n = 1$$

(25) **(A).** $V = 120V$

$$\lambda = \frac{1227pm}{\sqrt{V}} = \frac{1227}{\sqrt{120}} \approx \frac{1227}{11} \approx 112 \text{ pm}$$

(26) **(D).** Wavelength same $\Rightarrow h\nu - \phi$ remains same $\Rightarrow$ no change in stopping potential.
Power of source becomes 1/3, results in : intensity becomes 1/3, distance becomes 1/3, result in : intensity becomes 9 times

⇒ Net effect intensity becomes 3 times

⇒ Saturation current becomes 3 times

(27) **(B).** More stopping potential ⇒ more incident frequency.

(28) **(A).** $(\text{freq})_{\text{blue light}} > (\text{freq})_{\text{green light}}$

(29) **(C).** Most energetic photon frequency

$$\frac{2\pi \times 10^{15}}{2\pi} = 10^{15} \text{Hz}$$

$$h\nu - \phi = K_{max}$$

$$\frac{6.4 \times 10^{-34} \times 10^{15}}{1.6 \times 10^{-19}} - 2eV = K_{max}$$

$$K_{max} = 2eV$$

(30) **(D).** $h \to ML^2T^{-1}$; $c \to LT^{-1}$

$e \to IT$; $\quad m \to M$

(31) **(A).** Let n be the average no. of electrons per unit volume, present in the beam of electrons, then impulse-momentum theorem gives $(nAv)(mv) = F$,

$P = F/A \qquad \Rightarrow n = P/(mv^2)$

$$\therefore \quad i = nAve = \frac{APe}{mv}$$

(32) **(C).** $n = \frac{\lambda_0}{\lambda}$; $p = \frac{h}{\lambda_0} = \frac{h}{n\lambda}$

(33) **(A).** $\frac{1}{2} m_\alpha v_\alpha^2 = \frac{K(2e)(ze)}{r_0}$; $r_0 = \frac{2K\left(\frac{2e}{m_\alpha}\right)(79\,e)}{v_\alpha^2}$

$$= \frac{2 \times (9 \times 10^9)(4.8 \times 10^7)(79 \times 1.6 \times 10^{-19})}{(2.1 \times 10^7)^2}$$

$$r_0 = 2.5 \times 10^{-14} m$$

(34) **(B).** Acceleration $a \propto \frac{v^2}{r}$

where $v \propto \frac{Z}{n}$ and $r \propto \frac{n^2}{Z} \Rightarrow a \propto \frac{Z^3}{n^4}$

Since both are in ground state i.e., n = 1

so $a \propto Z^3 \Rightarrow \frac{a_{He^+}}{a_H} = \left(\frac{Z_{He^+}}{Z_H}\right)^3 = \left(\frac{2}{1}\right)^3 = \frac{8}{1}$.

(35) **(C).** The activity

$$\left(-\frac{dN}{dt}\right) = \lambda N \Rightarrow N = \left(-\frac{dN}{dt}\right)\left(\frac{T_{1/2}}{\log_e 2}\right)$$

Taking the ratio of this expression for ^{240}Pu to this same expression for ^{243}Am,

$$\frac{N_{Pu}}{N_{Am}} = \frac{\left(-\frac{dN_{Pu}}{dt}\right)(T_{1/2})_{Pu}}{\left(-\frac{dN_{Am}}{dt}\right)(T_{1/2})_{Am}} = \frac{(5\mu ci) \times (6560y)}{(4.45\mu ci) \times (7370y)} = 1$$

i.e. the two samples contains equal number of nuclei.

(36) **(B).** Energy required to knock out the electron in the n^{th} orbit $= +\frac{13.6}{n^2} eV \Rightarrow E_3 = +\frac{13.6}{9} eV$.

(37) **(B).** For α-decay : ${}_xA^y \longrightarrow {}_{x-2}B^{y-4} + \alpha$

For β⁻-decay : ${}_xA^y \longrightarrow {}_{x+1}B^y + {}_{-1}\beta^0$

For β⁺ decay : ${}_xA^y \longrightarrow {}_{x-1}B^y + {}_{+1}\beta^0$

For k-capture : there will be no change in the number of protons.
Hence, only case in which no of protons increases is β^--decay.

(38) **(C).** $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \frac{3R}{16} \Rightarrow \lambda = \frac{16}{3R} = \frac{16}{3} \times 10^{-5} cm$

$$\text{Frequency } n = \frac{c}{\lambda} = \frac{3 \times 10^{10}}{\frac{16}{3} \times 10^{-5}} = \frac{9}{16} \times 10^{15} \text{Hz}$$

(39) **(B).** Energy released $= 13.6\left[\frac{1}{(2)^2} - \frac{1}{(4)^2}\right] = 2.55 eV$

(40) **(A).** $\frac{1}{\lambda} = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36}$

$$R = \frac{36}{5\lambda} = \frac{36}{5 \times 6563 \times 10^{-10}} = 1.09 \times 10^7 m^{-1}$$

(41) **(D).** Let initial no. of U-atoms $= N_0$
After time t, (age of rock), let no. of atoms remaining undecayed = N.

$$\therefore \frac{238\,N}{226\,(N_0 - N)} = \frac{4}{3} \quad \therefore \frac{N_0}{N} = 1.79$$

$$t = \frac{T \log N_0 / N}{\log 2} = \frac{4.5 \times 10^9 \times \log 1.79}{0.301} = 3.78 \times 10^9 \text{ years.}$$

(42) **(B).** $K_\alpha = \frac{(A-4)}{A}Q$

Here, A = 220, Q = 5.5 MeV

$$K_\alpha = \left(\frac{220-4}{220}\right)5.5\text{ MeV} = \left(\frac{216}{220}\right)5.5\text{ MeV} = 5.4\text{ MeV}$$

(43) **(C).** Here, $\lambda_L = 1215$ Å

For the first line of Lyman series

$$\frac{1}{\lambda_L} = R\left[\frac{1}{1^2}-\frac{1}{2^2}\right] = R\left[1-\frac{1}{4}\right] = \frac{3R}{4}$$

$$\therefore \quad \lambda_L = \frac{4}{3R} \qquad \text{........ (1)}$$

For the first line of Balmer series

$$\frac{1}{\lambda_B} = R\left[\frac{1}{2^2}-\frac{1}{3^2}\right] = R\left[\frac{1}{4}-\frac{1}{9}\right] = \frac{5R}{36}$$

$$\therefore \quad \lambda_B = \frac{36}{5R} \qquad \text{........ (2)}$$

From eq. (1) and (2),

$$\frac{\lambda_B}{\lambda_L} = \frac{36/5R}{4/3R} = \frac{36\times 3}{4\times 5}$$

$$\lambda_B = \frac{108}{20}\times\lambda_L = \frac{108}{20}\times 1215 = 6561\text{ Å}$$

(44) **(A).** Triton energy is less than that of a He^3 nucleus.

(45) **(A).** Mean life, $\tau = \frac{1}{\lambda}$

and half life, $T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$

∵ $\tau > T_{1/2}$. Greater fraction will decay in longer time. Hence, fraction decayed in one mean life must be greater than the fraction decayed in one half life i.e. $f_1 > f_2$.

(46) **(B).** Here, $n = \frac{t}{T_{1/2}} = \frac{38}{3.8} = 10$

$$N = N_0\left(\frac{1}{2}\right)^n = m = m_0\left(\frac{1}{2}\right)^n$$

$$= 15\text{mg}\times\left(\frac{1}{2}\right)^{10} = \frac{15}{1024} = 0.015\text{ mg}$$

(47) **(A).** Bohr's model assumes a central force and circular orbit which accounts for a constant angular momentum with vector pointing perpendicular to force vector. This is an approximate model.

(48) **(B).** Energy, $E_n = -\frac{13.6}{n^2}\text{eV}$

In ground state energy,

$$E_1 = -\frac{13.6}{1^2}\text{eV} = -13.6\text{ eV}$$

In first excited state energy

$$E_2 = -\frac{13.6}{2^2} = -3.4\text{ eV}$$

Then the required energy = $E_2 - E_1$

$= -3.4 - (-13.6) = 10.2$ eV

(49) **(C).** Energy of any level $\propto Z^2$, which is greatest for Li^{2+}]

(50) **(B).** $\frac{1}{\lambda} = RZ^2\left(1-\frac{1}{4}\right)$

(51) **(A).** λ longest $\Rightarrow E_{min}$

For Balmer λ longest is for $n = 2 \to 3$

For Lyman λ longest is for $n = 1 \to 2$

$\Rightarrow$ λ longest Balmer > λ longest Lyman

(52) **(C).** $E = \frac{E_0Z^2}{n^2} = E_0 \Rightarrow n = Z = 3$,

For Lithium $r = \frac{r_0n^2}{Z} = \frac{r_0.3^2}{3} = 3r_0$

(53) **(D).** $13.6Z^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right) = 7.55 \Rightarrow Z = 2$,

∴ $E = 13.6\times Z^2 = 54.4$ eV

(54) **(D).** Binding Energy $= -ME \propto n^2$,

for 1st excited state n = 2,

and for 2nd excited state, n = 3.

(55) **(A).** He^+ being a hydrogen like atom,

$$E = 13.6\,z^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right),\ n_1 = 1,\ n_2 = \infty$$

(56) **(D).** An electron orbiting around the nucleus of an atom has a magnetic dipole moment, exerts an electric force on the nucleus equal to that on it by the nucleus and produce a magnetic induction at the nucleus.

(57) **(A).** Activity A ∝ N/T

$$\frac{T_1}{T_2} = \frac{N_1}{N_2}\times\frac{A_2}{A_1} = \frac{2N_2}{N_2}\times\frac{2A_1}{A_1} = \frac{4}{1}$$

(58) **(D).** $N \to P + \beta + \nu$

(59) **(D).** $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$; $n_1 = 2,\ n_2 = 4$

$$\frac{1}{\lambda} = R\left[\frac{1}{4}-\frac{1}{16}\right] = R\left[\frac{4-1}{16}\right] = \frac{3R}{16} \quad ; \quad \lambda = \frac{16}{3R}$$

(60) **(C).** $\lambda \propto n^2$; $\frac{\lambda_{Lymann}}{\lambda_{Balmer}} = \left(\frac{1}{2}\right)^2 = \frac{1}{4} = 0.25$

(61) **(A).** $N = \frac{N_0}{2^n} = \frac{N_0}{2^{1/2}} = \frac{N_0}{\sqrt{2}}$

(62) **(C).** 1 C i = 3.7×10^{10} dis / sec

(63) **(D).** Magnetic dipole moment

$$M = IA = \frac{e}{2\pi r/v}\times\pi r^2 = \frac{erv}{2}$$

Angular momentum L = mvr

$$\therefore \quad \frac{M}{L} = \frac{erv}{2} \times \frac{1}{mvr} = \frac{e}{2m}$$

(64) **(D).** $E = \frac{-13.6}{n^2}\,\text{eV} \quad ; \quad E \propto -\frac{1}{n^2}$

(65) **(D).** $R = R_0\,(A)^{1/3} = R_0\,[64]^{1/3} = 4.8$ fermi

(66) **(B).** $X_Z^A \to Y_D^C$

$C = A - 16, \; D = Z - 8 + 3 = Z - 5$

(67) **(B).** $E_2 > E_1$. Because of decrease in mass number more stability will come.

(68) **(C).** Velocity $v \propto 1/n$

And radius $r \propto n^2 \Rightarrow r \propto 1/v^2$

$$\therefore \quad \frac{r_2}{r_1} = \left(\frac{v_1}{v_2}\right)^2 = \left(\frac{v}{v/3}\right)^2 = 9 \quad \therefore \quad r_2 = 9r_1 = 9R$$

(69) **(C).** $N = N_0 e^{-\lambda t}$

For A, $N_A = N_0 e^{-15x \times \frac{1}{6x}} = N_0 e^{-5/2}$

For B, $N_B = N_0 e^{-3x \times \frac{1}{6x}} = N_0 e^{-1/2}$

$$\therefore \quad \frac{N_A}{N_B} = \frac{e^{1/2}}{e^{5/2}} = e^{\frac{1}{2} - \frac{5}{2}} = e^{-2}$$

(70) **(D).** Energy released $Q = BE_P - BE_R$

(1) $D \to 2B$

$Q = 2 \times 8.5 \times 60 - 7 \times 120 = 180$ MeV

(2) $C \to B + A$

$Q = [8.5 \times 60 + 5 \times 30] - 8 \times 90 = -60$ MeV

(3) $B \to 2A$

$Q = 2 \times 5 \times 30 - 8.5 \times 60 = 300 - 510 = -210$ MeV

(71) **(B).** Energy required to remove 2nd electron

$= z^2\,(13.6)\,\text{eV} = 2^2\,(13.6)\,\text{eV} = 54.4$ eV

$\therefore$ Total energy = 24.6 + 54.4 = 79 eV

(72) **(A).** $h\nu = 3E - E$ or $\frac{hc}{\lambda} = 2E$ .... (1)

In the 2nd case, $\frac{5E}{3} - E = \frac{hc}{\lambda'}$

$$\frac{hc}{\lambda'} = \frac{5E - 3E}{3} = \frac{2E}{3} \; ; \; \frac{hc}{\lambda'} = \frac{2}{3}\left(\frac{hc}{2\lambda}\right) \quad \text{[From eq. (1)]}$$

$\lambda' = 3\lambda$

(73) **(D).** Electron emission during β-decay is always accompanied by antineutrino.

(74) **(B).** $0 = (A - 4)\,v' + 4v$

$(A - 4)\,v' = -4v$

$$v' = \frac{-4v}{A - 4}$$

(75) **(C).** In 1st two seconds 100β particles and in next two seconds 50β particles

$$T_{1/2} = 2\text{ sec} \; ; \; T_m = \frac{T_{1/2}}{0.693} = \frac{2}{0.693}$$

(76) **(B).** $\frac{m}{t} = 4 \times 10^8\ \text{kgs}^{-1}$

$$E = mc^2 \Rightarrow \frac{E}{t} = \left(\frac{m}{t}\right)c^2 \Rightarrow \frac{E}{t} = 4 \times 10^8 \times 9 \times 10^{16}$$

$$\Rightarrow \frac{E}{t} = 3.6 \times 10^{25}\ \text{Js}^{-1} \Rightarrow \frac{E}{t} = 3.6 \times 10^{25}\,\text{W}$$

(77) **(A).** $E_n = -\frac{13.6}{n^2} = -\frac{13.6}{(3)^2} = -1.51$ eV

(78) **(D).** ${}_Z X^A \xrightarrow{\alpha} {}_{Z-2}Y^{A-4} \xrightarrow{2\beta^-} {}_Z X^{A-4}$

(79) **(B).** $m_1 v_1 = m_2 v_2$

$$\frac{v_1}{v_2} = \frac{m_2}{m_1} = \left(\frac{R_2}{R_1}\right)^3 \; ; \; m \propto A \propto R^3$$

$$\frac{v_1}{v_2} = \left(\frac{2}{1}\right)^3 = \frac{8}{1}$$

(80) **(C).** $\nu = \frac{c}{\lambda} = RC\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = RC\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5RC}{36}$

(81) **(C).** TE = –KE = PE/2

(82) **(D).** $N = \frac{N_0}{2^n} = \frac{N_0}{2^{1/2}} = 0.707\,N_0$

(83) **(C).** Let $\lambda_A = \lambda \;\; \therefore \;\; \lambda_B = 2\lambda$

If N_0 is total no. of atoms in A and B at t = 0, then initial rate of disintegration of A = λN_0, and initial rate of disintegration of B=$2\lambda N_0$

As $\lambda_B = 2\lambda_A \; \therefore \; T_B = \frac{1}{2}T_A$

i.e. half life of B is half the half life of A.

After one half life of A.

$$\left(-\frac{dN}{dt}\right)_A = \frac{\lambda N_0}{2}$$

Equivalently, after two half lives of B

$$\left(-\frac{dN}{dt}\right)_B = \frac{2\lambda N_0}{4} = \frac{\lambda N_0}{2}$$

Clearly, $\left(-\frac{dN}{dt}\right)_A = -\left(\frac{dN}{dt}\right)_B$

after n = 1, i.e., one half life of A.

(84) **(C).** $6000 = A_0 e^{-280\lambda} \; ; \; 3000 = A_0 e^{-420\lambda}$

$2 = e^{-280\lambda} \; ; \; A_0 = 3000$

(85) **(C).** $E = \Delta mc^2 = [4 \times 4.0026 - 15.9994] \times 931.5 = 10.24$ MeV

(86) **(B).** Transition from ∞ ton n = 3 will produce smallest wavelength in infrared region.

$$K\times\frac{3}{4}=\frac{1}{\lambda_{uv}}\ ;\ K\times\frac{1}{9}=\frac{1}{\lambda_{inf}}$$

$$\lambda_{inf}=\frac{27}{4}\times\lambda_{uv}\approx 823\text{nm}$$

(87) **(A).** Rest mass energy of U will be greater than the rest mass energy of the nucleus in which it breaks (as conservation of momentum is always followed).

(88) **(D).** At time t = 0 ; $A_0=\frac{dN_0}{dt}$

and at time t

$$A=\frac{dN}{dt}\ ;\ \frac{A}{A_0}=\frac{dN/dt}{dN_0/dt}=\frac{3260}{6520}$$

From activity law $A=A_0e^{-\lambda t}$

$$e^{\lambda t}=\frac{A_0}{A}\qquad \text{or}\quad l=\frac{2.303}{t}\log\frac{A_0}{A}$$

$$\lambda=\frac{2.303}{2\times 60}\log 2=\frac{2.303}{2\times 60}\times 0.3010=5.7\times 10^{-3}\text{per sec}$$

(89) **(C).** $l=\frac{0.693}{T}=\frac{0.693}{5\ \acute{}\ 3600}=3.85\times 10^{-5}$ per sec

EXERCISE-3

(1) **8.** $B=\frac{\mu_0}{2}\frac{i}{r}\Rightarrow B\propto\frac{i}{r}\Rightarrow B\propto\frac{e}{T\times r_n}$

$$B\propto\frac{v_n}{r_n^2}\qquad\left(\therefore\ T=\frac{2\pi r}{v}\right)$$

$$B\propto\frac{z}{n}\times\frac{z^2}{n^4}\qquad\left(r_n\propto\frac{n^2}{z},\ v_n\propto\frac{z}{n}\right)\ ;\ B\propto\frac{z^3}{n^5}$$

(2) **41.** $\frac{hc}{eV_0}=\lambda\ \&\ \frac{hc}{3eV_0}=\lambda-\Delta\lambda\Rightarrow V_0=\frac{2hc}{3e\Delta\lambda}=41\text{kV}$

(3) **4.** $A=A_0e^{-\lambda t}$ and $i=i_0e^{-t/\tau}$

Given : $\frac{A}{i}=\frac{A_0}{i_0}\frac{e^{-\lambda t}}{e^{-t/\tau}}=\frac{A_0}{i_0}e^{\left(-\lambda+\frac{1}{\tau}\right)t}$

For constant value of i/A

$$-\lambda+\frac{1}{\tau}=0\ \therefore\ \lambda=\frac{1}{\tau}\ ;\ T_{mean}=\tau=0.4\text{ sec.}$$

(4) **5.** Expected number of parents that survives for time is

$N=N_0e^{-\lambda t}$

The probability of survival for a nucleon is $\frac{N}{N_0}=e^{-\lambda t}$

For $t=5t_{1/2}=5\frac{\ln 2}{\lambda},\ \frac{N}{N_0}=2^{-5}$

(5) **4.** Energy released from n = 5 to n = 1

$$E=13.6\left(\frac{1}{1^2}-\frac{1}{5^2}\right)=13.6\times\frac{24}{25}\text{eV}$$

Momentum of photon = $13.6\times\frac{24}{25}\times\frac{1.6\times 10^{-19}}{3\times 10^8}$

Momentum of H-atom = $\frac{13.6\times 24\times 1.6\times 10^{-19}}{25\times 3\times 10^8}$

Velocity of H-atom = $\frac{13.6\times 24\times 1.6\times 10^{-19}}{75\times 10^8\times 1.67\times 10^{-27}}=4$ m/s

(6) **320.** Nuclear reaction will be as follows

$$Po^{210}\longrightarrow Pb^{206}+He^4+Q$$

Mass defect in this equation is

$$\Delta m=m_{Po}-m_{Pb}-m_{He}=0.00564\text{ amu}$$

∴ Energy released by the decay of one polonium nuclei is (931) Δm MeV

$Q=8.4\times 10^{-13}$ J

693 days of polonium are equivalent to 5 half lives of polonium, because $\frac{693}{138.6}=5$

So, number of nuclei left after 5 half lives are

$$N=N_0\left(\frac{1}{2}\right)^5\ ....\ (i)\ ;\ \left(-\frac{dN}{dt}\right)=\lambda N=\frac{\ln(2)}{t_{1/2}}\times N$$

So, energy released per day = $\left(\frac{\ln(2)}{t_{1/2}}\right)N\ (8.4\times 10^{-13})$ J

But only 10% of this energy is used as electric power.

So, $\left(\frac{10}{100}\right)\left\{\frac{\ln(2)}{t_{1/2}}\right\}N\ (8.4\times 10^{-13})=1.2\times 10^7$ J

$$\therefore\ N=\frac{(1.2\times 10^7)(100)(t_{1/2})}{(10)(\ln 2)(8.4\times 10^{-13})}=2.857\times 10^{22}$$

∴ Initial number of nuclei required are

$N_0=(2^5)N=9.1424\times 10^{23}$ ..... (2)

∴ Mass of polonium required is

$$m=\left(\frac{9.1424\times 10^{23}}{6\times 10^{23}}\right)\times 210=320\text{gm}$$

(7) **154.** $P=700\times 10^3\times 1.6\times 10^{-19}\times\frac{dN}{dt}=10\times 10^{-3}$

$$\frac{dN}{dT}=\frac{10^{-12}}{10^{-14}}\times\frac{1}{7\times 16}=\frac{10^{12}}{112}=\lambda N_0$$

$$\lambda = \frac{\ln 2}{14\times 86400}$$

$$\Rightarrow N_0 = \frac{14\times 86400\times 10^{12}}{11.2\ln 2} = 154\times 10^{15}$$

(8) **1.** $N = N_0 e^{-\lambda t}$; $\frac{dN}{dt} = 10^{10} = N_0(\lambda)\, e^{-10^{-9}}\, t$

At (t = 0), $10^{10} = N_0\, 10^{-9}$

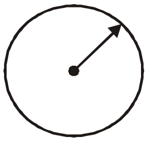
$N_0 = 10^{19}$

Mass of sample $= N_0\, 10^{-25} = N_0$ (mass of the atom)

$= 10^{-6}$ kgm $= 10^{-6}\times 10^{3}$ gm $= 10^{-3}$ gm $= 1$ mg

(9) **7.** $\frac{hc}{\lambda} = \phi + eV$

$$\frac{1240\ (eV)\ (nm)}{200\ (nm)} = 4.7\ (eV) + eV$$



$$\frac{1240}{200}e = 4.7e + eV$$

$6.2 - 4.7 = V \quad \therefore\ V = 1.5$ volt

$$\frac{1}{4\pi\varepsilon_0}\frac{Q}{R} = 1.5\ ;\quad (9\times 10^{9})\frac{Ne}{\frac{1}{100}} = 1.5$$

$9\times 10^{11}\, Ne = 1.5$

$$N = \frac{1.5}{9\times 10^{11}\times 1.6\times 10^{-19}} = \frac{15}{16}\times\frac{1}{9}\times 10^{8}$$

$$= \frac{5}{3\times 16}\times 10^{8} = \frac{50}{48}\times 10^{7} \qquad \therefore Z = 7$$

(10) **1.** Slope of graph is h/e = constant

$\Rightarrow$ 00001

(11) **4.** $f = (1 - e^{-\lambda t}) = 1 - e^{-\lambda t} \approx 1 - (1 - \lambda t) = \lambda t$

$f = 0.04$

Hence % decay ≈ 4%

(12) **2.** $\frac{hc}{\lambda} - \left\{13.5\text{eV}\cdot\frac{1}{n^2}\right\} = 10.4$

$$\Rightarrow \frac{1242\text{ eV}}{90} - \frac{13.6}{n^2} = 10.4 \Rightarrow \frac{41.4}{3} - \frac{13.6}{n^2} = 10.4$$

$$\Rightarrow 13.8 - 10.4 = \frac{13.6}{n^2} \Rightarrow 3.4 = \frac{13.6}{n^2} \Rightarrow n^2 = 4 \Rightarrow n = 2$$

(13) **3.** $E'\times\frac{12.5}{100} = E$; $E = \frac{E'}{8}$; $E = \frac{E'}{2^3}$

(E = Power requirement to the village,

E' = power of plant)

Number of half life = 3

So total time required = 3 × T years

(14) **2.** $A_P = A_0 e^{-t/\tau}$, $A_Q = A_0 e^{-t/2\tau}$

$$R_P = \frac{A_0}{\tau}e^{-t/\tau},\quad A_Q = \frac{A_0}{2\tau}e^{-t/2\tau}$$

At $t = 2\tau$, $\frac{R_P}{R_Q} = \frac{\frac{A_0}{\tau}e^{-2}}{\frac{A_0}{2\tau}e^{-1}} = \frac{2}{e}$

(15) **2.** $L = \frac{nh}{2\pi} = \frac{3h}{2\pi}$; $n = 3$

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h2\pi r}{3h} = \frac{2\pi r}{3}\ ;\quad r = a_0\frac{n^2}{Z}$$

$$\lambda = \frac{2\pi}{3}a_0\frac{n^2}{Z} = \frac{2\pi}{3}a_0\frac{3^2}{3} = 2\pi a_0$$

(16) **6.** Incident energy, $E_1 = \frac{hc}{\lambda} = \frac{1.237\times 10^{-6}}{970\times 10^{-10}} = 12.75\text{eV}$

$\Rightarrow$ e^- jumps to state of $E = -13.6 + 12.75 = -0.85$ eV

$\Rightarrow$ $n = 4$

$\therefore$ Number of lines in emission spectrum is 6.

(17) **9.** ${}^{12}_{5}B \rightarrow {}^{12}_{6}C + {}^{0}_{-1}e + \overline{\nu}$

Mass of ${}^{12}_{6}C = 12.000$ u (by definition if 1 a.m.u.)

Q-value of reaction,

$Q = (M_B - M_C)\times c^2 = (12.014 - 12.000)\times 931.5$

$= 13.041$ MeV

4.041 MeV of energy is taken by ${}^{12}_{6}C^*$

$\Rightarrow$ Max. K.E. of β-particle is $(13.041 - 4.041) = 9$ MeV

EXERCISE-4

(1) **(C).** $E = -13.6\frac{Z^2}{n^2} = -13.6\times\frac{1}{4} = -3.4\text{eV}$

Required energy is = + 3.4 eV

(2) **(A).** Covalent bond is due to wave nature.

(3) **(A).** $W_0 = h\nu_0 = \frac{hc}{\lambda_0}$

$$\frac{(\lambda_0)K}{(\lambda_0)Na} = \frac{(W_0)Na}{(W_0)K} = \frac{2.3}{4.5} = \frac{1}{2}$$

(4) **(A).** $n = \frac{15}{3} = 3$ half lives ; $N = \frac{N_0}{2^n} = \frac{N_0}{2^3} = \frac{N_0}{8}$

(5) **(A).** α-particle (He^{2+}) and electron (β-particle) are emitted by radioactive compound, protons are not emitted.

(6) **(D).** $T = \frac{\ell n 2}{\lambda} \Rightarrow \lambda = \frac{\ell n 2}{T}$; $N = \frac{N_0}{2^n}$

$$1250 = \frac{5000}{2^n} \Rightarrow \frac{1}{2^n} = \frac{1}{2^2} \Rightarrow n = 2$$

$$\frac{t}{T} = 2 \Rightarrow \frac{5}{T} = 2 \Rightarrow T = 2.5 \text{ minute}$$

$$\lambda = \frac{\ell n\ 2}{2.5} = 0.4\ \ell n 2$$

(7) (D). Protons are not emitted in radioactive decay.

(8) **(D).** Energy of γ-ray is maximum so wavelength is minimum.

(9) **(B).** ${}_{92}U^{238} \rightarrow {}_{2}He^{4} + {}_{90}Pu^{234}$

Momentum remains consered

$$(4m)\,u = (234\,m)\ ;\ v = \frac{4}{234}u$$

(10) **(A).** There are 8α particles

$4\beta^-$ particles

$2\beta^+$ particles

So atomic no. is decreased by = 8 × 2 = 16

and atomic no. is increased by = 4 × 1 = 4

and atomic no. is decreased by = 2 × 1 = 2

So finally atomic no. is decreased by = 16 – 4 + 2 = 14

Final Z = 92 – 14 = 78

(11) **(D).** $hf_1 = W_0 + \frac{1}{2}mv_1^2$ .....(1); $hf_2 = W_0 + \frac{1}{2}mv_2^2$ .....(2)

On taking (1) – (2)

$$h(f_1 - f_2) = \frac{1}{2}m(v_1^2 - v_2^2)\ ;\ v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$$

(12) **(B).** Mass of two different nuclei is different so recoiling energy is different, so energy of two photons is different.

(13) **(A).** ${}^{133}_{55}Cs$

(14) **(D).** First excited state of Li^{++} means second orbit.

$$E = -\frac{13.6 \times 9}{4} = 30.6\text{eV}$$

(15) **(A).** Distance of closest approach

$$r_0 = \frac{2KZe^2}{E} = \frac{2 \times 9 \times 10^9 \times 92\ (1.6 \times 10^{-19})^2}{5 \times 10^6 \times 1.6 \times 10^{-19}}$$

$= 10^{-14}$ meter $= 10^{-12}$ cm.

(16) **(C).** $\frac{3}{2}KT \times 2 = 7.7 \times 10^{-14}$

$$\frac{3}{2} \times 1.38 \times 10^{-23} \times 2 \times T = 7.7 \times 10^{-14}$$

$T \simeq 10^9$ K

(17) **(B).** Momentum $p_1 = p_2$

$m_1v_1 = m_2v_2$

$$\frac{4}{3}\pi r_1^3 dv_1 = \frac{4}{3}\pi r_2^3 dv_2\ ;\ \left(\frac{r_1}{r_2}\right)^3 = \frac{v_2}{v_1} = \frac{1}{2}\ ;\ \frac{r_1}{r_2} = \left(\frac{1}{2}\right)^{1/3}$$

(18) **(A).** ${}_{1}H^{2} + {}_{1}H^{2} \rightarrow {}_{2}He^{4}$

$(4 \times 7) - [(1.1) \times 2 + (1.1) \times 2] = 23.6$ MeV

(19) **(B).** Surface is reflecting so change in momentum

$$= 2 \times p = \frac{2E}{c}$$

(20) **(D).** $h\nu = \phi + E_K$

$E_K = h\nu - \phi$

This is equation of straight line, whose slope is 'h'.

(21) **(A).** $\lambda = \frac{hc}{W_0} = \frac{12420 \times 10^{-10}}{W_0\,(eV)} = \frac{12420 \times 10^{-10}}{4eV} = 310nm$

(22) **(B).** Intensity $\propto \frac{1}{\text{distance}^2}$

Distance is halved intensity becomes four times, so emitted electron becomes four times.

(23) **(C).** $\lambda = \frac{h}{\sqrt{2mE}}$

(24) **(A).** I ⇒ n = 1 to n = 3 shows absorption

II ⇒ n = 4 to n = 3 emission of energy 0.6 eV

III ⇒ n = 2 to n = 1 emission of energy 10.2 eV

IV ⇒ n = 4 to n = 2 emission of energy 2.5 eV

(25) **(A)** $R = R_0 A^{1/3}\ ;\ R = R_0\,(125)^{1/3}$

$$3.6 = R_0\,(27)^{1/3}\ ;\ R = \frac{5}{3} \times 3.6 = 6 \text{ fermi}$$

(26) **(B).** $X + n \rightarrow \alpha + {}_{3}Li^{7}$

$X + {}_{0}n^{1} \rightarrow {}_{2}He^{4} + {}_{3}Li^{7}$

So X is ${}_{5}B^{10}$

(27) **(D).** $I = \frac{I_0}{2^n}\ ;\ \frac{1}{8} = \frac{1}{2^n} \Rightarrow n = 3 \Rightarrow \frac{x}{x_{1/2}} = 3$

$$\Rightarrow \frac{36}{x_{1/2}} = 3 \Rightarrow x_{1/2} = 12mm$$

(28) **(C).** $N = \frac{N_0}{2^n}$;Remaining fraction $\frac{1}{8} = \frac{N_0}{2^n}\ ;\ 1 - \frac{7}{8} = \frac{1}{8}$

$$n = 3 \Rightarrow \frac{t}{T} = 3 \Rightarrow \frac{15}{T} = 3 \Rightarrow T = 5\,\text{min}.$$

(29) **(A).** It is a practical curve.

(30) **(D).** The energy delivered by radiation to a target.

(31) **(A).** ${}_{3}Li^{7} + {}_{1}P^{1} \rightarrow {}_{4}Be^{8} + X$

X may be gamma photons

(32) **(D).** Distance of closest approach

$$r_0 = \frac{2KZe^2}{E} = \frac{2KZe^2}{\frac{1}{2}mv^2}$$

(33) **(D).** ${}_{1}P^{1} + {}_{3}Li^{7} \rightarrow 2\,({}_{2}He^{4})$

$\Delta E = (2 \times 4 \times 7.06) - (7 \times 5.60) = 17.28$ MeV

(34) **(C).** $E = W_0 + eV_0 = 6.2 + 5 = 11.2$ eV

$$\lambda = \frac{hc}{E} = \frac{12420 \times 10^{-10}}{E\,(eV)} = \frac{12420 \times 10^{-10}}{11.2\,(eV)}$$

≅ 1000 Å which is in ultraviolet region.

(35) **(D).** Time taken is 10^{-10} sec.

(36) **(D).** As wavelength increase, energy of photon decreases and electron coming out form depth, decreases.

(37) **(C).** When electron transit 2 to 1 it emits maximum energy =10.2 eV.

(38) **(D).** $E = mc^2 = mc \times c = P \times c\ ;\ P = \frac{E}{c} = \frac{h\nu}{c}$

(39) **(B).** $\Delta E = \Delta M \times C^2$; $\Delta M = (8M_P + 9M_n - M_0)$
There are 8 protons and 9 neutrons in ${}_8O^{17}$ nucleus.

(40) **(B).** γ-ray have no charge and no mass.

(41) **(B).** $T_X = T_Y$

$$\frac{0.693}{\lambda_X} = \frac{1}{\lambda_Y} \Rightarrow 0.693\lambda_Y = \lambda_X. \text{ So } \lambda_Y > \lambda_X$$

So Y will decay faster.

(42) **(A).** $F = \frac{k}{r}$; $\frac{mv^2}{r} = \frac{k}{r} \Rightarrow v = \text{constant}$

$$mvr = \frac{2h}{2\pi} \Rightarrow v \propto \frac{n}{r} \; ; \quad \frac{n}{r} = \text{constant} \; ; r \propto n$$

and v is constant so KE is also constant.

(43) **(A).** According to Bragg's $2d \sin \phi = n\lambda$
Here, $i = 90 - \phi$. So $\phi = 90 - i$
$2d \sin (90 - i) = n\lambda$; $2d \cos i = n\lambda$.

(44) **(A).** $2d \cos i = \frac{12.27}{\sqrt{V}}$ Å

$$2 \times 1 \times \cos 30 = \frac{12.27}{\sqrt{V}} \Rightarrow 2 \times \frac{\sqrt{3}}{2} = \frac{12.27}{\sqrt{V}}$$

$$\Rightarrow \quad v = \frac{150}{3} = 50V$$

(45) **(C).** There will be a principal maxima at the centre on both sides of which subsidiary maximas and alternately minimas are observed.

(46) **(A).** Energy is released when heavy nuclei undergo fission or light nuclei undergo-fusion because $\frac{BE}{A}$ increases.

(47) **(D).** Energy of I – R radiation < energy of U – V radiation

(48) **(A).** If B.E. of product is more energy is released.

(49) **(B).** $W = \frac{hc}{\lambda} - K_{max} = \frac{1240}{400} - 1.68 = 1.42eV$

(50) **(D).** Since the frequency of ultraviolet light is less than the frequency of X–rays, the energy of each incident photon will be more for X–rays

$$K.E_{photoelectron} = h\nu - \phi$$

Stopping potential is to stop the fastest photoelectron, $V_0 = \frac{h\nu}{e} - \frac{\phi}{e}$

So, $K.E_{max}$ and V_0 both increases.
But K.E ranges from zero to $K.E_{max}$ because of loss of energy due to subsequent collisions before getting ejected and not due to range of frequencies in the incident light.

(51) **(C).** After decay, the daughter nuclei will be more stable hence binding energy per nucleon will be more than that of their parent nucleus.

(52) **(B).** Conserving the momentum

$$0 = \frac{M}{2}V_1 - \frac{M}{2}V_2$$

$$V_1 = V_2 \qquad \text{...... (1)}$$

$$\Delta mc^2 = \frac{1}{2}.\frac{M}{2}V_1^2 + \frac{1}{2}.\frac{M}{2}V_2^2 \qquad \text{..... (2)}$$

$$\Delta mc^2 = \frac{M}{2}V_1^2 \; ; \; \frac{2\Delta mc^2}{M} = V_1^2 \; ; \; V_1 = c\sqrt{\frac{2\Delta m}{M}}$$

(53) **(B).** In positive beta decay a proton is transformed into a neutron and a positron is emitted.

$$p^+ \rightarrow n^0 + e^+$$

No. of neutrons initially was A – Z
No. of neutrons after decay (A – Z) – 3 × 2 (due to alpha particles) + 2 × 1 (due to positive beta decay)
The no. of proton will reduce by 8. [as 3 × 2 (due to alpha particles) + 2(due to positive beta decay)]
Hence atomic number reduces by 8.

(54) **(A).** $4 \times 10^3 = 10^{20} \times hf$

$$f = \frac{4 \times 10^3}{10^{20} \times 6.023 \times 10^{-34}} = 6.03 \times 10^{16} \text{ Hz}$$

The obtained frequency lies in the band of X-rays.

(55) **(C).** $\frac{2}{3}N_0 = N_0e^{-\lambda t_1}$; $\frac{1}{3}N_0 = N_0e^{-\lambda t_2}$

$$2 = e^{-\lambda (t_2 - t_1)} \; ; \quad \lambda (t_2 - t_1) = \ln 2$$

$$(t_2 - t_1) = \frac{\ln 2}{\lambda} = 20 \text{ min.}$$

(56) **(C).** $E_1 = -\frac{13.6\,(3)^2}{(1)^2}$; $E_3 = -\frac{13.6\,(3)^2}{(3)^2}$

$$\Delta E = E_3 - E_1 = 13.6\,(3)^2 \left[1 - \frac{1}{9}\right] = \frac{13.6 \times 9 \times 8}{9}$$

$$\Delta E = 108.8 \text{ eV}$$

(57) **(D).** $h\nu = h\nu_0 + k_{max}$
$k_{max} = h\nu - h\nu_0$

(58) **(D).** If n = 4 ; lines $= \frac{n\,(n-1)}{2} = 6$

(59) **(C).** Both are true

(60) **(A).** ${}_0n^1 \rightarrow {}_1H^1 + {}_{-1}e^0 + \bar{\nu} + Q$

$$\Delta m = m_n - m_\alpha - m_e$$

$$= (1.6725 \times 10^{-27} - 1.6725 \times 10^{-27} - 9 \times 10^{-31}) \text{ kg}$$

$$= -9 \times 10^{-31} \text{ kg}$$

Energy $= 9 \times 10^{-31} \times (3 \times 10^8)^2 = 0.511$ MeV
which is nearly equal to 0.73 Mev but as energy will be required.
Since mass is increasing so answer = 0.511 Mev

(61) **(D).** As λ is increased, there will be a value of λ above which photoelectrons will be cease to come out so photocurrent will become zero.

(62) **(D).** $\Delta E = h\nu$

$$\nu = \frac{\Delta E}{h} = k\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = \frac{k \times 2n}{n^2(n-1)^2} = \frac{2k}{n^3} \propto \frac{1}{n^3}$$

(63) **(A).** $\frac{1}{\lambda} = Rz^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) \quad \therefore \ \lambda = \frac{4}{3Rz^2}$

$$\lambda_1 = \frac{4}{3R}, \lambda_2 = \frac{4}{3R}, \lambda_3 = \frac{4}{12R}, \lambda_4 = \frac{4}{27R}$$

$\Rightarrow \ \lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$

(64) **(D).** $mv = qBR$

$$KE_{(max)} = \frac{(mv)^2}{2m} = 0.8eV \ ; \ h\nu = 13.6\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\therefore \quad W = h\nu - KE_{(max)} = 13.6\ \frac{5}{36} - 0.8 = 1.1\ eV$$

(65) **(D).** $PE = -27.2\frac{z^2}{n^2}eV \ ; TE = -\frac{13.6z^2}{n^2}eV \ ; \ KE = \frac{13.6z^2}{n^2}eV$

$KE = \frac{13.6}{n^2}eV$, As n decreases, KE ↑

$PE = -\frac{27.2}{n^2}eV$, As n decreases, PE ↓

$TE = -\frac{13.6}{n^2}eV$, As n decreases, TE ↓

(66) **(B).** Franck-Hertz exp.– Discrete energy level.
Photo-electric effect– Particle nature of light
Davison-Germer exp.– Diffraction of electron beam

(67) **(C).** For A : Number of half lives = 80/20 = 4

$$[A] = \frac{x_0}{2^4} \ ; \ \Delta[A] = x_0\left[1 - \frac{1}{16}\right] = \frac{15}{16}x_0$$

For B : Number of half lives = 80/40 = 2

$$[B] = \frac{x_0}{2^2} \ ; \ \Delta[B] = \frac{3x_0}{4} \ ; \ \frac{\Delta[A]}{\Delta[B]} = \frac{15/16}{3/4} = 5 : 4$$

(68) **(D).** $V_0 = \sqrt{\frac{2}{m}\left(\frac{hc}{\lambda} - \phi\right)} \quad ; \quad V' = \sqrt{\frac{2}{m}\left(\frac{4hc}{3\lambda} - \phi\right)}$

$$\frac{V'}{V} = \sqrt{\frac{\frac{4}{3}\left(\frac{hc}{\lambda} - \phi\right)}{\frac{hc}{\lambda} - \phi}} = \sqrt{\frac{\frac{4}{3}\left(\frac{hc}{\lambda} - \frac{3\phi}{4}\right)}{\frac{hc}{\lambda} - \phi}}$$

We can see that $\frac{\frac{hc}{\lambda} - \frac{3\phi}{4}}{\frac{hc}{\lambda} - \phi} > 1 \Rightarrow \ V' > V\sqrt{\frac{4}{3}}$

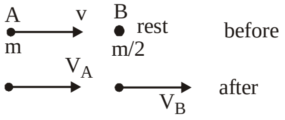
(69) **(C).** $\frac{hc}{\lambda_2} = -E - \left(-\frac{4E}{3}\right) = \frac{E}{3}$

$$\frac{hc}{\lambda_1} = -E - (-2E) = E \ ; \ \frac{\lambda_1}{\lambda_2} = \frac{1}{3}$$

(70) **(A).** $T = \frac{\ln 2}{\lambda} \ ; \ \frac{N_0 - N}{N} = 0.3 \Rightarrow \ N = \frac{N_0}{1.3}$

$$N = N_0e^{-\lambda t} \ ; \ \frac{1}{1.3} = e^{-\lambda t} \ ; \ t = \frac{\ln(1.3)}{\lambda} = T\frac{\ln(1.3)}{\ln(2)}$$

(71) **(A).**



$mv = mV_A + \frac{m}{2}V_B$ (Conservation of momentum)

$V_B - V_A = V$ (e =1)

$$\frac{\lambda_A}{\lambda_B} = \frac{h/p_A}{h/p_B} = \frac{p_B}{p_A} = \frac{\frac{m}{2}V_B}{mV_A} = \frac{1}{2}\frac{V_B}{V_A}$$

$$V_A = \frac{V}{3}, \quad V_B = \frac{4V}{3} \quad ; \quad \frac{\lambda_A}{\lambda_B} = \frac{1}{2} \times \frac{4V/3}{V/3} = 2$$

(72) **(D).** $\lambda_{min} = \frac{hc}{eV} \ ; \ \ln\lambda_{min} = \ln\frac{hc}{eV} - \ln V \quad (y = k - x)$

(73) **(B).** For Series limit of Lyman : $n_1 = 1$ and $n_2 = \infty$

$$\Rightarrow \quad v_P = RcZ^2\left(\frac{1}{1} - \frac{1}{\infty}\right)$$

For Series limit of Pfund: $n_1 = 5$ and $n_2 = \infty$

$$\Rightarrow \quad v_P = RcZ^2\left(\frac{1}{25} - \frac{1}{\infty}\right) = \frac{v_L}{25}$$

(74) **(C).** $\frac{1}{\Lambda_n} \approx RZ^2\left(\frac{1}{1^2} - \frac{1}{n^2}\right) \ ; \ \Lambda_n = \frac{1}{RZ^2}\left(1 - \frac{1}{n^2}\right)^{-1}$

Since n is very large, using binomial

$$\Lambda_n = \frac{1}{RZ^2}\left(1 + \frac{1}{n^2}\right) \ ; \ \Lambda_n = \frac{1}{RZ^2} + \frac{1}{RZ^2}\left(\frac{1}{n^2}\right)$$

$$\Lambda_n = A + \frac{B}{\lambda_n^2}\text{. As } \lambda_n = \frac{2\pi r}{n} = 2\pi\left(\frac{n^2h^2}{4\pi^2 mZe^2}\right)\frac{1}{n} \propto n$$

(75) **(A).** Activity $A = \lambda N$
For A : $10 = (2N_0)\lambda_A$; For B : $20 = N_0\lambda_B$
$\therefore \ \lambda_B = 4\lambda_A \Rightarrow (T_{1/2})_A = 4\,(T_{1/2})_B$

(76) **(A).** $\frac{hc}{\lambda_1} = \phi + \frac{1}{2}m(2v)^2 \ ; \ \frac{hc}{\lambda_2} = \phi + \frac{1}{2}mv^2$

$$\Rightarrow \frac{\frac{hc}{\lambda_1}-\phi}{\frac{hc}{\lambda_2}-\phi}=4 \Rightarrow \frac{hc}{\lambda_1}-\phi=\frac{4hc}{\lambda_2}-4\phi \Rightarrow \frac{4hc}{\lambda_2}-\frac{hc}{\lambda_1}=3\phi$$

$$\Rightarrow \phi=\frac{1}{3}hc\left(\frac{4}{\lambda_2}-\frac{1}{\lambda_1}\right)=\frac{1}{3}\times 1240\left(\frac{4\times 350-540}{350\times 540}\right)=1.8\text{ eV}$$

(77) **(B).** Energy released for transition n = 2 to n = 1 of hydrogen atom $E=13.6\,Z^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$

$Z=1,\ n_1=1,\ n_2=2$

$$E=13.6\times 1\times\left(\frac{1}{1^2}-\frac{1}{2^2}\right)=13.6\times\frac{3}{4}\text{eV}$$

For He^+ ion z = 2

(A) n = 1 to n = 4

$$E=13.6\times 2^2\times\left(\frac{1}{1^2}-\frac{1}{4^2}\right)=13.6\times\frac{15}{4}\text{eV}$$

(B) n = 2 to n = 4

$$E=13.6\times 2^2\times\left(\frac{1}{2^2}-\frac{1}{4^2}\right)=13.6\times\frac{3}{4}\text{eV}$$

(C) n = 2 to n = 5

$$E=13.6\times 2^2\times\left(\frac{1}{2^2}-\frac{1}{5^2}\right)=13.6\times\frac{21}{25}\text{eV}$$

(D) n = 2 to n = 3

$$E=13.6\times 2^2\times\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=13.6\times\frac{5}{9}\text{eV}$$

Energy required for transition of He^+ for n=2 to n = 4 matches exactly with energy released in transition of H for n = 2 to n = 1.

(78) **(D).**

$\frac{h}{\lambda_1}=P_1$

$P_2=\frac{h}{\lambda_1}$

$$\vec{P}_1=\frac{h}{\lambda_1}\hat{i}\ \ \&\ \ \vec{P}_2=\frac{h}{\lambda_2}\hat{j}$$

Using momentum conservation

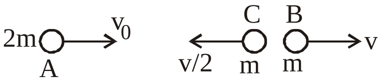
$$\vec{P}=\vec{P}_1+\vec{P}_2=\frac{h}{\lambda_1}\hat{i}+\frac{h}{\lambda_2}\hat{j}$$

$$|\vec{P}|=\sqrt{\left(\frac{h}{\lambda_1}\right)^2+\left(\frac{h}{\lambda_2}\right)^2}$$

$$\frac{h}{\lambda}=\sqrt{\left(\frac{h}{\lambda_1}\right)^2+\left(\frac{h}{\lambda_2}\right)^2}\ \ ;\ \ \frac{1}{\lambda^2}=\frac{1}{\lambda_1^2}+\frac{1}{\lambda_2^2}$$

(79) **(A).** Mass densities of all nuclei are same so their ratio is 1.

(80) **(D).**



Let mass of B and C is m each.
By momentum conservation

$$2mv_0=mv-\frac{mv}{2}\ \ ;\ \ v=4v_0$$

$$p_A=2mv_0\ ;\ p_B=4mv_0\ ;\ p_c=2mv_0$$

De-Broglie wavelength $\lambda=\frac{h}{p}$

$$\lambda_A=\frac{h}{2mv_0},\ \lambda_B=\frac{h}{4mv_0},\ \lambda_C=\frac{h}{2mv_0}$$

(81) **(A).** $T\propto\frac{r}{v}\propto\frac{n^2}{z}\times\frac{n}{z}\propto\frac{n^3}{z^2}$; $\frac{T_1}{T_2}=\frac{n_1^3}{n_2^3}=\frac{1}{8}$

$$T_2=8T_1=8\times 1.6\times 10^{-16}=12.8\times 10^{-16}$$

$$f_2=\frac{1}{12.8\times 10^{-16}}\approx 7.8\times 10^{14}$$

(82) **11.** Energy of photon. $E=\frac{1240}{310}=4\text{eV}>2\text{eV}$

(so photoelectric effect will take place)
$=4\times 1.6\times 10^{-19}=6.4\times 10^{-19}$ Joule

No. of photons falling per second $=\frac{6.4\times 10^{-5}\times 1}{6.4\times 10^{-19}}=10^{14}$

No. of photoelectron emitted per second $=\frac{10^{14}}{10^3}=10^{11}$

(83) **(B).** $\ln\left[\frac{A_0}{A_t}\right]=\lambda t\Rightarrow \ln 2=\lambda t_{1/2}$ …(i)

$\Rightarrow\ \ln\left[\frac{700}{500}\right]=\lambda(30\text{ min})$ …(ii)

Eq. (i) / (ii) $\frac{\ln 2}{\ln(7/5)}=\frac{t_{1/2}}{30\text{ min}}$

$\Rightarrow$ (2.06004) 30 = $t_{1/2}$ = 61.8 min.

(84) **(A).** λ_d for electron $=\frac{h}{\sqrt{2mE}}$; λ for photon $=\frac{hC}{E}$

$$\text{Ratio}=\frac{h}{\sqrt{2mE}}\frac{E}{hC}=\frac{1}{C}\sqrt{\frac{E}{2m}}$$

(85) **(C).** $\lambda_B=2\lambda_A$

$$\frac{h}{\sqrt{2T_Bm}}=\frac{2h}{\sqrt{2T_Am}}$$

$T_A=4T_B$ ....(i)
and $T_B=(T_A-1.5)$ eV ....(ii)
From (i) and (ii)
$3T_B=1.5\text{ eV}\Rightarrow T_B=0.5\text{ eV}$
$T_B=0.5\text{ eV}=4.5\text{ eV}-\phi_B$
$\phi=4\text{eV}$

(86) **(C).** $Y \propto \frac{1}{\left(\sin\frac{\theta}{2}\right)^4}$

(87) **(C).** By de-Broglie hypothesis

$$\lambda = \frac{h}{mv} \ ; \quad \lambda_0 = \frac{h}{m\sqrt{2}v_0} \qquad \text{........(1)}$$

$$\lambda' = \frac{h}{\sqrt{v_0^2 + v_0^2 + \left(\frac{eE_0t}{m}\right)^2}} = \frac{h}{m\sqrt{2v_0^2 + \frac{e^2E_0^2t^2}{m^2}}} \qquad \text{........(2)}$$

By (1) and (2), $\lambda' = \frac{\lambda_0}{\sqrt{1+\frac{e^2E_0^2t^2}{2m^2v_0^2}}}$

(88) **486.** For Balmer series,

$$\frac{1}{\lambda} = R_H\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right) \ ; \quad \frac{\lambda_2}{\lambda_1} = \frac{\frac{1}{2^2} - \frac{1}{3^2}}{\frac{1}{2^2} - \frac{1}{4^2}} \ ; \quad \frac{\lambda_2}{6561} = \frac{5/36}{3/16}$$

$$\lambda_2 = \frac{20}{27} \times 6561 = 4860 \text{ Å} = 486 \text{ nm}$$

(89) **(D).** 1 Rydberg energy = 13.6 eV
So, ionisation energy = $(13.6\ Z^2)$ eV = 9 × 13.6eV
$Z = 3$

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = 1.09 \times 10^7 \times 9 \times \frac{8}{9} \ ; \quad \lambda = 11.4 \text{ nm}$$

EXERCISE-5

PART - A (DUAL NATURE OF MATTER AND RADIATION)

(1) **(C).** $E = \frac{hc}{\lambda} \Rightarrow E = \frac{12375}{\lambda \text{ (in Å)}}\text{eV} \Rightarrow E = \frac{12375}{4100}\text{eV}$

$\Rightarrow E \approx 3\text{eV}$

(2) **(C).** We know that, $h\nu - \phi = K_{max} = \frac{1}{2}mv_{max}^2$

According to question, $\frac{5h\nu_0 - h\nu_0}{2h\nu_0 - h\nu_0} = \frac{v_2^2}{v_1^2}$

$v_2 = 2v_1 = 2 \times 4 \times 10^6 = 8 \times 10^6$ m/s

(3) **(A).** A photo-cell employs photoelectric effect to convert light energy into photoelectric current.

(4) **(A).** When electrons emitted from cathode collide with gas molecules atoms, they knock out outer electrons and produce positively charged ions. They become part of positive ray.

(5) **(C).** 1MeV = $10^6 \times 1.6 \times 10^{-19}$ joule
Momentum of photon

$$= \frac{E}{c} = \frac{1.6 \times 10^{-13}}{3 \times 10^8} = \frac{1.6}{3} \times 10^{-21} = \frac{16}{3} \times 10^{-22}$$

$= 5 \times 10^{-22}$ kg m/sec.

(6) **(D).** Since $p = \frac{nh\nu}{t} \Rightarrow \frac{n}{t} = \frac{p}{h\nu} = \frac{2 \times 10^{-3}}{6.6 \times 10^{-34} \times 6 \times 10^{14}}$
$= 5 \times 10^{15}$

(7) **(D).** Number of emitted electrons

$$N_E \propto \text{Intensity} \propto \frac{1}{(\text{Distance})^2}$$

Therefore, as distance is doubled,
N_E decreases by (1/4) times.

(8) **(A).** $KE_{max} = h\nu - \phi$
or $h\nu = KE_{max} + \phi = 5\text{ eV} + 6.2\text{ eV} = 11.2\text{ eV}$

$$\lambda = \frac{12420 \times 10^{-10}}{11.2\text{ (eV)}} \cong 1000 \text{ Å}$$

which is in ultraviolet region.

(9) **(B).** $m_ev_e = mv$

$$v = \frac{m_ev_e}{m} = \frac{9.1 \times 10^{-31} \times 3 \times 10^6}{10^{-6}} = 2.7 \times 10^{-18} \text{ m/s}$$

(10) **(B).** Saturation current ∝ intensity

(11) **(A).** Curves (a) and (b) represent incident radiations of same frequency but of different intensities.

(12) **(A).** $\lambda = 667 \times 10^{-9}$m, $P = 9 \times 10^{-3}$W

$P = \frac{Nhc}{\lambda}$, N : No. of photons emitted/sec.

$$N = \frac{9 \times 10^{-3} \times 667 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8} = \frac{9 \times 6.67 \times 10^{-10}}{3 \times 6.6 \times 10^{-26}} \simeq 3 \times 10^{16} \text{ /sec}$$

(13) **(A).** Power of source S_1, $P_1 = E_1 N_1 = \frac{N_1hc}{\lambda_1}$

Power of source S_2, $P_2 = N_2E_2 = \frac{N_2hc}{\lambda_2}$

$$\therefore \quad \frac{\text{Power of } S_2}{\text{Power of } S_1} = \frac{P_2}{P_1} = \frac{\frac{N_2hc}{\lambda_2}}{\frac{N_1hc}{\lambda_1}} = \frac{N_2\lambda_1}{N_1\lambda_2}$$

$$= \frac{(1.02 \times 10^{15} \text{ photons / s}) \times (5000\text{Å})}{(10^{15} \text{ photons/s}) \times (5100\text{Å})} = \frac{51}{51} = 1$$

(14) **(D).** $eV = KE_{max}$

(15) **(C).** $\lambda \propto 1/\sqrt{V}$

(16) **(C).** $\frac{v_1}{v_2} = \sqrt{\frac{1-0.5}{2.5-0.5}} = \frac{1}{2}$

(17) **(B).** $\frac{1}{2}mv^2 = eV$

(18) **(A).** Concept of threshold frequency

(19) **(A).** K.E. = $h\nu - h\nu_{th} = eV_0$ (V_0 = cutoff voltage)

$$V_0 = \frac{h}{e}\,(8.2\times10^{14} - 3.3\times10^{14}) = 2V$$

(20) **(B).** $KE_{max} = 10\text{ eV};\ \phi = 2.75\text{ eV}$

$E = \phi + KE_{max} = 12.75\text{ eV}$

= Energy difference between n = 4 and n = 1

⇒ Value of n = 4

(21) **(A).** Given that, $\left(\frac{hc}{\lambda}\right)\times N = 200\times\frac{25}{100}$

$$N = \frac{200\times25}{100}\times\frac{\lambda}{hc} = \frac{200\times25\times0.6\times10^{-6}}{100\times6.6\times10^{-34}\times3\times10^{8}}$$

$= 1.5\times10^{20}$

(22) **(C).** $n\rightarrow 2-1$; $E = 10.2\text{ eV},\ KE = E - \phi,$

$Q = 10.20 - 3.57$; $h\nu_0 = 6.63\text{ eV}$

$$\nu_0 = \frac{6.63\times1.6\times10^{-19}}{6.67\times10^{-34}} = 1.6\times10^{15}$$

(23) **(A).** $\lambda = \frac{h}{p}$; $\frac{d\lambda}{\lambda} = -\frac{dp}{p}$; $\frac{0.5}{100} = \frac{p}{p'}$ ⇒ $p' = 200p$

(24) **(B).** $K.E_{max} = E - W$

$$\frac{1}{2}mv_1^2 = (1-0.5)\text{ eV} = 0.5\text{eV}$$

$$\frac{1}{2}mv_2^2 = (2.5-0.5)\text{ eV} = 2\text{eV}$$

$$\frac{v_1}{v_2} = \sqrt{\frac{0.5}{2}} = \frac{1}{\sqrt{4}} = 2$$

(25) **(B).** $\lambda_P = \frac{h}{p} = \frac{hc}{E}$ and $\lambda_e = \frac{h}{p} = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda_P \propto \lambda_e^2$

(26) **(D).** $h\,(2\nu) = h\nu + \frac{1}{2}mv_{max}^2 \Rightarrow v_{max} = \sqrt{\frac{2h\nu}{m}}$

(27) **(B).** $E = h\nu - \phi \Rightarrow 0.5 = h\nu - \phi$...(1)

$0.8 = 1.2\,h\nu - \phi$ ...(2)

Equation (1) × 1.2 – eq. (2)

$-0.2 = -0.2\phi$; $\phi = 1\text{eV}$

(28) **(B).** $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$ $(\because p = \sqrt{2mE})$

$$\lambda' = \frac{h}{\sqrt{2m\,(16E)}} = \frac{\lambda}{4} = 0.25\lambda$$; % change = –75%

(29) **(A).** According to De-Broglie, $p = h/\lambda$

(30) **(A).** $eV_s = \frac{hc}{\lambda} - \phi$; $3eV_0 = \frac{hc}{\lambda} - \phi$ .... (1)

$eV_0 = \frac{hc}{2\lambda} - \phi$ .... (2) × 3

$$\frac{3eV_0}{2} = \frac{3hc}{2\lambda} - 3\phi$$

Substracting both the equations, $\phi = \frac{hc}{4\lambda}$

So, $\lambda_{th} = \frac{hc}{\phi} = \frac{hc}{hc/4\lambda} = 4\lambda$

(31) **(D).** Energy of photon (E) = $\frac{12400}{5000} = 2.48\text{ eV}$

Work function $(\phi_0) = 2.28\text{ eV}$

According to Eienstein equation $E = \phi_0 + (K.E.)_{max}$

⇒ $2.48 = 2.28 + (K.E.)_{max} \Rightarrow (K.E.)_{max} = 0.20\text{ eV}$

For electron $\lambda = \frac{h}{\sqrt{2mE}} \approx 28\text{Å}$. So, $\geq 2.8\times10^{-9}$ m

(32) **(B).** $KE_1 = \frac{hc}{\lambda} - \phi$; $KE_2 = \frac{hc}{\lambda/2} - \phi = \frac{2hc}{\lambda} - \phi$

$$KE_2 = 3KE_1 \Rightarrow \frac{2hc}{\lambda} - \phi = 3\left(\frac{hc}{\lambda} - \phi\right)$$

$$\Rightarrow\ 2\phi = \frac{hc}{\lambda} \Rightarrow\ \phi = \frac{hc}{2\lambda}$$

(33) **(A).** $\lambda_e = \frac{h}{\sqrt{2mE}},\ \lambda_p = \frac{hc}{E},\ E = \frac{hc}{\lambda_p}$

$$\frac{\lambda_e}{\lambda_p} = \frac{h}{\sqrt{2mE}}\,\frac{E}{hc} = \frac{1}{c}\sqrt{\frac{E}{2m}}$$

(34) **(D).** **Case I :** $eV = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$ .... (1)

Case II : $e\frac{V}{4} = \frac{hc}{2\lambda} - \frac{hc}{\lambda_0} \Rightarrow eV = \frac{4hc}{2\lambda} - \frac{4hc}{\lambda_0}$ .... (2)

Eq. (1) – eq. (2)

$$\frac{hc}{\lambda} - \frac{2hc}{\lambda} = -\frac{4hc}{\lambda_0} + \frac{hc}{\lambda_0} \Rightarrow \frac{hc}{\lambda} = \frac{3hc}{\lambda_0} \Rightarrow \lambda_0 = 3\lambda$$

(35) **(A).** Momentum, $P = \frac{h}{\lambda} \Rightarrow E = \frac{p^2}{2m} \Rightarrow \frac{h^2}{2m\lambda^2} = \frac{hc}{\lambda_0}$

$$\Rightarrow\ \lambda_0 = \frac{hc}{h^2}2m\lambda^2 = \frac{2mc\lambda^2}{h}$$

(36) **(D).** $E_{max} = E - \phi$

$2\text{ eV} = 5\text{ eV} - \phi \Rightarrow \phi = 3\text{ eV}$

Now $eV_0 = E' - \phi = 6\text{ eV} - 3\text{ eV} = 3\text{ eV}$

So, stopping potential is –3V.

(37) **(A).** Kinetic energy of thermal neutron with equilibrium is $\frac{3}{2}KT$

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mK.E.}} = \frac{h}{\sqrt{2m\left(\frac{3}{2}KT\right)}} = \frac{h}{\sqrt{3mKT}}$$

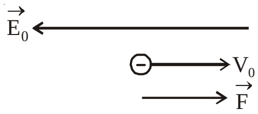
(38) **(A).** $\lambda_0 = 3250$ Å, $\lambda = 2356$ Å

$$\frac{1}{2}mv^2 = hc\left[\frac{1}{\lambda}-\frac{1}{\lambda_0}\right] \; ; \; v = \sqrt{\frac{2hc}{m}\left[\frac{1}{\lambda}-\frac{1}{\lambda_0}\right]}$$

$$= \sqrt{\frac{2\times 12400\times 1.6\times 10^{-19}}{9.1\times 10^{-31}}\left[\frac{714}{2536\times 3250}\right]}$$

$= 0.6 \times 10^6$ m/s $= 6 \times 10^5$ m/s

(39) **(C).** Initial de-Broglie wavelength



Acceleration of electron, $a = \frac{eE_0}{m}$

Velocity after time 't': $V = \left(V_0 + \frac{eE_0}{m}t\right)$

$$\text{So, } \lambda = \frac{h}{mV} = \frac{h}{m\left(V_0 + \frac{eE_0}{m}t\right)}$$

$$= \frac{h}{mV_0\left[1+\frac{eE_0}{mV_0}t\right]} = \frac{\lambda_0}{1+\frac{eE_0}{mV_0}t}$$

(40) **(C).** $E = W_0 + \frac{1}{2}mv^2 \; ; \; h(2\nu_0) = h\nu_0 + \frac{1}{2}mv_1^2$

$h\nu_0 = \frac{1}{2}mv_1^2$ ..... (i)

$h(5\nu_0) = h\nu_0 + \frac{1}{2}mv_2^2 \; ; \; 4h\nu_0 = \frac{1}{2}mv_2^2$ ..... (ii)

Divide (i) by (ii), $\frac{1}{4} = \frac{v_1^2}{v_2^2} \; ; \; \frac{v_1}{v_2} = \frac{1}{2}$

(41) **(B).** For an electron accelerated through a potential V.

$$\lambda = \frac{12.27}{\sqrt{V}}\text{Å} = \frac{12.27\times 10^{-10}}{\sqrt{10000}} = 12.27\times 10^{-12}\text{ m}$$

PART-B (ATOMS AND NUCLEI)

(1) **(A).** KE = –TE = 3.4 eV

(2) **(C).** ${}_1^2H$ and ${}_1^3H$ requires a and b amount of energies for their nucleons to be separated.

${}_2^4He$ releases c amount of energy in its formation i.e., in assembling the nucelons as nucleus.
Hence, energy released = c – (a + b) = c – a – b

(3) **(A).** Isotones mens equal number of neutrons i.e., (A – Z) = 74 – 34 = 71 – 31 = 40

(4) **(D).** B.E. per nucleon is smaller for lighter as well as heavier nucleus. But fusion reaction occurs for small mass number nuclei and fission reaction occurs for larger mass number nuclei to attain reaction binding energy per nucleon.

(5) **(C).** Binding energy per nucleon for fission products is higher relative to binding energy per nucleon for parent nucleus, i.e., more masses are lost and are obtained as kinetic energy of fission products.
So, the given ratio < 1.

(6) **(A).** Energy of ground state 13.6eV

Energy of first excited state $= -\frac{13.6}{4} = -3.4\text{eV}$

Energy of second excited state $= -\frac{13.6}{9} = -1.5\text{eV}$

Difference between ground state and 2nd excited state = 13.6 – 1.5 = 12.1 eV
Electron can be excited upto 3rd orbital
No. of possible transition $1 \to 2, 1 \to 3, 2 \to 3$
So, three lines are possible.

(7) **(A).** ${}_1D^2 \longrightarrow {}_2He^4$
Energy released = 28 – 2 × 2.2 = 23.6MeV
(Binding energy is energy released on formation of Nucleus)

(8) **(D).** Let at time t_1 and t_2, no. of particles be N_1 and N_2.

So, $R_1 = \frac{dN_1}{dt} = -\lambda N_1 \; ; \; R_2 = \frac{dN_2}{dt} = -\lambda N_2$

$$\frac{R_1}{R_2} = \frac{\lambda N_1}{\lambda N_2} = \frac{N_1}{N_1 e^{-\lambda(t_2 - t_1)}}$$

(9) **(C).** $R = R_0 A^{1/3}$.
For berellium, $R_1 = R_0 (9)^{1/3}$.
For germanium, $R_2 = R_0 A^{1/3}$.

$$\frac{R_1}{R_2} = \frac{(9)^{1/3}}{(A)^{1/3}} \Rightarrow \frac{1}{2} = \frac{(9)^{1/3}}{(A)^{1/3}} \Rightarrow \frac{1}{8} = \frac{9}{A}$$

$\Rightarrow A = 8 \times 9 = 72$

(10) **(D).** Energy in the first excited state

$$= \frac{-13.6}{n^2} = \frac{-13.6}{2^2} = -3.4\text{eV}$$

But K.E. = – (Total energy) = + 3.4 eV.

(11) **(A).** In beta minus decay (β^-), a neutron is transformed into a proton, and an electron is emitted from the nucleus along with antineutrino. $n = p + e^- + \bar{\nu}$

(12) **(A).** The difference in mass of a nucleus and its constituents, Δm is called the mass defect and is given by
$\Delta M = [ZM_p + (A - Z)M_n] - M$
and binding energy $= \Delta Mc^2$
$= [\{ZM_p + (A - Z)M_n\} - M]c^2$

(13) **(D).** $R = R_0 A^{1/3}$

For $^{27}_{13}Al$, $R_1 = R_0 (27)^{1/3} = 3R_0$

For $^{125}_{32}Te$, $R_2 = R_0 (125)^{1/3} = 5R_0$

$$\frac{R_2}{R_1} = \frac{5R_0}{3R_0};\ R_2 = \frac{5}{3}R_1 = \frac{5}{3} \times 3.6 = 6 \text{ fm.}$$

(14) **(C).** $N = N_0 e^{-\lambda t}$

$$\frac{N_A}{N_B} = \frac{e^{-5\lambda t}}{e^{-\lambda t}} = \left(\frac{1}{e}\right)^2;\ \left(\frac{1}{e}\right)^2 = e^{-4\lambda t} = \left(\frac{1}{e}\right)^{4\lambda t}$$

$\Rightarrow 4\lambda t = 2 \ \therefore\ t = 1/2\lambda$

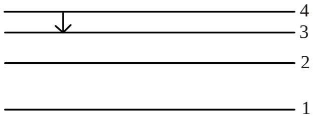
(15) **(D).** $E_1 = -13.6 \text{ eV};\ E_2 = \frac{-13.6}{4}\text{eV}$

$\Delta E = E_2 - E_1 = 10.2 \text{ eV}$

(16) **(D).** $\frac{N_1}{N_2} = \frac{1}{e} = \frac{e^{-5\lambda t}}{e^{-\lambda t}} = e^{-4\lambda t}\ \ \therefore\ 1 = 4\lambda t \text{ or } t = 1/4\lambda$

(17) **(A).** $\frac{1}{2}mv^2 = \frac{k\,z_1 z_2}{r}$

(18) **(C).** $\frac{n\,(n-1)}{2} = 6$



$n^2 - n - 12 = 0$

$(n-4)(n+3) = 0$ or $n = 4$

For maximum wavelength ΔE should be minimum.

(19) **(C).** $_ZX^A \to {}_2\alpha^4 + 2\,{}_{-1}\beta^0 + {}_ZY^{A-4}$

(20) **(D).** $^{A}_{Z}X \longrightarrow {}^{A}_{Z+1}Y : \beta,$

$^{A}_{Z+1}Y \longrightarrow {}^{A-4}_{Z-1}B^* \longrightarrow {}^{A-4}_{Z-1}B : \alpha$

$^{A-4}_{Z-1}B^* \longrightarrow {}^{A-4}_{Z-1}B : \gamma$

(21) **(A).** Energy of an hydrogen like atom like He^+ in an n^{th} orbit is given by $E_n = -\frac{13.6Z^2}{n^2}\text{eV}$

For He^+ ion, Z = 2

For first excited state, n = 2

$$\therefore\ E_2 = -\frac{4\,(13.6)}{(2)^2}\text{eV} = -13.6\text{eV}$$

(22) **(D).** According to activity law

$R = R_0 e^{-\lambda t}$ ...(i)

where, R_0 = initial activity at t = 0

R = activity at time t, λ = decay constant

$R_0 = N_0$ counts per minute

$R = N_0/e$ counts per minute, t = 5 minutes

Substituting these values in equation (i), we get

$$\frac{N_0}{e} = N_0 e^{-5\lambda};\ e^{-1} = e^{-5\lambda}$$

$5\lambda = 1$ or $\lambda = 1/5$ per minute

At $t = T_{1/2} = \frac{\ln 2}{\lambda}$,

The activity R reduces to $R_0/2$.

$$T_{1/2} = \frac{\log_e 2}{\lambda} = \frac{\log_e 2}{(1/5)} = 5\log_e 2 \text{ min.}$$

(23) **(B).** For ^7_3Li nucleus, Mass defect, $\Delta M = 0.042$ u

$\therefore$ $1u = 931.5 \text{ MeV}/c^2$

$\therefore$ $\Delta M = 0.042 \times 931.5 \text{ MeV}/c^2 = 39.1 \text{ MeV}/c^2$

Binding energy,

$$E_b = \Delta Mc^2 = \left(39.1\frac{\text{MeV}}{c^2}\right)c^2 = 39.1 \text{ MeV}$$

Binding energy per nucleon,

$$E_{bn} = \frac{E_b}{A} = \frac{39.1\text{MeV}}{7} = 5.6 \text{ MeV}$$

(24) **(C).** $E = \frac{(\text{momentum})^2}{2M} = \frac{\left(\frac{h\nu}{c}\right)^2}{2M}$

(25) **(A).** $\left(1 - \frac{1}{4}\right) = z^2\left[\frac{1}{4} - \frac{1}{16}\right]\ \ \therefore\ z = 2$

(26) **(C).** After t second fractional amount of X left is $\frac{1}{16}$ or $\left(\frac{1}{2}\right)^4$ $\therefore t = 4 \times T_{1/2};\ t = 4 \times 50 = 200$ years

(27) **(D).** Fusion reaction takes place at high temperature because kinetic energy is high enough to overcome the coulomb repulsion between nuclei.

(28) **(D).** α emission decreases mass number by 4 and atomic number by 2.

Two β^- emission increases atomic number by two but leaves mass number unchanged.

(29) **(B).** Initially $P \to 4N_0$, $Q \to N_0$

Half life $T_P = 1$ min., $T_Q = 2$ min.

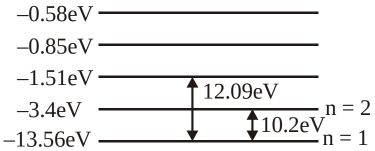
Let after time t number of nuclie of P and Q are equal

that is $\frac{4N_0}{2^{t/1}} = \frac{N_0}{2^{t/2}}$ or $\frac{4}{2^{t/2}} = 1$ or t = 4 min.

so at t = 4 min, $N_p = \frac{(4N_0)}{2^4} = \frac{N_0}{4}$

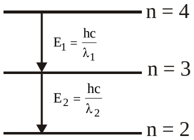
$$\text{Population of R} = \left(4N_0 - \frac{N_0}{4}\right) + \left(N_0 - \frac{N_0}{4}\right) = \frac{9N_0}{2}$$

(30) **(B).**



Difference of 11.1eV is not possible.

(31) **(D).**



$$E = \frac{hc}{\lambda_1} = 13.6\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right] \text{ .... (1)}$$

$$E = \frac{hc}{\lambda_2} = 13.6\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] \text{ .... (2)}$$

Dividing eq. (2) by (1), $\frac{\lambda_1}{\lambda_2} = \frac{\frac{1}{4} - \frac{1}{9}}{\frac{1}{9} - \frac{1}{16}} = \frac{20}{7}$

(32) **(D).** $N_1 = \frac{N_{01}}{(2)^{t/20}}$, $N_2 = \frac{N_{02}}{(2)^{t/10}}$; $N_1 = N_2$

$$\frac{40}{(2)^{t/20}} = \frac{160}{(2)^{t/10}} \;;\; 2^{t/20} = 2^{(t/10-2)}$$

$$\frac{t}{20} = \frac{t}{10} - 2 \;;\; \frac{t}{10} - \frac{t}{20} = 2 \;;\; t = 40$$

(33) **(A).** For emission

$$\frac{1}{\lambda} = Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = R\left(\frac{1}{1^2} - \frac{1}{5^2}\right) = R\left(1 - \frac{1}{25}\right)$$

Linear momentum, $P = \frac{h}{\lambda} = h \times R \times \frac{24}{25}$

$$= mv = \frac{24hR}{25} \;;\; v = \frac{24hR}{25m}$$

(34) **(D).** For infrared λ high ∴ ΔE should be low.

(35) **(B).** $N_1 = N_0 e^{-\lambda t}$; $N_1 = \frac{1}{3}N_0$

$$\frac{N_0}{3} = N_0 e^{-\lambda t_2} \quad \text{...... (1)}$$

$$N_2 = \frac{2}{3}N_0 \;;\; \frac{2}{3}N_0 = N_0 e^{-\lambda t_1} \quad \text{...... (2)}$$

From eq. (1) and (2)

$$\frac{1}{2} = e^{-\lambda(t_2 - t_1)} \;;\; \lambda(t_2 - t_1) = \ln 2$$

$$t_2 - t_1 = \frac{\ln 2}{\lambda} = T_{1/2} = 50 \text{ days}$$

(36) **(D).** Energy released per u $= \left(\frac{0.02866}{4}\right)$ (931 MeV)

$= 6.675$ MeV

(37) **(C).** $\underset{N_x}{X} \xrightarrow{\hspace{2cm}} \underset{N_y}{Y}$ (stable)

$$\frac{N_x}{N_y} = \frac{1}{7} \Rightarrow \frac{N_x}{N_x + N_y} = \frac{N}{N_0} = \frac{1}{8}$$

By using $N = N_0 e^{-\lambda t}$ we have

$$\frac{N_0}{8} = N_0 e^{-\lambda t} \Rightarrow t = 3 \times 20 = 60 \text{ years}$$

(38) **(B).** $\left(\frac{\lambda_{Lyman}}{\lambda_{Balmer}}\right)_{max} = \frac{\left(\frac{1}{2^2} - \frac{1}{3^2}\right)}{\left(\frac{1}{1^2} - \frac{1}{2^2}\right)} = \frac{5/36}{3/4} = \frac{5}{27}$

(39) **(C).** Energy incident

$$= \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{975 \times 10^{-10} \times 1.6 \times 10^{-19}} \text{eV} = 12.75 \text{ eV}$$

The Hydrogen atom will be excited to n = 4

Number of spectral lines $= \frac{4(4-1)}{2} = 6$

(40) **(D).** Q = 2 (BE of He) – (BE of Li)

$= 2 \times (4 \times 7.06) - (7 \times 5.60) = 56.48 - 39.2 = 17.3$ MeV

(41) **(C).** X : Y = 1 : 7 ; X : (X + Y) = 1 : 8 = 1 : $2^3 \Rightarrow$ 3 half life

∴ $\Delta T = 3 \times 1.4 \times 10^9$ yrs $= 4.2 \times 10^9$ yrs.

(42) **(A).** $R = R_0 (A)^{1/3}$; $R_{Al} = R_0 (27)^{1/3} = 3R_0$

$$R_{Te} = R_0 (125)^{1/3} = 5R_0 = \frac{5}{3}R_{Al}$$

(43) **(A).** $V = (2.19 \times 10^6 \text{ m/sec})\ (Z/n)$

$= (2.19 \times 10^6 \text{ m/sec})\ (2/3) = 1.46 \times 10^6$ m/s

(44) **(A).** For Lyman series

$$\left(\frac{1}{\lambda_{max}}\right)_L = R\,(1)^2\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right] \;;\; (\lambda_{max})_L = \frac{4}{3R}$$

For Balmer series

$$\left(\frac{1}{\lambda_{max}}\right)_B = R\,(1)^2\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right] \;;\; (\lambda_{max})_B = \frac{36}{5R}$$

$$\frac{(\lambda_{max})_L}{(\lambda_{max})_B} = \frac{4}{3R} \times \frac{5R}{36} = \frac{5}{27}$$

(45) **(B).** By Conservation of linear momentum: $p_f = p_i = 0$

$$p_{He} - p_{Th} = 0 \Rightarrow p_{He} = p_{Th}$$

But $K \propto \frac{1}{m}$ and $m_{He} < m_{Th.}$ So, $K_{He} > K_{Th}$

(46) **(C).** $R_H = 10^7 m^{-1}$. Last line $n_2 = \infty$, $n_1 = 2$

$$\frac{1}{\lambda} = R\left(\frac{1}{4}\right) = 0.25 \times 10^7 \text{ m}^{-1}$$

(47) **(C).** $\lambda = \frac{1}{R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)}$; $\lambda' = \frac{1}{R\left(\frac{1}{3^2} - \frac{1}{4^2}\right)}$

$$\frac{\lambda'}{\lambda}=\frac{\left(\frac{1}{2^2}-\frac{1}{3^2}\right)}{\left(\frac{1}{3^2}-\frac{1}{4^2}\right)}\Rightarrow \lambda'=\frac{20\lambda}{7}$$

(48) **(D).** Number of active nuclei falls from 60% to 15%.

So sample becomes $\frac{1}{4}$th $=\frac{1}{2^2}$th

So, number of half-lives = 2. Time t = 2 × 30 = 60 min.

(49) **(A).** $\lambda_A=8\lambda\,,\ \lambda_B=\lambda$

$$N_B=\frac{N_A}{e}\Rightarrow\ N_0e^{-\lambda t}=\frac{N_0e^{-8\lambda t}}{e}$$

$$-\lambda t=-8\lambda t-1\Rightarrow 7\lambda t=-1\Rightarrow t=-\frac{1}{7\lambda}$$

Best answer is t = 1/7λ

(50) **(B).** For last line of Balmer : $n_1=2$ & $n_2=\infty$

$$\frac{1}{\lambda_B}=RZ^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]=R\,(1)^2\left[\frac{1}{2^2}-\frac{1}{\infty^2}\right]\ ;\ \lambda_B=\frac{4}{R}\ .....(1)$$

For last line of Lyman series: $n_1=1$ & $n_2=\infty$

$$\frac{1}{\lambda_L}=RZ^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]=R\,(1)^2\left[\frac{1}{1^2}-\frac{1}{\infty^2}\right]$$

$$\lambda_L=\frac{1}{R}\qquad ....(2)\ ;\ \frac{\lambda_B}{\lambda_L}=\frac{4/R}{1/R}=4$$

(51) **(B).** KE = – (total energy)

So, Kinetic energy : total energy = 1 : –1

(52) **(C).** Number of nuclei remaining = 600–450 = 150

$$\frac{N}{N_0}=\left(\frac{1}{2}\right)^n\ ;\ \frac{150}{600}=\left(\frac{1}{2}\right)^{\frac{1}{t_{1/2}}}\ ;\ \left(\frac{1}{2}\right)^2=\left(\frac{1}{2}\right)^{\frac{1}{t_{1/2}}}$$

$t=2t_{1/2}=2\times 10=20$ minute

(53) **(C).** In Bohr's model of H atom

$$\text{K.E.}=|\text{TE}|=\frac{|U|}{2}=3.4\ \text{eV}$$

$U=-6.8$ eV

(54) **(A).** α-particle is nucleus of Helium which has two protons and two neutrons.