Electron Emission:

Metals have free electrons and these normally cannot escape out of the metal surface.

The free electron is held inside the metal surface by the attractive forces of the ions.

A certain minimum amount of energy is required to be given to an electron to pull it out from the surface of the metal and this energy is known as "Work Function".

Work function $(\phi) = 5.65\text{eV}$, highest (for platinum)

$\phi = 1.88\text{eV}$, lowest (for cesium)

This minimum energy required for the electron emission can be supplied by any one of the following processes.

(a) Thermionic emission: "Sufficient thermal energy can be imparted to free electrons" by suitably heating

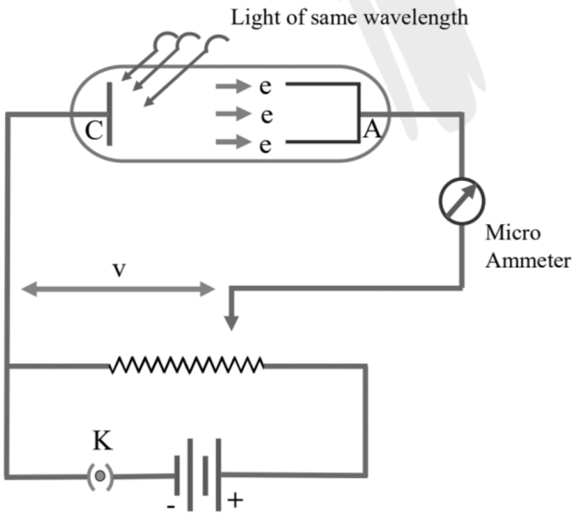
(b) Field emission: "By applying a very strong electric field $(\approx 10^8 \text{V/m})$".

(c) Photo electric emission: "By irradiating the metal surface with suitable E.M radiation".

Photoelectric effect:

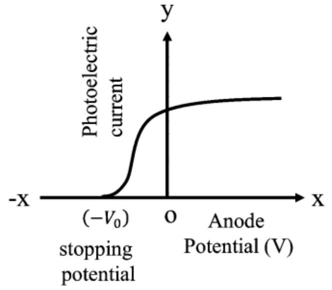
- The photoelectric effect, first discovered by Hertz in 1887, revealed that high voltage sparks pass more easily through illuminated cathodes. Hallwachs expanded on this, finding that zinc plates exposed to ultraviolet light became positively charged, with further illumination increasing the positive charge. These observations led to the understanding that ultraviolet light triggers the emission of negatively charged particles, later named photoelectrons, from the zinc plate. The phenomenon of electrons being released from a metal plate by electromagnetic radiation of the right wavelength became known as the photoelectric effect.

Lenard's Experimental Study of Photoelectric effect:

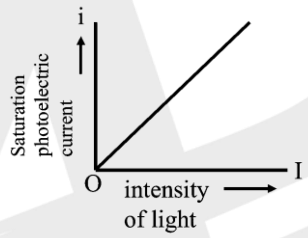


The work done by the stopping potential is equal to the maximum kinetic energy of the electron$(-e)(-V_0) = \frac{1}{2}mv_{max}^2$

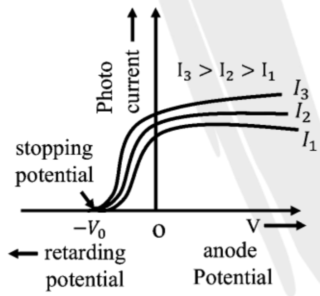
- A graph is plotted with current on y-axis and applied voltage on x-axis. It is as shown in below graph



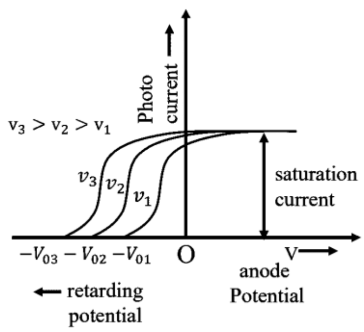
- **Variation of Photocurrent with intensity of incident light:** Keeping the frequency of incident light and nature of the cathode constant, for different intensities of incident light saturation photocurrent is measured.
  When a graph is plotted with saturation photocurrent on y-axis and intensity of incident light on x-axis, it is as shown in figure.



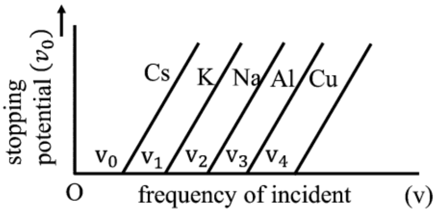
- **Variation of saturation photocurrent with stopping potential at constant intensity:**
  Keeping the frequency of incident light and nature of the cathode constant, for different intensities of incident light photocurrent is measured. When a graph is plotted with photocurrent on y-axis and applied voltage on x-axis. It is as shown in figure.



- **Variation of frequency of incident light on stopping potential:**
  Keeping the intensity of incident light and nature of the cathode constant, for different frequencies of incident light, photocurrent is measured. When a graph is plotted with photocurrent on y-axis and applied voltage on x-axis. It is as shown in figure.



- **Variation of Stopping potential with frequency of incident light:**
  When a graph is plotted with stopping potential on y-axis and frequency of incident radiation on x-axis, keeping the metal constant, then it is as shown in figure.



LAWS OF PHOTOELECTRIC EFFECT:

- Below a certain threshold frequency, electrons are not emitted from a metal surface, regardless of the intensity of the incident radiation.
- The maximum kinetic energy of photoelectrons depends linearly on the frequency of the incident radiation but is unaffected by its intensity.
- The maximum kinetic energy of photoelectrons is directly proportional to the frequency of the incident radiation. Additionally, the saturation photocurrent increases with the intensity of the incident radiation but remains independent of its frequency. Moreover, there is no time delay between the incidence of the radiation and the emission of photoelectrons.

QUANTUM THEORY OF LIGHT:

A photon is a packet of energy, given by $E = h\nu$ where $h = 6.62 \times 10^{-34}$ Js
(Where Planck's constant, $h = 6.62 \times 10^{-34}$ Js $= 4.14 \times 10^{-15}$ eVs)
v = frequency of the wave associated with photon then $C = \nu\lambda$
$C = 3 \times 10^8 \, ms^{-1}$ = velocity of light
λ = wavelength of the wave associated with photon $\therefore E = h\nu = \dfrac{hC}{\lambda}$

INTENSITY

- Intensity (I) of radiation at a given point is the energy transmitted through unit area in unit time. Intensity (I) of a radiation at a distance 'r' from a monochromatic source of power 'P' is, $I = \dfrac{P}{4\pi r^2}$.
  If 'N' photons are emitted in time 't' by a monochromatic source of power 'P' then $P = \dfrac{Nh\nu}{t} = \dfrac{NhC}{\lambda t}$.
  So increase in intensity of monochromatic radiation means increases in the number of photons incident on unit area in unit time.

EINSTEIN'S PHOTOELECTRIC EQUATION:

- When a photon of energy hν is absorbed by an electron, an amount of energy at least equal to work function W (provided $h\nu > W$) is used up in liberating the electron from the surface and the difference $(h\nu - W)$ is equal to the maximum kinetic energy of that electron.

$$\therefore \frac{1}{2} m V_{max}^2 = h\nu - W \quad \text{... (1)}$$

$$\therefore \quad h\nu = W + \frac{1}{2} m V_{max}^2 \quad \text{... (2)}$$

$$\therefore h\nu = h\nu_0 + \frac{1}{2} m V_{max}^2 \quad \text{... (3)}$$

Photo electric cells:-

- A device which converts light energy into electrical energy is known as a photo electric cell or photocell.
- It is a technological application of the photo electric effect.
- It is a device whose electrical properties are affected by light.
- There are three types of photo cells.

  (1) Photo emissive cells (2) Photo voltaic cells (3) Photo conductive cells.
- Photo emissive cells depend upon outer photoelectric effect whereas photo voltaic and photo conductive cells depend upon inner photoelectric effect.
- Photo emissive cells are of two types.

  1. Vacuum type and 2. Gas filled type

DUAL NATURE OF MATTER - (de-BROGLIE HYPOTHESIS):

- Photoelectric effect and Compton effect proves that radiation behaves like particles (photons), where as Interference and Diffraction proves that radiation behaves like waves.

  So 'radiation has dual nature' i.e., radiation behaves like particles when interacting with matter and radiation behaves like waves when propagating in a medium.

de Broglie Hypothesis

- According to de Broglie particles like electron, proton and neutron, also have both wave and particle properties. The waves associated with moving particle are called matter waves and the wavelength is called the de Broglie wavelength of a particle.

  For a photon Energy, $E = \frac{hc}{\lambda} = mc^2$

  where m = effective mass then wavelength $\lambda = \frac{h}{mc} = \frac{h}{p}$

  where p = momentum of the photon.

  de Broglie extended the same for particles also. So if a particle of mass 'm' is moving with velocity ''v' then its momentum p = mv, hence de Broglie wavelength of the matter wave associated with is given by = $\lambda = \frac{h}{p} = \frac{h}{mv}$

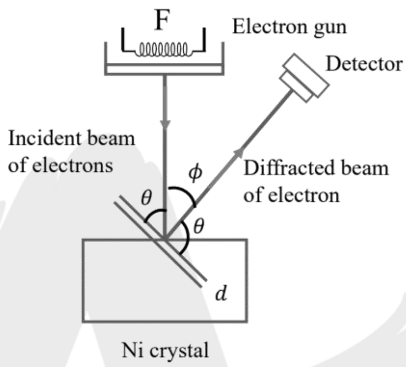
  Davisson and Germer studied the scattering of electrons by a nickel target. The wavelength of diffracted electrons was determined by Davisson and Germer. The experimental values of wavelength λ were found to agree with the theoretical value $\lambda = \frac{h}{mv}$

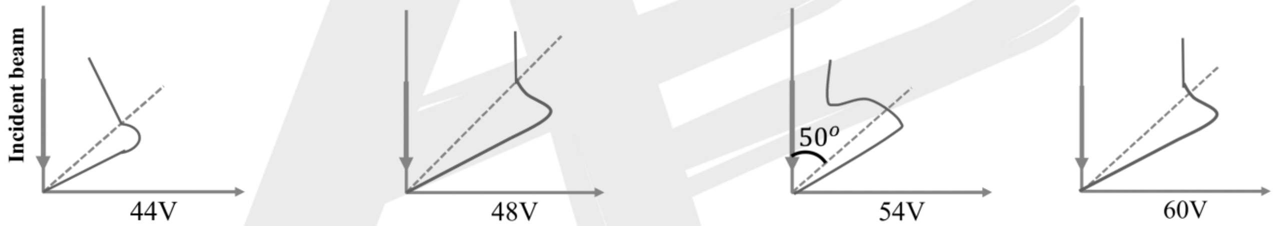
  Hence it is concluded that electrons behaves like waves and undergo diffraction.
- For definite sized objects like a car the corresponding wavelength is very small to detect the wave properties. But the de-Broglie wavelength of the electron is large enough to be observed. Because of their small mass, electrons have a small momentum and hence large wavelength $\lambda = h/p$.

HEISENBERG UNCERTAINTY PRINCIPLE

- The matter-wave picture elegantly incorporated the Heisenberg's uncertainty principle. According to the principle, it is not possible to measure both the position and momentum of an electron (or another particle) at the same time exactly. There is always some uncertainty (Δx) in the specification of position and some uncertainty (Δp)in the specification of momentum. The product of Δx and Δp is of the order of h (with $\hbar = \frac{h}{2\pi}$)i.e., $\Delta x \Delta p = h$

Davisson And Germer's Electron Diffraction Experiment





- If the de Broglie waves are associated with electron, then these should be diffracted like x-rays. Using the Bragg's formula $2d\sin\theta = n\lambda$, we can determine the wavelength of these waves.

  Where 'd' is the distance between the diffracting planes. $\theta = \left[\frac{180-\phi}{2}\right]$ = glancing angle for incident beam = Bragg's angle.

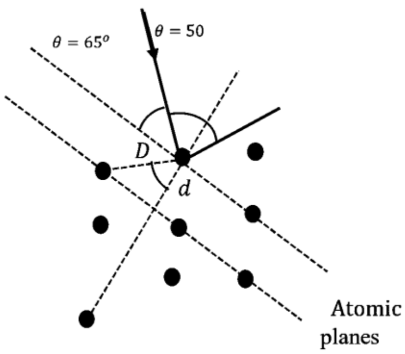
- The distance between diffracting planes in Ni – crystal for this experiment is $d = 0.91\overset{o}{A}$ and for n=1; $\lambda = 2 \times 0.91 \times 10^{-10} \sin 6\,5 = 1.65\overset{o}{A}$

  Now de Broglie wavelength can also be determined using the formula;

$$\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{54}} = 16.7\overset{o}{A}$$

Thus the de Broglie hypothesis is verified.

(x) The Bragg's formula can be rewritten in the form containing inter atomic distance D and scattering angle 'ϕ'



$\therefore \theta = 90 - \frac{\phi}{2}$ and $d = D\cos\theta = D\sin\frac{\phi}{2}$

using $\sin\theta = \cos\frac{\phi}{2}$ or $\lambda = 2d\sin\theta = 2d\left(\sin\frac{\phi}{2}\right)\cos\frac{\phi}{2} = d\sin\phi$

$$\boxed{\lambda = d\sin\phi}$$

X-RAYS:

Roentgen discovered the X-rays.

(i) Most commonly x-rays are produced by the deceleration of high energy electrons bombarding a hard metal target.

(ii) The target should have

(a) high atomic weight

(b) high melting point

(c) high thermal conductivity

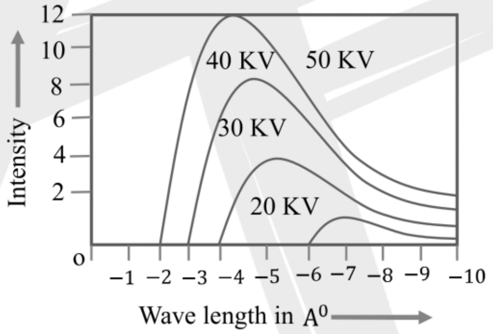
(iii) They are electromagnetic waves of very short wavelength. i.e., order of wavelength $0.1A^{o}$ to $100A^{o}$, order of frequency $10^{16}Hz$ to $10^{19}Hz$, order of energy 124eV to 124 keV

(iv) Most of the kinetic energy of electrons is converted into heat and only a fraction is used in producing x-rays (less than 1% x - rays and more than 99% heat).

X-RAY SPECTRUM

(i) Continuous X-ray spectrum:

It is produced when high speed electrons are suddenly stopped by a metal target.



$$\boxed{\lambda_{min} = \frac{hc}{eV} = \frac{12400}{V}\overset{o}{A}}$$

$\therefore \lambda_{min} \alpha \frac{1}{V}$ it is Duane and Hunt's law

Maximum frequency of emitted x- ray photon is

$$\boxed{\nu_{max} = \frac{eV}{h}}$$

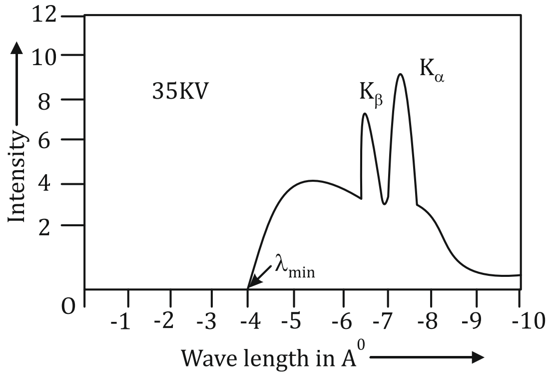
Efficiency of x- ray tube

$$\eta = \frac{\text{out put power}}{\text{input power}} \times 100$$

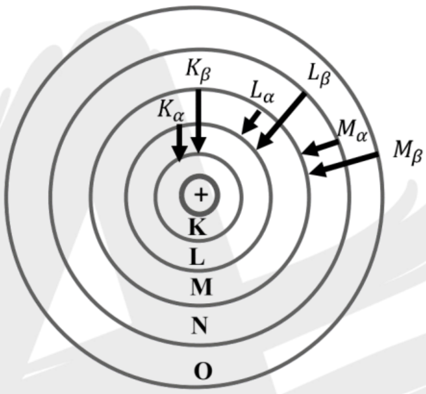
Input power $P = VI$.

Where V is P.D applied to x-ray tube I = anode current.

(ii) Characteristic X-ray spectrum:



Produced due to transition of electrons from higher energy level to lower energy level in target atoms



(f) Relation among the energies $E_{k\alpha} < E_{k\beta} < E_{k\gamma}$, $E_{k\alpha} > E_{L\alpha}$

(g) Intensity of x-rays $I_{k\alpha} > I_{k\beta} > I_{k\gamma}$

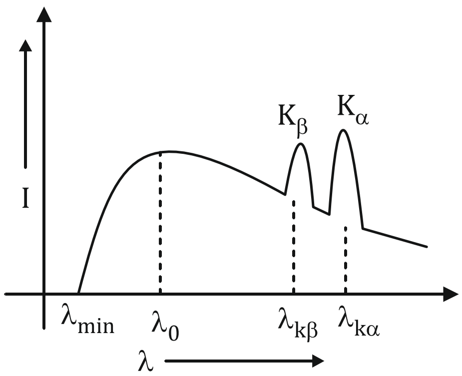
(h) Relation among frequencies $\nu_{k\alpha}, \nu_{k\beta}$ and $\nu_{L\alpha}$ is

$$\nu_{K\beta} = \nu_{k\alpha} + \nu_{L\alpha} \Rightarrow \frac{1}{\lambda_{K\beta}} = \frac{1}{\lambda_{K\alpha}} + \frac{1}{\lambda_{L\alpha}}$$

(h) $E_K - E_L = h\nu_{K\alpha} = \dfrac{hc}{\lambda_{K\alpha}}$ or $E_K - E_M = h\nu_{K\beta} = \dfrac{he}{\lambda_{K\beta}}$

$$E_L - E_M = h\nu_{L\alpha} = \frac{he}{\lambda_{K\alpha}}$$

(iii) Intensity and wavelength $(I-\lambda)$ graph



As target potential V is increased

(a) $(\lambda_0 - \lambda_{min}())$ decreases

(b) Wavelength of k_α remains constant.

(c) difference between λ_{k_α} and λ_{min} increases

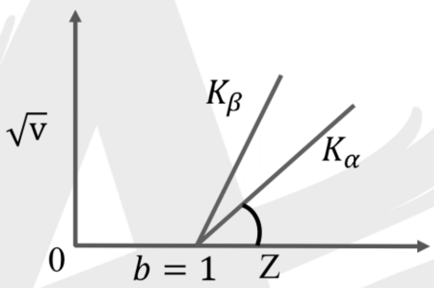
(d) difference between λ_{k_α} line and λ_{min} line remains constant.

(e) Difference between $\lambda_{k\alpha} - \lambda_0$ increases.

MOSELEY'S LAW

(1) "The square root of frequency (v) of the spectral line of the characteristic x-rays spectrum is directly proportional to the atomic number(z) of the target element.

$\sqrt{v} \propto Z$ or $\sqrt{v} \propto a(Z-b)$



(ii) The slope (a) of $\sqrt{v}$ - Z curve varies from series to series and also from line to line of a given series.

For K series

$$\sqrt{\frac{v_1}{v_2}} = \left(\frac{Z_1 - 1}{Z_2 - 1}\right)$$

$$\Rightarrow \sqrt{\frac{\lambda_2}{\lambda_1}} = \left(\frac{Z_1 - 1}{Z_2 - 1}\right)$$

(2) $a_{k\gamma} > a_{k\beta} > a_{k\alpha}$

(3) The intercept on 'Z' axis gives the screening constant 'b' and it is constant for all spectral lines in given series but varies with the series.

$b = 1$ for k series $(k_\alpha, k_\beta, k_\gamma)$

$b = 7.4$ for L series

(4) The wavelength of characteristic X-rays is given by

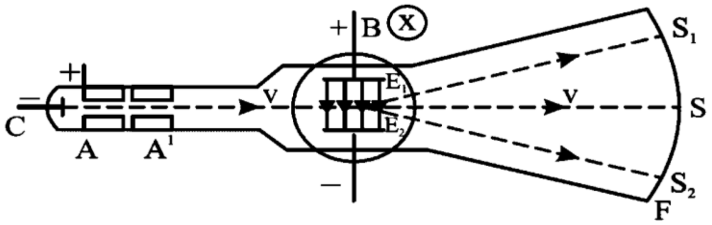
$$\frac{1}{\lambda} = R(Z-b)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

(5) Ratio of wavelengths k_α and k_β lines from a given target is

$$\frac{\lambda_{k\alpha}}{\lambda_{k\beta}} = \frac{32}{27}$$

J.J. Thomson's experimental determination of specific charge of an electron:

- Cathode rays can move undeflected through mutually perpendicular electric and magnetic fields acting in same region.



- If only electric field is switched on, Electric force on the electron which is vertically upwards is,

  $F_e = eE \rightarrow$ (1)

  Where Electric field $E = \frac{V^1}{d}$

  V^1 = potential difference between the plates E_1 and E_2

  d=distance between the plates E_1 and E_2.

- If only magnetic field is switch on,

  Magnetic force acting on the electron, which is vertically downwards is, $F_m = Bev \rightarrow$ (2)

  Where B = magnetic induction field

  e = charge of electron, v = velocity of electron

- If both electric and magnetic fields are applied simultaneously and the electrons moves undeflected, then magnetic and electric forces acting on the electrons are equal and opposite.

  $\therefore F_m = F_e$ BeV = eE

  $\therefore$ Velocity of electron $v = \frac{E}{B} \rightarrow$ (3)

  As the electron is accelerated from cathode to anode, the work done on the electron by the accelerating voltage is equal to the increase in kinetic energy of the electron, K.E. of electron at anode = work done on the electron

  $\frac{1}{2}mv^2 = eV_0 \rightarrow$ (4); $\therefore \frac{e}{m} = \frac{v^2}{2V_0} \rightarrow$ (5)

  Where V_0 = potential difference between cathode and Anode.

  m = mass of electron, e = charge of electron

  v = velocity of electron.

  substituting equation (3) in (5) we get

  $\frac{e}{m} = \frac{E^2}{2V_0B^2} \rightarrow$ (6)

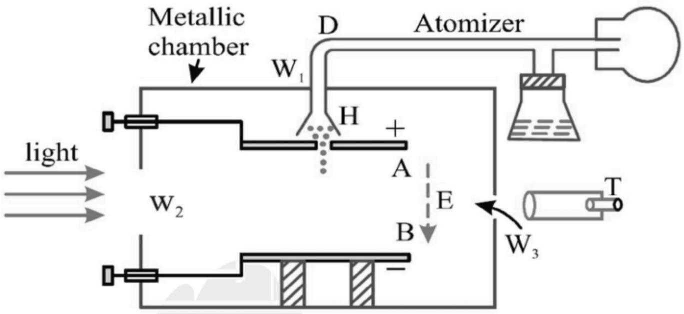
  Since we know E, B and V0, specific charge of electron can be calculated.

  The value of specific charge of electron as measured by J.J. Thomson is $1.7588 \times 10^{11} \mathrm{Ckg}^{-1}$

Determination of charge of an electron:

Millikan's oil drop method. [Additional]

- Millikan's method to find charge of an oil drop is based on the measurement of terminal velocity of the charged oil drop under the action of gravity and under the combined action of gravity and electric field.



- Charge on the drop can be calculated using the formula

$$q = \frac{6\pi\eta\left(V_g + V_e\right)}{E}\left(\frac{9\eta V_g}{2\left(d-d^1\right)g}\right)^{1/2}$$

Where η = coefficient of viscosity of air

d = density of oil; d^1 = density of air

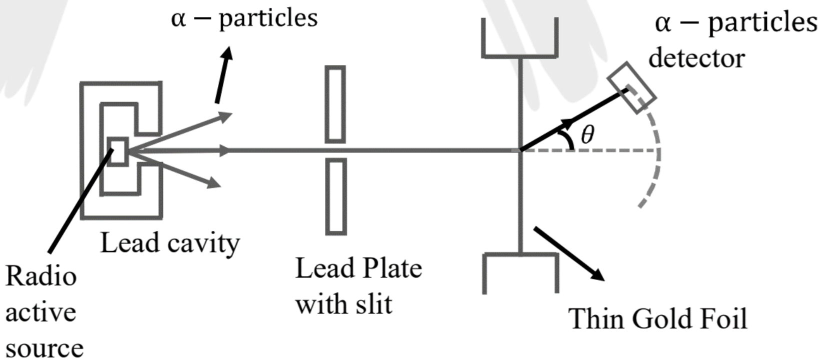
E = Intensity of electric field between the plated

g = acceleration due to gravity.

V_e = terminal velocity of the oil drop in electric field

V_g = terminal velocity of the oil drop in gravitational field

Rutherford's $\alpha-$ particle scattering experiment:

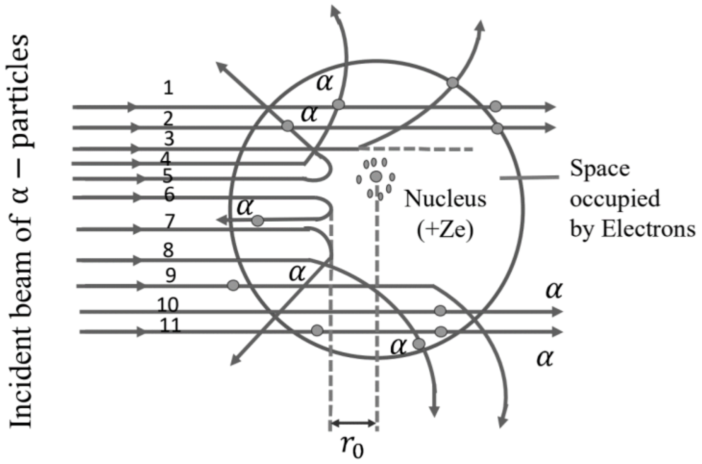


Experimental Observations:

(a) Most of the α-particles were found to pass through the gold- foil without being deviated from their paths.

(b) Some a-particles were found to be deflected through small angles $\theta < 90^\circ$

(c) Few α-particles were found to be scattered at fairly large angles from their initial path $\theta > 90^\circ$



(d) A very small number of a-particles about 1 in 8000 practically retracted their paths or suffered deflections of nearly 180°.

Distance of Closest Approach:

➢ An α -particle which moves straight towards the nucleus in head on direction reaches the nucleus i.e., it moves close to a distance r_0 as shown the figure.

$$r_0 = \frac{1}{4\pi\epsilon_0}\frac{4Ze^2}{m_\alpha {v_\alpha}^2}$$

Note: The number of α -particles scattered at an angle θ is given by $N = \frac{QntZ^2e^4}{(8\pi\varepsilon_0)^2r^2E^2\sin^4\left(\frac{\theta}{2}\right)}$ where

$Q \rightarrow$ Total number of a particles striking the foil

$n \rightarrow$ number of atoms per unit volume of the foil

$r \rightarrow$ distance of screen from the foil

$t \rightarrow$ thickness of the foil

$Z \rightarrow$ Atomic number of atoms of the metal foil

$0 \rightarrow$ angle of scattering

$E \rightarrow$ kinetic energy of a particles

$N\alpha t$; $N\alpha Z^2$; $N\alpha\frac{1}{\sin^4\frac{\theta}{2}}$

$N\alpha\frac{1}{E^2}$ or $N\alpha\frac{1}{\upsilon^4}$

Where v is the velocity of α particles falling on the foil.

Impact Parameter(b):

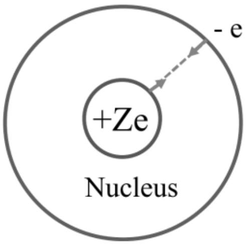
The perpendicular distance of the initial velocity vector of the a.- particle from centre of the nucleus is called "impact parameter".

$$b = \frac{ze^2\cos\left(\frac{\theta}{2}\right)}{4\pi\epsilon_0\times\frac{1}{2}mv^2}$$

Bohr's model of Hydrogen like atoms:

Electron can revolve around the nucleus only in certain allowed orbits called stationary orbits and the

$$\frac{k(Ze)e}{r^2} = \frac{mV^2}{r} \text{ ; where } k = \frac{1}{4\pi\varepsilon_0}$$



➢ **Radius of Bohr's orbit:**

In general, the radius of the nth orbit of a hydrogen like atom is given by $r_n = 0.53\left(\frac{n^2}{Z}\right)\overset{o}{A}$ where $n = 1,2,3, \ldots\ldots (4)$

Velocity of the Electron in the orbit:

The velocity of an electron in n^{th} orbit $V_n = \frac{nh}{2\pi m r_n}$ hence

$$V_n = \frac{2\pi ke^2}{h}.\left(\frac{Z}{n}\right) \qquad \left(\therefore r_n = \frac{n^2h^2}{4\pi^2 kZme^2}\right) \ldots (5)$$

i.e. the velocity of electron in any orbit is independent of the mass of the electron. The above equation can also be written as

$$\therefore V_n = \left(\frac{c}{137}\right).\frac{Z}{n} m/s \quad \ldots (6)$$

Where 'c' is the speed of light in vacuum.

Time period of electron in the orbit:

Angular velocity of electron in n^{th} orbit

$$\omega_n = \frac{V_n}{r_n} = \frac{\omega_0 Z^2}{n^3} \text{ where } \omega_0 = \frac{8\pi^3 k^2 e^4 m}{h^3} \quad \ldots\ldots (7)$$

Is the angular velocity of electron in first Bohr's orbit. The time period of rotation of electron in

$$n^{th} \text{ orbit } T = \frac{2\pi}{\omega_n} = \frac{n^3}{2\pi\omega_0 Z^2} \quad \ldots\ldots. (8)$$

i.e. $T \propto \frac{n^3}{Z^2}$

The time period of rotation increases as n increases and is independent on the mass of the electron.

Energy of the electron in the orbit:

➢ The kinetic energy of the electron revolving around the nucleus in n^{th} orbit is given by

$$K_n = \frac{1}{2}mV^2 = \frac{1}{2}m\left[\frac{2\pi ke^2}{h}.\frac{Z}{n}\right]^2$$

$$K_n = \frac{2\pi^2k^2e^4}{k^2}.\left(\frac{mZ^2}{n^2}\right) \text{..... (9)}; \qquad K_n \alpha \frac{mZ^2}{n^2}$$

If the reference level (zero potential energy level) is at infinity then the electrostatic potential energy is given by

$$U_n = -\frac{k(Ze)e}{r_n} = -kZe^2\left[\frac{4\pi^2kmZe^2}{n^2h^2}\right]$$

$$U_n = -\frac{4\pi^2k^2e^4}{h^2}\left(\frac{mZ^2}{n^2}\right) \text{..... (10)}$$

Total energy of the electron in n^{th} orbit.

$$E_n = K_n + U_n = -\frac{2\pi^2k^2mZ^2e^4}{n^2h^2}$$

$$E_n = -\frac{2\pi^2k^2e^4}{h^2}\left(\frac{mZ^2}{n^2}\right) \text{....... (11)}$$

The expression of total energy for hydrogen like atom may be simplified as

$$E_n = -13.6\frac{Z^2}{n^2}eV, \qquad n = 1,2,3 \text{.... (12)}$$

Where -13.6 eV is the total energy of the electron in the ground state of an hydrogen atom.

From the equations (9),(10)&(11) it is clear that PE: K.E : T.E = -2:1 :-1

i.e., $\frac{PE}{-2} = \frac{KE}{1} = \frac{TE}{-1}$

Emission of radiation:

When an electron jumps from higher energy level n_2 to a lower energy level n_1 in stationary atom, the difference in energy is radiated as a photon whose frequency *v* is given by Planck's formula.

$$E_{n_2} - E_{n_1} = hv$$

(or) $hv = E_2 - E_1 = 13.6Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ e.V

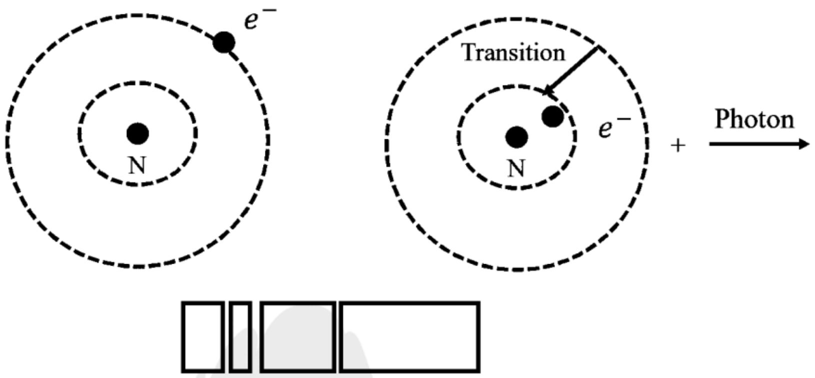
$\left(\therefore E_n = -\frac{13.6Z^2}{n^2}e.V\right)$ since 1eV = 1.6×10^{-19} J

Hence $h\frac{c}{\lambda} = (21.8\times10^{-18})Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ J (or) wave number $v = \frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] m^{-1}$

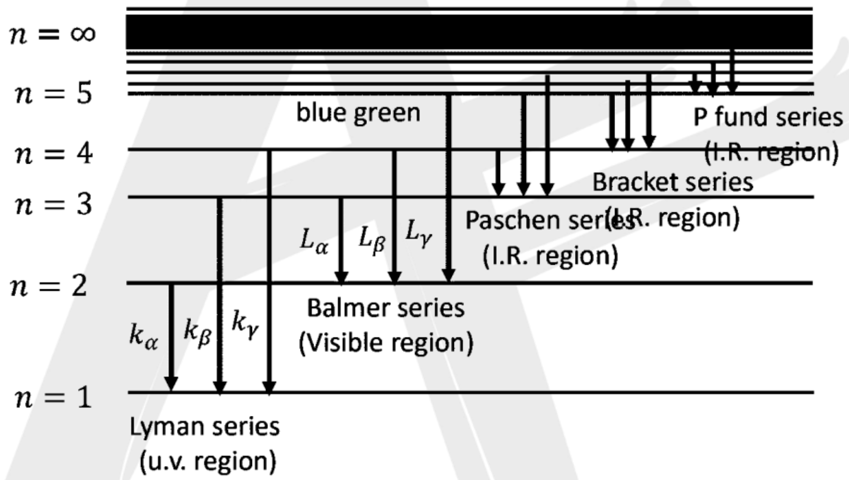
where R is called for "Rydberg constant", when the nucleus is infinitely massive as compared to the revolving electron. In other words, the nucleus is considered to be stationary. The numerical value of R is $1.097\times10^7 m^{-1}$.

Emission Spectrum of Hydrogen atom:

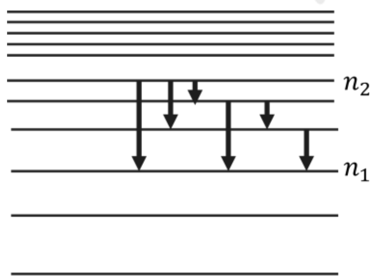
Electron in hydrogen atom, can be in excited state for very small time of the order of 10^{-8} second. Collection of such emitted photon frequencies is called an emission spectrum. This is as shown in figure.



Emission spectrum



Note: In an atom emission transition may start from any higher energy level and end at any energy level below of it. Hence in emission spectrum the total possible number of emission lines from some excited state n, to another energy state $n_1 (< n_2)$ is $\frac{(n_2-n_1)(n_2-n_1+1)}{2}$



Note 1: for $n_2 = 4$, and $n_1 = 1$, the number of possible lines are 6.

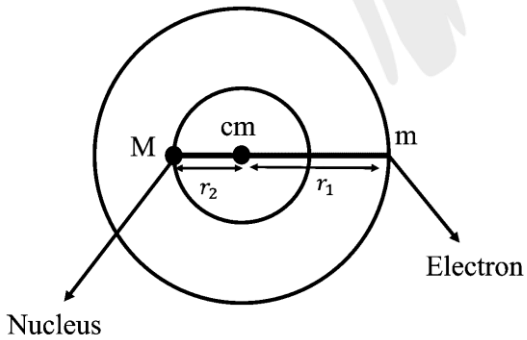
Note 2: If AE is the energy difference between two given energy states, then due to transition between these two states wavelength of emitted photon is $\lambda(\overset{o}{A}) = \frac{12400}{\Delta E(eV)}$

Limitation of Bohr's model :

- Bohr's model, despite its notable achievements, faced limitations in interpreting multi-electron atoms' optical spectra and lacked experimental verification of its orbital concept. It was only applicable to single-electron atoms and failed to explain chemical bonding and increased stability of molecules. The model assumed well-defined orbits, conflicting with the Heisenberg uncertainty principle. Quantum mechanics later revealed that electrons exist as charge clouds rather than in fixed orbits, leading to a more comprehensive understanding of atomic behavior.

S.N	Name of the series	Final state (n_1)	Initial state (n_2)	Formula	Series limit	Maximum Wavelength	Region
1.	Lyman	$n_1 = 1$	$2, 3, 4....\infty$	$\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{1}{R} = 911A^o$	$\lambda = \frac{4}{3R}$	UV
2.	Balmer	$n_1 = 2$	$3, 4, 5....\infty$	$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{4}{R}$	$\lambda = \frac{36}{5R}$	Visible
3.	Paschen	$n_1 = 3$	$4, 5, 6....\infty$	$\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{9}{R}$	$\lambda = \frac{144}{7R}$	Near IR
4.	Brackett	$n_1 = 4$	$5, 6, 7....\infty$	$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{16}{R}$	$\lambda = \frac{400}{9R}$	Middle IR
5.	Pfund	$n_1 = 5$	$6, 7, 8....\infty$	$\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n_2^2}\right)$	$\lambda = \frac{25}{R}$	$\lambda = \frac{9000}{11R}$	Far IR

Effect of finite mass of nucleus on Bohr's model of an atom



Let m be the mass of electron, M be the mass of the nucleus, Z be its atomic number and r be the separation between them. If r_1, r_2 are distances of centre of mass from electron and nucleus respectively then $r_1 + r_2 = r$ and

$$r_1 = \frac{Mr}{M+m}, r_2 = \frac{mr}{M+m}$$

A system of this type is equivalent a single particle of mass u revolving around the position of the heavier particle(nucleus) in an orbit of radius r.

From (1) and (2) $r = \dfrac{\varepsilon_0 n^2 h^2}{\pi z \mu e^2}$

Radius of orbit of such a particle in a quantum state n is $r_n = \dfrac{\varepsilon_0 n^2 h^2}{\pi z \mu e^2} \Rightarrow r_n \propto \dfrac{n^2}{\mu z}$

Potential energy of the system $PE = \dfrac{-Ze^2}{4\pi\varepsilon_0 r}$ and $KE = \dfrac{1}{2} I_1 \omega^2 = \dfrac{1}{2}(I_1 + I_2)\omega^2$

i.e., $KE = \dfrac{1}{2}\mu r^2 \omega^2 = \dfrac{1}{2}\dfrac{Ze^2}{4\pi\varepsilon_0 r}\left(\because \mu r^2 \omega^2 = \dfrac{Ze^2}{4\pi\varepsilon_0}\right)$

$\therefore$ Total energy of the system (or equivalent particle of mas μ) $E = PE + KE$

$$E = -\frac{Ze^2}{8\pi\varepsilon_0 r} = -\frac{Ze^2}{8\pi\varepsilon_0} \times \frac{\pi Z \mu e^2}{n^2 h^2 \varepsilon_0} = -\frac{Z^2 \mu e^4}{8\varepsilon_0^2 n^2 h^2}$$

i.e. Energy of n^{th} quantum state

$$E_n = \frac{-Z^2 \mu e^4}{8\varepsilon_0^2 n^2 h^2} = \frac{-mZ^2 \mu e^4}{8\varepsilon_0^2 n^2 h^2 \times m} = \frac{-me^4}{8\varepsilon_0^2 h^2} \times \left(\frac{Z^2 \mu}{n^2 m}\right)$$

$$E_n = -13.6\left(\frac{z^2}{n^2}\right) \times \frac{\mu}{m} eV = -13.6\left(\frac{Z^2}{n^2}\right) \times \frac{M}{M+m} eV = \frac{-13.6}{1+\frac{m}{M}}\left(\frac{Z^2}{n^2}\right) eV$$

$\dfrac{1}{\lambda} = \dfrac{R_0 Z^2}{\left(1+\dfrac{m}{M}\right)}\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$ where R_0 is Rydberg's constant when the nucleus is stationary.

Excitation by collision

When an atom is bombarded by particles like electron, proton, neutron, a - particle etc, the loss in KE of the system during collision may be used in excitation of the atom

Loss in KE will be maximum in perfectly inelastic collision. In this case if V is common velocity after collision, from conservation of linear momentum

$$mu + 0 = (M+m)V \Rightarrow V = \frac{mu}{M+m}$$

$\therefore$ Maximum possible loss in KE is $\Delta K = \dfrac{1}{2}mu^2 - \dfrac{1}{2}(M+m)V^2$

i.e., $\Delta K = \dfrac{1}{2}\left(\dfrac{Mm}{M+m}\right)u^2$

If KE_{min} is the minimum KE that should be min processed by the colliding particle to excite the electron, $\Delta K \geq \Delta E$ for excitation

$$\frac{1}{2}\frac{mM}{M+m}u^2 \geq \Delta E \Rightarrow \frac{1}{2}mu^2 \geq \Delta E\left(\frac{M+m}{M}\right) \Rightarrow KE\left(\frac{M+m}{M}\right)\left(1+\frac{m}{M}\right)_{min}$$

NUCLEUS:

The nucleus of an atom is at the centre. Most of the mass of an atom is at the centre. The entire positive charge of an atom lies in the nucleus.

- Generally, atomic number is denoted by Z and mass number is denoted by A and (AZ) gives number of neutrons (N) in the nucleus.

  $\therefore$ N= A-Z; A=Z+ N

TYPES OF NUCLEI:

- **ISOTOPES:**

  Atomic nuclei having same atomic number but different mass numbers are known as isotopes. They occupy same position in the periodic table and possess identical chemical properties.

  They have same proton number.

Ex: (1) ${}_3Li^6{}_3Li^7$ (2) ${}_1H^1,{}_1H^2,{}_1H^3$

- **ISOTONES:** Atomic nuclei having same number of neutrons are called isotones.

Ex: (1) ${}_{17}Cl^{37},{}_{19}K^{39},$ (2) ${}_7Cl^{17},{}_8O^{18},{}_9F^{19}$

- **ISOBARS:**

  Atomic nuclei having same mass number but different atomic numbers are called Isobars. They have same number of nucleons.

Ex: (1) ${}_{18}Ar^{40},{}_{20}Ca^{40},$ (2) ${}_{32}Ge^{76},{}_{34}Se^{76}$

- **ISOMERS:**

  Atomic nuclei having same mass number and same atomic number but different nuclear properties are called isomers.

Ex:- $m_{35}Br^{80}$ metastable Bromine and $g_{35}Br^{80}$ ground state Bromine are two isomers with different half lives

- **ISODIAPHERS:**

  Nuclei having different atomic number (Z) and mass number (A) but with same excess number of neutrons over protons (A-Z) are called isodiapheres.

Ex: - ${}_{11}Na^{23},{}_{13}Al^{27}$

SIZE OF THE NUCLEUS:

Nuclear sizes are very small and are measured in fermi (or) femtometer. 1 fermi= 10^{-15}m.

Radius of the nucleus depends on number of nucleons $R = R_0A^{1/3}$.

DENSITY OF THE NUCLEUS:

- Density of nucleus is independent of mass number of the atom.
- Density of nucleus is of the order of $10^{14}gm/cc = 10^{17}kg/m^3$

ATOMIC MASS UNIT (A.M.U):

This unit is called as atomic mass unit (amu). 1 amu is equal to one twelfth part of the mass of carbon $\left({}_{6}C^{12}\right)$ isotope. Mass of ${}_{6}C^{12}$ is exactly 12 amu.

$$1\text{amu} = 1\text{u} = \frac{1}{12} \times \text{(Mass of one carbon atom)}$$

$$= \frac{1}{12} \times \frac{12}{N} = \frac{1}{N}\text{gm} = \frac{1}{6.023 \times 10^{23}}\text{gm}$$

$$= 1.660565 \times 10^{-24}\text{gm} = 1.660565 \times 10^{-27}\text{Kg}$$

MASS - ENERGY EQUIVALENCE:

According to Einstein's mass-energy equivalence principle, mass is another form of energy. Mass can be converted into energy & energy can be converted into mass according to the equation E= mC^2.

NUCLEAR FORCES:

The attractive force which holds the nucleons together in the nucleus is called nuclear force.

Properties of nuclear forces :

(1) Nuclear forces are strongest forces in nature. Nuclear forces are about 1038 times as strong as gravitational forces. The relative strengths of the gravitational, Coulomb's and nuclear forces are

$$F_g : F_e : F_n = 1 : 10^{36} : 10^{38}$$

(2) Nuclear forces are short range forces.

(3) Nuclear forces are basically strong attractive forces, but contain a small component of repulsive forces.

(4) Nuclear forces are saturated forces.

MASS DEFECT, BINDING ENERGY, EINSTEIN'S MASS ENERGY RELATION

When matter is completely annihilated, energy released is $E = mC^2$

The energy equivalent to 1 amu is $931.5\text{MeV} = 1.4925 \times 10^{-10}\text{J}$

MASS DEFECT: Atomic mass is always less than the sum of the masses of constituent particles. The difference between the total mass of the nucleons and mass of the nucleus of an atom gives mass defect.

$$\Delta m = \left[\left[ZM_p + (A - Z)M_n\right] - M_{nucleus}\right]$$

Z= Atomic number; M_p = Mass of proton

M_n = Mass of neutron; A=Mass number

$M_{nuclues}$ = Mass of nucleus.

BINDING ENERGY:

The energy required to bring the nucleons from infinity to form the nucleus is called binding energy or it is the energy required to split a nucleus into nucleons. It is energy equivalent of mass defect BE=$[\Delta m]C^2$

NOTE: BE = mass defect × 931.5 MeV if mas is expressed in a.m.u.

B.E. per nucleon = Binding fraction

$$\frac{\text{Binding Energy}}{\text{Mass Number}} = \frac{\Delta m \times 931\,\text{MeV}}{A}$$

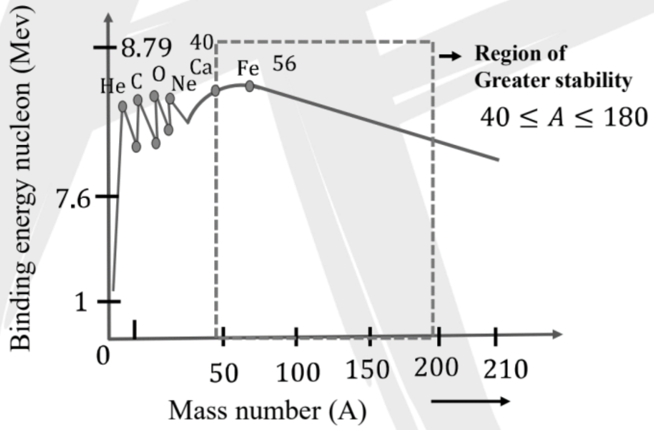
➢ Binding energy is not a measure of stability of a nucleus.

PACKING FRACTION OF A NUCLEUS:

Packing fraction: It is defined as the mass defect per nucleon. Packing fraction $= \frac{\Delta m}{A} = \frac{M-A}{A}$

➢ Packing fraction measures the stability of nucleus. Smaller the value of packing fraction, large is the stability of the nucleus.

VARIATION OF B.E. PER NUCLEON WITH MASS NUMBER



- Nuclei with A> 220 are distinctly unstable. That means from A> 220 single heavy nucleus breaks into two nearly equal nuclei with mass number A<150 and so which are most stable. This process takes at right of the BE curve as shown in figure. This process explains the nuclear fission.
- Light nuclei such as hydrogen combine to form heavy nucleus to form helium for greater stability. This process takes at left of the BE curve as shown in figure. This process explains the nuclear fusion.

NATURAL RADIOACTIVITY:

Spontaneous decay of naturally occurring unstable nuclei by emission of certain sub particles (like a, B, and y radiation) is called natural radio activity.

The emission of these rays takes place because of the instability of the nucleus. In the process of emitting these rays, a nucleus tries to attain the stability.

MODES OF DECAY:

The radioactive nucleus before decay is called a parent nucleus, the nucleus resulting from its decay by particles (Radiation) emission is called daughter nuclei.

This daughter nuclei may be stable (or) unstable.

$$\underset{\text{Parent}}{X} \longrightarrow \underset{\text{Daughter}}{Y} + \underset{\text{Radiation}}{R} + \underset{\text{Energy}}{Q}$$

Here R may be either α particle (or) β particle (or) γ radiation Q is the energy of the emitted particles (or radiation).

α -DECAY:

$${}_{z}X^{A} \Rightarrow {}_{z-2}Y^{A-4} + {}_{2}He^{4} + Q$$

Ex: ${}_{88}Ra^{226} \rightarrow {}_{86}Rn^{222} + {}_{2}He^{4} + 4.87\text{MeV}$

Both electric charge and nucleon number are conserved in the process of α decay.

Application:

When a stationary Radioactive nucleus x decays into another nucleus y by emitting an a-particle.

$x \rightarrow y + \alpha + Q$

Applying LCM if a particle moves forward with a momentum 'P' then daughter nucleus y recoils with same momentum °P' so that total momentum of the system is zero. Hence $\boxed{P_y = P_\alpha}$.

The energy released 'Q' is in the form of K.E of daughter nucleus 'y' and 'α'-particle.

$$\boxed{Q = KE_y + KE_\alpha}$$

Ratio of kinetic energies $\boxed{\dfrac{KE_y}{KE_\alpha} = \dfrac{M_\alpha}{M_y}}$

$(\because \; KE = \dfrac{P^2}{2m}$ and $KE \propto \dfrac{1}{m}$ when 'P' is same)

$$1 + \frac{KE_y}{KE_\alpha} = 1 + \frac{M_\alpha}{M_y}; \frac{KE_\alpha + KE_y}{KE_\alpha} = \frac{M_y + M_\alpha}{M_y}$$

$$\boxed{KE_\alpha = Q\left(\frac{M_y}{M_\alpha + M_y}\right)}; \quad \boxed{KE_y = Q\left(\frac{M_\alpha}{M_\alpha + M_y}\right)}$$

Notice that KE_α is very close to (but smaller than) Q.

$\beta - \text{DECAY}:$

When a nucleus disintegrates by radiating β- rays, its is said to undergo $\beta - \text{decay}$.

$${}_{z}X^{A} \rightarrow {}_{Z+1}Y^{A} + {}_{-1}e^{0}.$$

Ex: $_{90}Th^{234} \rightarrow _{91}Pa^{234} + _{-1}e^{0}$

Both electric charge and nucleon number are conserved in β decay also.

γ -DECAY:

When a nucleus disintegrates by radiation γ - rays, it is said to undergo y- decay. Gamma rays are nothing but electromagnetic radiations of short wavelengths (not exceeding 10-10m.)

The emission of y - rays from the nucleus does not alter either atomic number Z or mass number A. It just results in the change of the energy state of a nucleus.

When a parent nucleus emits an α or β particle, the daughter nucleus may be formed in one of excited states. Such a nucleus will eventually comes to the ground state. In this process γ – radiation will be emitted.

$$_{Z}X^{A} \rightarrow _{Z}X^{A} + \gamma\,\text{Photon(s)}$$

Example: $_{38}{*}Sr^{87} \rightarrow _{38}Sr^{87} + \gamma$

$_{38}Sr$ is isomer of $_{38}Sr$

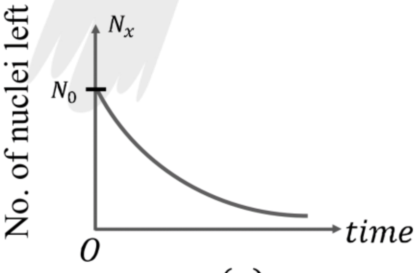
RADIOACTIVE DECAY LAW:

The rate of radioactive decay (or) the number of nuclei decaying per unit time at any instant is directly proportional to the number of nuclei (N) present at that instant and is independent of the external physical conditions like temperature, pressure etc.

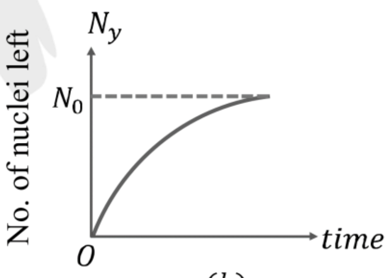
$$\left(\frac{dN}{dt}\right) \propto N; \left(\frac{dN}{dt}\right) = -\lambda N \qquad \dots (1)$$

$$\therefore \log_e\left(\frac{N}{N_0}\right) = -\lambda t; \frac{N}{N_0} = e^{-\lambda t}; \boxed{N = N_0 e^{-\lambda t}} \qquad \dots (2)$$

$$\therefore \boxed{t = \frac{1}{\lambda}\ln\left(\frac{N_0}{N}\right)}$$



(a)



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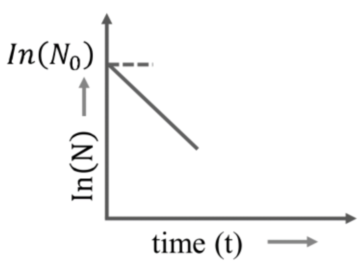


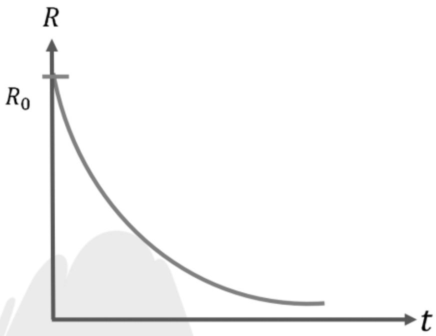
(C)

ACTIVITY (R):

The number of decays per unit time (or) decay rate is called activity (R)

$$|R| = \left|\frac{dN}{dt}\right| = \frac{d}{dt}\left(N_0 e^{-\lambda t}\right) \text{ (or) } R = \lambda N = \lambda N_0 e^{-\lambda t} \text{ (or)}$$

$R = R_0 e^{-\lambda t}$, where $R_0 = \lambda N_0$ is the decay rate at t=0, called initial activity.



If a nucleus can decay simultaneously by n processes, which have activities R_1, R_2 ,..... and R_n. Then the resultant activity $R = R_1 + R_2 + ... + R_n$. If nucleus decays simultaneously more than one process is called parallel decay. The S.I. unit of activity is Becquerel (Bq) and other units are curie (Ci) and Ruther ford (Rd).

1 Bq = 1 decay per second,

1 Rd = 10^6 decays per second.

1 Ci = 3.7×10^{10} decays per second.

Note: Curie is approximately equal to the activity of one gram of pure radium.

HALF LIFE (T):

As the name suggests, the half-life of a radioactive sample is defined as "The time interval during which the activity of a radio-active sample falls to half of its value, (or) The time interval during which the number of radioactive nuclei of a sample disintegrate to half of its original number of nuclei"

$$\therefore \boxed{T = \frac{\ln 2}{\lambda} = \frac{2.303 \log 2}{\lambda} = \frac{0.693}{\lambda}}$$

The above relation establishes that the half - life (T) depends upon the decay constant of the radioactive substance. The value of A is different for different radioactive substances.

Application:

In a radioactive sample the number of nuclides undecayed after n- half lives (i.e., t=nT) is

$$2^n = \frac{N_0}{N}; \text{ or } \boxed{N = N_0\left(\frac{1}{2}\right)^n}$$

AVERAGE LIFE (OR) MEANLIFE:

The average life is defined as the total life time of all the nuclei divided by the total number of original nuclei.

$$T = \frac{\sum \text{life span of individual nucleus}}{\text{Total number of original nuclei}} = \frac{\sum t}{N_0}$$

$$\tau = \int_0^\infty t\frac{\lambda N_0 e^{-\lambda t}}{N_0}dt; \qquad \boxed{\tau = \frac{1}{\lambda}}$$

The mean life (or) averages life of a radio active sample is reciprocal to decay constant.

We know that $N = N_0 e^{-\frac{t}{T}XT} = \frac{N_0}{e} = 0.37_0 = 37\%$ of N_0

Hence average life period of a radioactive sample can also be defined as "The time interval during which 63% of sample decays or sample reduces to 37% of its original amount".

RELATION BETWEEN HALF LIFE PERIOD AND AVERAGE LIFE PERIOD

We Know that $T = \frac{0.693}{\lambda}$ & $T = \frac{1}{\lambda}$

NEUTRON

- It is electrically neutral and its mass is slightly greater than that of proton. It was discovered by Chadwick
- Bothe - Becker equation:

  $${}_4Be^9 + {}_2He^4 \rightarrow \left[{}_6C^{13}\right] \rightarrow {}_6C^{12} + {}_0n^1$$

- Neutron is unstable outside the nucleus.

  ${}_0n^1 \rightarrow {}_1H^1 + {}_{-1}e^0 + \bar{v}$ (antineutrino)

- It has high penetrating power and low ionizing power.
- Slow moving neutrons are called thermal neutrons. Fast moving neutrons convert into thermal neutrons when they pass through a substance called moderator.

NUCLEAR FISSION

- Nuclear Fission is a nuclear reaction in which a heavy atomic nucleus like U^{235}, splits into two approximately equal parts, emitting neutrons and liberating large amount of energy.
- Energy of about 200 MeV is released during one fission reaction of ${}_{92}U^{235}$. The most probable nuclear fission reaction is

  $${}_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + {}_3n^1 + \text{energy}$$

  There is no guarantee that U^{235}, always breaks into Barium and Krypton.

CHAIN REACTION:

- Chain-reaction: The process of continuation of nuclear fission which when once started continues spontaneously without the supply of additional neutrons from outside is defined as chain reaction. Reproduction factor (K): "It is the ratio of number of neutrons in any particular generation to the number of neutrons in the preceding generation.

Case(i): K<1; Chain reaction is not maintained. (Subcritical state)

Case (ii): K=1: Chain reaction is maintained at steady rate. (Critical state). In the state electricity is produced in the reactors at steady rate

Case (iii): K>1: Chain reaction becomes self-sustained and lead to atomic explosion (super critical state)

- Uncontrolled chain reaction takes place in atom bomb.

NUCLEAR USION:

- The phenomenon in which two lighter nuclei combine to form a heavier nucleus of massless than the total mass of the combining nuclei is called nuclear fusion. This mass defect appears as energy.
- At temperatures of about $10^7 K$, light nuclei combine to give heavier nuclei. Hence, fusion reactions are called thermo nuclear reactions.
- Nuclear fusion takes place in the sun and other stars.
- Energy produced in a single fission of $_{92}U^{235}$ is larger than that in a single fusion of Hydrogen into Helium.

STELLAR AND SOLAR ENERGY:

Stellar and solar energy is due to fusion.

The cycles that occur are.

Proton - Proton Cycle & Carbon - Nitrogen Cycle

PROTON-PROTON CYCLE:

The Thermonuclear reactions involved are:

$$2\left({}_1H^1\right)+2\left({}_1H^1\right)\rightarrow 2\left({}_1H^2\right)+2\left({}_{+1}e^0\right)+Q_1$$

$$2(1H^2) + 2(1H^1) \rightarrow 2(1H^2) + Q_2$$

$$He^3 +_2 He^3 \rightarrow \left({}_2He^4\right)+2\left({}_1H^2\right)+Q_3$$

On adding up these reactions, we obtain.

$$4(1H^1) \rightarrow_2 He^4 + 2_{+1}e^0 + Q$$

Where $Q = Q_1 + Q_2 + Q_3$ is the total energy evolved in the fusion of 4 hydrogen nuclei (protons) to form Helium nucleus. The value of Q as calculated from mass defect comes out to be 26.7 MeV

CARBON – NITROGEN CYCLE:

Proposed by Bethe- It consists of following reactions.

$_6C^{12} +_1 H^1 \rightarrow _7H^{13} + Q_1$; $_7N^{13} \rightarrow _6C^{13} + \left(_1e^0\right) + Q_2$ $_6C^{13} \rightarrow _1H^1 \rightarrow _7N^{14} + Q_3$;

$_7N^{14} \rightarrow _1H^1 \rightarrow _8O^{15} + Q_4$ $_8O^{15} \rightarrow _7N^{15} + \left(_{+1}e^0\right) + Q_5$; $_7N^{15} \rightarrow _1H^1 \rightarrow _6C^{12} +_2 He^4 + Q_6$

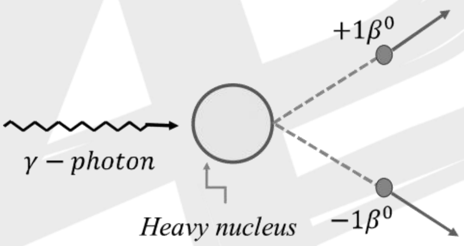
On adding all these 6 equations, we get

$$4_1H^1 \rightarrow _2He^4 + 2\left(_{+1}e^0\right) + Q$$

Where $Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5 + Q_6$. The value of Q as calculated from mass defect is 26.7 MeV.

PAIR AND PRODUCTION AND PAIR ANNIHILATION: When an energetic y-photon falls on a heavy nucleus, it is absorbed by the nucleus and a pair of electron and position is produced. This phenomenon is called as pair production and can be represented by the following equation:

$$\underset{(\gamma-\text{photon})}{h\nu} = \underset{(\text{Positron})}{_{+1}\beta^0} + \underset{(\text{electron})}{_{-1}\beta^0}$$



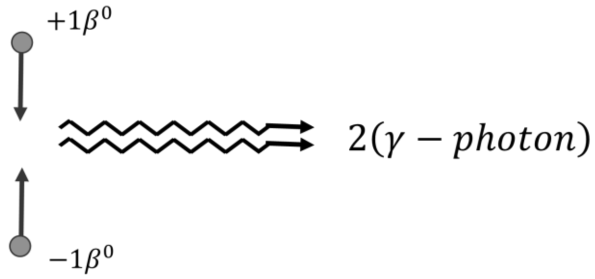
The rest mass energy of electron or positron is:

$E_0 = m_0c^2 = (9.1 \times 10^{-31}) \times (3 \times 10^8)^2$

$= 8.2 \times 10^{-14}\text{J} \simeq 0.51\text{MeV}$

Hence for pair production, the minimum energy of γ-photon must be $2 \times 0.51 = 1.02\text{MeV}$. If the energy of γ -photon is less than this, there may be Compton's effect. If energy of γ -photon is greater than E_0, then extra energy will become kinetic energy of the particles. If E is the energy of γ -photon, the kinetic energy of each particle will be, $K_{\text{electron}} = K_{\text{positron}} = \frac{E-2E_0}{2}$

The inverse process of pair production is called pair annihilation. According to it when electron and a positron come also to each other, annihilate each other and produces minimum two γ-photons. Thus $\underset{(\text{Positron})}{+1\beta^0} + \underset{(\text{electron})}{-1\beta^0} = \underset{(\gamma-\text{photon})}{2hf}$



EXCERCISE-I

1. Let $n_r \, n_r$ and n_b be respectively the number of photons emitted by a red bulb and a blue bulb of equal power in a given time :

(A) $n_r = n_b$ (B) $n_r < n_b$ (C) $n_r > n_b$ (D) data insufficient

2. The stopping potential for the photoelectrons emitted from a metal surface of work function 1.7 eV is 10.4 V. Identify the energy levels corresponding to the transitions in hydrogen atom which will result in emission of wavelength equal to that of incident radiation for the above photoelectric effect:

(A) n = 3to1 (B) n = 3to2 (C) n = 2to1 (D) n = 4to1

3. When a photon of light collides with a metal surface, number of electrons, (if any) coming out is :

(A) only one (B) only two (C) infinite (D) only three

4. A point source of light is used in a photoelectric effect. If the source is removed farther from the emitting metal, the stopping potential:

(A) will increase (B) will decrease
(C) will remain constant (D) will either increase or decrease

5. A proton and an electron are accelerated by same potential difference starting from rest have de-Broglie wavelength λ_p and λ_e.

(A) $\lambda_e = \lambda_p$ (B) $\lambda_e < \lambda_p$ (C) $\lambda_e > \lambda_p$ (D) $2\lambda_e = \lambda_p$

6. An electrons with initial kinetic energy of 100 eV is accelerated through a potential difference of 50V. Now the de-Broglie wavelength of electron becomes :

(A) $1\,\overset{o}{A}$ (B) $\sqrt{1.5}\,\overset{o}{A}$ (C) $\sqrt{3}\,\overset{o}{A}$ (D) $\sqrt{2}\,\overset{o}{A}$

7. If h is Planck's constant is SI system, the momentum of a photon of wavelength $0.001\,\overset{o}{A}$ is :

(A) 10^{-2} h (B) 10^{13} h (C) 10^{2} h (D) 10^{12} h

8. If the electron in a hydrogen atom were in the energy level with n = 4, how much energy in joule would be required to ionise the atom? (Ionisation energy of H-atom is 2.18×10^{-18} J) :

(A) 6.54×10^{-19} (B) 1.43×10^{-19} (C) 2.42×10^{-19} (D) 1.36×10^{-19}

9. The ionisation potential of hydrogen atom is 13.6 volt. The energy required to remove an electron from the third orbit of hydrogen is :

(A) 3.4 eV (B) 6.8 eV (C) 13.6 eV (D) 1.51 eV

10. Radius of the first Bohr orbit of singly ionised helium atom is :

(A) $0.53\,\overset{o}{A}$ (B) $1.06\,\overset{o}{A}$ (C) $0.265\,\overset{o}{A}$ (D) $0.264\,\overset{o}{A}$

11. An electron in Bohr's hydrogen atom has an energy of −3.4eV. The angular momentum of the electron is :

(A) $\frac{h}{\pi}$ (B) $\frac{h}{2\pi}$ (C) $\frac{nh}{2\pi}$ (n is an integer) (D) $\frac{2h}{\pi}$

12. Which of the following wavelength falls in a X-ray region ?

(A) $10,000\,\mathring{A}$ (B) $1000\,\mathring{A}$ (C) $1\,\mathring{A}$ (D) $10^{-2}\,\mathring{A}$

13. The penetrating power of X-ray increases with the :

(A) Increase of its velocity (B) Increase in its intensity

(C) Decrease in its velocity (D) Increase in its frequency

14. The "K_α" X-rays emission line of tungsten occurs at $\lambda = 0.021$ nm. The energy difference between K and L levels in this atom (in keV) is

15. The surface area of a nucleus varies with mass number A as

(A) $A^{2/3}$ (B) $A^{1/3}$ (C) A (D) None of these

16. The following nuclear reaction is an example of ${}^{12}_{6}C + {}^{4}_{2}H \rightarrow {}^{16}_{8}O$ + energy:

(A) fission (B) fusion (C) alpha decay (D) beta decay

17. Fast neutrons may most easily be slowed down by which one of the following methods?

(A) passing them through a substance rich in hydrogen

(B) allowing them to collide elastically with heavy nuclei

(C) using lead shielding

(D) passing them through an increasing potential gradient space

18. 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 decreases (D) the minimum wavelength decreases

19. When the nucleus of an electrically neutral atom undergoes a radioactive decay process, it will remain neutral after the decay if the process is :

(A) α decay (B) β^- decay (C) β^+ decay (D) K-capture

20. The kinetic energies of the photoelectrons ejected from a metal surface by light of wavelength $2000\mathring{A}$ range from 0 to 3.2×10^{-19} Joule. Then find the stopping potential.

(A) 1 volt (B) 2 volt (C) 3 volt (D) 4 volt

EXCERCISE-II

1. 10^{-3}W of 5000$\overset{o}{A}$ light is directed on a photoelectric cell. If the current in the cell is 0.32 μA, the percentage of incident photons which produce photoelectrons, is:

(A) 0.4% (B) .04% (C) 20% (D) 0.08%

2. The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 8eV fall on it is 6 eV. The stopping potential in volts is :

(A) 2 (B) 4 (C) 6 (D) 10

3. Radiation of two photon energies five times and nine times the work function of metal are incident successively on the metal surface. The ratio of the maximum velocity of photoelectrons emitted in the two cases will be :

(A) 1 : 2 (B) 2 : 1 (C) 1 : 4 (D) $1:\sqrt{2}$

4. Photons with energy 5 eV are incident on a cathode C, on a photoelectric cell. The maximum energy of the 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 :

(A) 3 V (B) –3 V (C) –1 V (D) 1 V

5. If a parallel beam of light having intensity I is incident normally on a perfectly reflecting surface, the force exerted on the surface, equals F (Assume that the cross section of beam remains constant). When the surface is held at an angle θ, the force is :

(A) $2F\tan\theta$ (B) $F\cos\theta$ (C) $F\cos^2\theta$ (D) $2F\cos^2\theta$

6. Let K_1 be the maximum kinetic energy of photoelectrons emitted by a light of wavelength λ_1 and K_2 corresponding to λ_2. If $\lambda_1 = 2\lambda_2$, then :

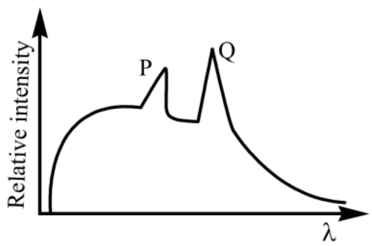
(A) $2K_1 = K_2$ (B) $K_1 = 2K_2$ (C) $K_1 < \frac{K_2}{2}$ (D) $K_1 > 2K_2$

7. The angular momentum of an electron in the hydrogen atom is $\frac{3h}{2\pi}$. Here h is Planck's constant. The kinetic energy of this electron is $\frac{15.1\text{eV}}{n}$. Find n?

8. Electron in a hydrogen atom is replaced by an identically charged particle muon with mass 207 times that of electron. Now the radius of K shell will be :

(A) $2.56\times10^{-3}\overset{o}{A}$ (B) $109.7\overset{o}{A}$ (C) $1.21\times10^{-3}\overset{o}{A}$ (D) $3.56\times10^{-3}\overset{o}{A}$

9. In a characteristic X-ray spectra of some atom superimposed on continuous X-ray spectra :



(A) P represents K_α line

(B) Q represents K_β line

(C) Q and P represents K_α and K_β lines respectively

(D) Relative positions of K_α and K_β depend on the particular atom

10. An energy of 24.6 eV is required to remove one of the electrons from a neutral helium atom. The energy (in eV) required to remove both the electrons from a neutral helium atom is:

11. Let u denote one atomic mass unit. One atom of an element of mass number A has mass exactly equal to Au:

(A) for any value of A

(B) only for A = 1

(C) only for A = 12

(D) for any value of A provided the atom is stable

12. Consider the nuclear reaction $X^{200} \longrightarrow A^{110} + B^{90}$

If the binding energy per nucleon for X, A and B is 7.4 MeV, 8.2. MeV and 8.2 MeV respectively, the energy released(in MeV) is

13. The binding energies of nuclei X and Y are E_1 and E_2 respectively. Two atoms of X fuse to give one atom of Y and an energy Q is released. Then :

(A) $Q = 2E_1 - E_2$ (B) $Q = E_2 - 2E_1$ (C) $Q = 2E_1 + E_2$ (D) $Q = 2E_2 + E_1$

14. The rest mass of the deuteron, ${}_1^2H$, is equivalent to an energy of 1876 MeV, the rest mass of a proton is equivalent to 939 MeV and that of a neutron to 940 MeV. A deuteron may disintegrate to a proton and a neutron if it :

(A) emits a γ-ray photon of energy 2 MeV

(B) captures a γ-ray photon of energy 2 MeV

(C) emits a γ-ray photon of energy 3 MeV

(D) captures a γ-ray photon of energy 3 MeV

15. Consider α-particles, β-particles and γ-rays, each having an energy of 0.5 MeV. Increasing order of penetrating powers, the radiations are :

(A) α, β, γ (B) α, γ, β (C) β, γ, α (D) γ, β, α

16. In the uranium radioactive series the initial nucleus is ${}_{92}U^{238}$, and the final nucleus is ${}_{82}Pb^{206}$. When the uranium nucleus decays to lead, the number of α-particles emitted is .... and the number of β-particles emitted ....

(A) 6, 8 (B) 8, 6 (C) 16, 6 (D) 32, 12

17. In a radioactive element the fraction of initial amount remaining after its mean life time is :

(A) $1-\frac{1}{e}$ (B) $\frac{1}{e^2}$ (C) $\frac{1}{e}$ (D) $1-\frac{1}{e^2}$

18. Activity of a radioactive substance is R_1 at time t_1 and R_2 at time $t_2 (t_2 > t_1)$. Then the ratio $\frac{R_2}{R_1}$ is:

(A) $\frac{t_2}{t_1}$ (B) $e^{-\lambda(t_1+t_2)}$ (C) $e\left(\frac{t_1-t_2}{\lambda}\right)$ (D) $e^{\lambda(t_1-t_2)}$

19. There are two radio nuclei A and B. A is an alpha emitter and B is a beta emitter. Their disintegration constants are in the ratio of 1 : 2. What should be the ratio of number of atoms of A and B at time t = 0 so that probabilities of getting α and β particles are same at time t = 0?

(A) 2 : 1 (B) 1 : 2 (C) e (D) e^{-1}

20. A certain radioactive substance has a half life of 5 years. Thus for a particular nucleus in a sample of the element, the probability of decay in ten years is :

(A) 50% (B) 75% (C) 100% (D) 25%

21. The decay constant of the end product of a radioactive series is :

(A) zero (B) infinite

(C) finite (non-zero) (D) depends on the end product

22. A radioactive substance is dissolved in a liquid and the solution is heated. The activity of the solution :

(A) is smaller than that of element

(B) is greater than that of elementt

(C) is equal to that of element

(D) will be smaller or greater depending upon whether the solution is weak or concentrated

23. In a certain nuclear reactor, a radioactive nucleus is being produced at a constant rate = 1000/s. The mean life of the radionuclide is 60 minutes. At steady state, the number of radionuclide will be :

(A) 4×10^4 (B) 24×10^4 (C) 24×10^5 (D) 36×10^5

24. A X-ray tube operates at an accelerating potential of 20 kV. Which of the following wavelengths will be absent in the continuous spectrum of X-ray?

(A) 12 pm (B) 75 pm (C) 65 pm (D) 95 pm

25. In photoelectric effect, stopping potential depends on :

(A) frequency of the incident light

(B) intensity of the incident light by varies source distance

(C) emitter's properties

(D) frequency and intensity of the incident light

EXCERCISE-III

1. In a photo-emissive cell, with exciting wavelength λ , the maximum kinetic energy of electron is K. If the exciting wavelength is changed to $\frac{3\lambda}{4}$ the kinetic energy of the fastest emitted electron will be:

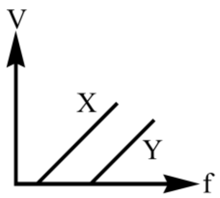
(A) $\frac{3K}{4}$ (B) $\frac{4K}{3}$ (C) less than $\frac{4K}{3}$ (D) greater than $\frac{4K}{3}$

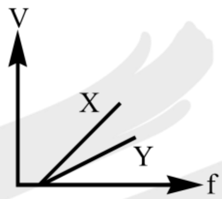
2. If the frequency of light in a photoelectric experiment is doubled, the stopping potential will :

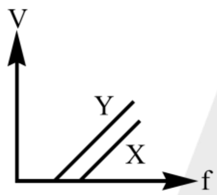
(A) be doubled (B) be halved

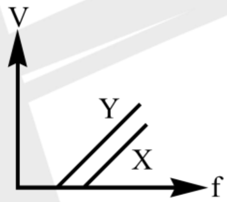
(C) become more than double (D) become less than double

3. In a photoelectric experiment, electrons are ejected from metals X and Y by light of intensity I and frequency f. The potential difference V required to stop the electrons is measured for various frequencies. If Y has a greater work function than X; which one of the following graphs best illustrates the expected results?

(A) 

(B) 

(C) 

(D) 

4. 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 take place)

5. An electron collides with a fixed hydrogen atom in its ground state. Hydrogen atom gets excited and the colliding electron loses all its kinetic energy. Consequently the hydrogen atom may emit a photon corresponding to the largest wavelength of the Balmer series. The min. K.E. of colliding electron will be :

(A) 10.2 eV (B) 1.9 eV (C) 12.1 eV (D) 13.6 eV

6. Consider the spectral line resulting from the transition $n = 2 \rightarrow n = 1$ in the atoms and ions given below. The shortest wavelength is produced by :

(A) hydrogen atom

(B) deuterium atom

(C) singly ionized helium

(D) doubly ionized lithium

7. In an atom, two electrons move around the nucleus in circular orbits of radii R and 4R. The ratio of the time taken by them to complete one revolution is : (Neglect electric interaction)

(A) 1 : 4 (B) 4 : 1 (C) 1 : 8 (D) 8 : 1

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

(A) 6 α (B) 8α (C) 4α (D) 8 α

9. If the frequencies of K_α, K_β and L_α X-rays for a material $v_{K_\alpha}, v_{K_\beta}, v_{L_\alpha}$ respectively, then :

(A) $v_{K_\alpha} = v_{K_\beta} + v_{L_\alpha}$ (B) $v_{L_\alpha} = v_{K_\alpha} + v_{K_\beta}$ (C) $v_{K_\beta} = v_{K_\alpha} + v_{L_\alpha}$ (D) None of these

10. A star initially has 10^{40} deutrons. It produces energy via, the processes $1H^2 +_1 H^2 \rightarrow_1 H^3 + p$ and $1H^2 +_1 H^3 \rightarrow_2 He^4 + n$. If the average power radiated by the star is 10^{16} W, the deuteron supply of the star is exhausted in a time of the order of :

(A) $10^6 sec$ (B) $10^8 sec$ (C) $10^{12} sec$ (D) $10^{16} sec$

11. The binding energies of the nuclei of ${}_2^4He$, ${}_3^7Li$, ${}_6^{12}C$ and ${}_7^{14}N$ are 28, 52, 90, 98 MeV respectively. Which of these is most stable?

(A) ${}_2^4He$ (B) ${}_3^7Li$ (C) ${}_6^{12}C$ (D) ${}_7^{14}N$

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

(A) 3α and $6\beta^-$ (B) 4α and $5\beta^-$ (C) 5α and $4\beta^-$ (D) 6α and $6\beta^-$

13. The radioactive sources A and B of half lives of 2 hr and 4 hr respectively, initially contain the same number of radioactive atoms. At the end of 2 hours, their rates of disintegration are in the ratio :

(A) 4 : 1 (B) 2 : 1 (C) $\sqrt{2}:1$ (D) 1 : 1

14. Two radioactive material A_1 and A_2 have decay constants of $10\lambda_0$ and λ_0. If initially they have same number of nuclei, the ratio of number of their undecayed nuclei will be $\left(\frac{1}{e}\right)$ after a time :

(A) $\frac{1}{\lambda_0}$ (B) $\frac{1}{9\lambda_0}$ (C) $\frac{1}{10\lambda_0}$ (D) 1

15. 90% of a radioactive samle is left undecayed after time t has elapsed. The percentage of the initial sample will decay in a total time 2t is

16. A particular nucleus in a large population of identical radioactive nuclei did survive 5 half lives of that isotope. Then the probability that this surviving nucleus will survive the next half life :

(A) $\frac{1}{32}$ (B) $\frac{1}{5}$ (C) $\frac{1}{2}$ (D) $\frac{1}{10}$

17. The activity of a sample reduces from A_0 to $\frac{A_0}{\sqrt{3}}$ in one hour. The activity after 3 more hours will be $\frac{A_0}{\alpha}$. Find α ?

18. Half life of radium is 1620 years. How many radium nuclei decay in 5 hours in 5 gm radium? (Atomic weight of radium = 223)

(A) 9.1×10^{12} (B) 3.23×10^{15} (C) 1.72×10^{20} (D) 3.2×10^{10}

19. The activity of a sample of radioactive material is A_1 at time t_1 and A_2 at time $t_2 (t_2 > t_1)$. Its mean life is T.

(A) $A_1t_1 = A_2t_2$

(B) $\frac{A_1 - A_2}{t_2 - t_1} = \text{constant}$

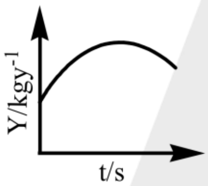
(C) $A_2 = A_1e^{(t_1 - t_2)/T}$

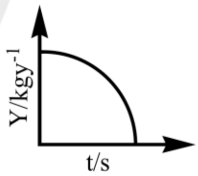
(D) $A_2 = A_1e^{(t_1 - Tt_2)}$

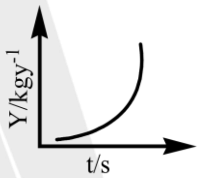
20. A ratioactive nuclide can decay simultaneously by two different processes which have decay constants λ_1 and λ_2. The effective decay constant of the nuclide is λ, then :

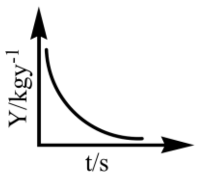
(A) $\lambda = \lambda_1 + \lambda_2$ (B) $\lambda = \frac{1}{2}(\lambda_1 + \lambda_2)$ (C) $\frac{1}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$ (D) $\lambda = \lambda_1 - \lambda_2$

21. The ratioacgtive nucleus of an element X decays to a stable nucleus of element Y. A graph of the rate of formation of Y against time would look like :

(A) 

(B) 

(C) 

(D) 

22. In the experiment on photoelectric effect using light having frequency greater than the threshold frequency, the photocurrent will certainly increase when :

(A) anode voltage is increased

(B) area of cathode surface is increased

(C) intensity of incident light is increased

(D) distance between anode and cathode is increased

23. An electron is in an excited state in hydrogen-like atom. It has a total energy of -3.4 eV. If the kinetic energy of the electron is E and its de-Broglie wavelength is λ, then :

(A) $E = 6.8\text{eV}, \lambda = 6.6 \times 10^{-10}\text{m}$

(B) $E = 3.4\text{eV}, \lambda = 6.6 \times 10^{-10}\text{m}$

(C) $E = 3.4\text{eV}, \lambda = 6.6 \times 10^{-11}\text{m}$

(D) $E = 6.8\text{eV}, 6.6 \times 10^{-9}\text{m}$

24. 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) $M_2 = 2M_1$ (B) $M_2 > 2M_1$ (C) $M_2 < 2M_1$ (D) $M_1 < 10(m_n + m_p)$

25. The instability of the nucleus can be due to various causes. An unstable nucleus emits radiations if possible to transform into less unstable state. Then the cause and the result can be :

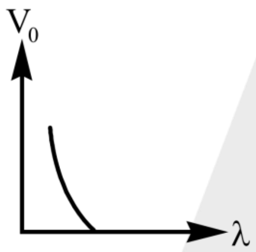
(A) a nucleus of excess nucleons is α active

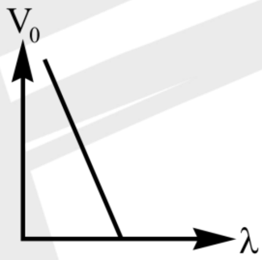
(B) an excited nucleus of excess protons is β^- active

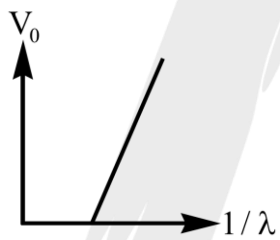
(C) an excited nucleus of excess protons is β^+ active

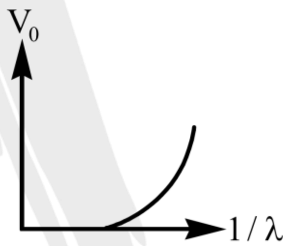
(D) an nucleus of excess neutrons is β^+ active

26. For photoelectric effect with incident photon wavelength λ, the stopping potential is V_0. Identify the correct variation(s) of V_0 with λ and $\frac{1}{\lambda}$.

(A) 

(B) 

(C) 

(D) 

27. At t = 0, light of intensity 10^{12} photons/s-m^2 of energy 6 eV per photon start falling on a plate with work function 2.5 eV. If area of the plate is $2\times10^{-4}\,m^2$ and for every 10^5 photons one photoelectron is emitted, find charge on the plate at t = 25 s is

(A) $2\times10^{-14}C$ (B) $4\times10^{-14}C$ (C) $6\times10^{-14}C$ (D) $8\times10^{-14}C$

EXCERCISE-IV

1. The frequency and the intensity of a beam of light falling on the surface of photoelectric material are increased by a factor of two. Treating efficiency of photoelectron generation as constant, this will :

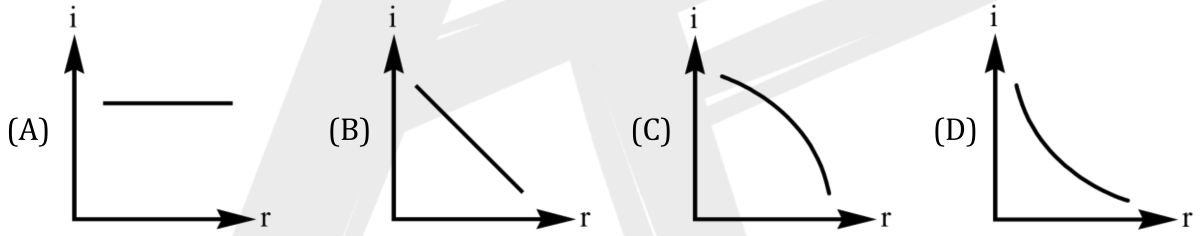
(A) increase the maximum energy of the photoelectrons, as well as photoelectric current by a factor of two

(B) increase the maximum kinetic energy of the photoelectrons and would increase the photoelectric current by a factor of two

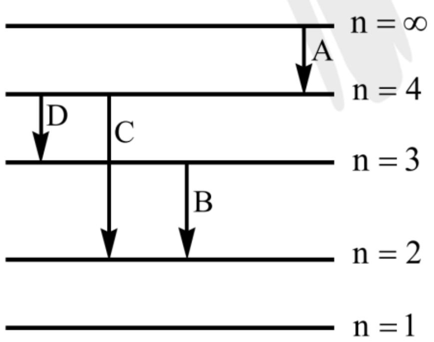
(C) increase the maximum kinetic energy of the photoelectrons by a factor of greater than two and will have no effect on the magnitude of photoelectric current produced

(D) not produce any effect on the kinetic energy of the emitted electrons but will increase the photoelectric current by a factor of two

2. A point source causes photoelectric effect from a small metal plate. Which of the following curves may represent the saturation photocurrent as a function of the distance between the source and the metal?



3. Consider the following electronic energy level diagram of H-atom: Photons associated with shortest and longest wavelengths would be emitted from the atom by the transitions labeled:



(A) D and C respectively

(B) C and A respectively

(C) C and D respectively

(D) A and C respectively

4. In a hydrogen atom, the binding energy of electron in the n^{th} state is E_n, then the frequency of revolution of the electron in the nth orbit is $\frac{\alpha E_0}{nh}$. Find α ?

5. In hydrogen and hydrogen like atoms, the ratio of difference of energies $E_{4n} - E_{2n}$ and $E_{2n} - E_n$ varies with its atomic number z and n as:

(A) $\frac{z^2}{n^2}$ (B) $\frac{z^4}{n^4}$ (C) $\frac{z}{n}$ (D) $z^0 n^0$

6. The elecvtron in a hydrogen atom makes transition from M shell to L. The ratio of magnitude of initial to final centripetal acceleration of the electron is :

(A) 49 : 16 (B) 81 : 16 (C) 16 : 49 (D) 16 : 81

7. The electron in a hydrogen atom makes a transition $n_1 \to n_2$ whose n_1 and n_2 are the principal quantum numebrs of the two states. Assume the Bohr model to be valid. The frequency of orbital motion of the electron in the initial state is $\frac{1}{64}$ of that in the final state. The possible values of n_1 and n_2 are :

(A) $n_1 = 4, n_2 = 2$ (B) $n_1 = 3, n_2 = 1$ (C) $n_1 = 8, n_2 = 1$ (D) $n_1 = 4, n_2 = 1$

8. When a hydrogen atom, initially at rest emits, a photon resulting in transition $n = 5 \to n = 1$, its recoil speed is $\frac{42}{n}$ m / s. Find n?

9. The electron in hydrogen atom in a sample is in n^{th} excited state, then the number of different spectrum lines obtained in its emission spectrum will be :

(A) $1 + 2 + 3 + \ldots\ldots + (n - 1)$

(B) $1 + 2 + 3 + \ldots\ldots + (n)$

(C) $1 + 2 + 3 + \ldots\ldots + (n + 1)$

(D) $1 \times 2 \times 3 \times \ldots\ldots \times (n - 1)$

10. In X-ray tube, when the accelerating voltage V is doubled, the difference between the wavelength of K_α line and the minimum cut off of continuous X-ray spectrum :

(A) remains constant

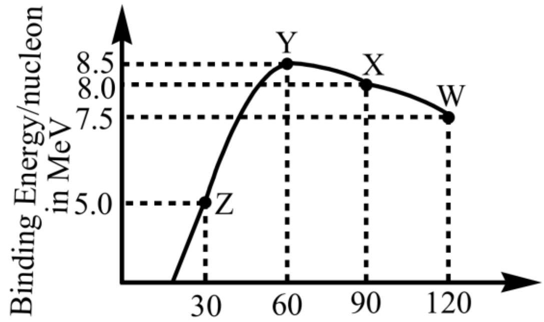
(B) becomes less than half

(C) becomes half

(D) becomes more than half

11. In an α -decay the kinetic energy of α -particle is 48 MeV and Q-value of the reaction is 50 MeV. The mass number of the mother nucleus (in amu) is : (Assume that daughter nucleus is in ground state)

12. Binding energy per nucleon vs. mass number curve for nuclei is shown in the figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would released energy is :



(A) $Y \rightarrow 2Z$ (B) $W \rightarrow X + Z$ (C) $W \rightarrow 2Y$ (D) $W \rightarrow Y + Z$

13. The half-life of substance X is 45 years, and it decomposes to substance Y. A sample from a meteorite was taken which contained 2% of X and 14% of Y by quantity of substance. If substance Y is not normally found on a meteorite, the approximate age (in years) of the meteorite is

14. **Statement-1 :** In the process of photoelectric emission, all the emitted photoelectrons have same KE.

Statement-2 : According to Einstein's photoelectric equation $KE_{max} = h\nu - \phi$.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

15. **Statement-1 :** An electron and a proton are accelerated through the same potential difference. The de-Broglie wavelength associated with the electron is longer.

Statement-2 : de-Broglie wavelength associated with a moving particle is $\lambda = \frac{h}{p}$ where, p is the linear momentum and both have same KE.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

16. **Statement-1 :** Two photons having equal wavelengths have equal linear momenta.

Statement-2 : When light shows its photon character, each photon has a linear momentum $p = \frac{h}{\lambda}$.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

17. **Statement-1 :** It is easy to remove a proton from $^{40}_{20}Ca$ nucleus as compared to neutron.

Statement-2 : Inside nucleus neutrons are acted on only by attractive forces but protons are also acted on by repulsive forces.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

18. **Statement-1 :** Consider the following nuclear reaction of an unstable $^{14}_{6}C$ nucleus initially at rest. The decay $^{14}_{6}C \longrightarrow {}^{14}_{7}N + {}^{0}_{-1}e + \bar{v}$. In a nuclear reaction total energy and momentum is conserved experiments show that the electrons are emitted with a continuous range of kinetic energies upto some maximum value.

Statement-2: Remaining energy is released as thermal energy.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

19. If radiation of all wavelengths from ultraviolet to infrared is passed through hydrogen gas at room temperature, absorption lines will be observed in the :

(A) Lyman series (B) Balmer series (C) both (A) and (B) (D) neither (A) nor (B)

20. X-rays are produced by accelerating electrons across a given potential difference to strike a meta target of high atomic number. If the electrons have same speed when they strike the target, the X-ray spectrum will exhibit :

(A) a maximum wavelength

(B) a continuous spectrum

(C) some discrete comparatively prominent wavelength

(D) uniform density over the whole spectrum

21. A nitrogen nucleus $_7N^{14}$ absorbs a neutron and can transform into lithium nucleus $_3Li^7$ under suitable conditions, after emitting :

(A) 4 protons and 3 neutrons

(B) 5 protons and 1 negative beta particle

(C) 1 alpha particles and 4 gamma particles

(D) 1 alpha particle, 4 protons and 2 negative beta particles

EXCERCISE-V

1. In a hypothetical system a particle of mass m and charge $-4q$ is moving around a very heavy particle having charge 2q. Assuming Bohr's model to be true to this system, the orbital velocity of mass m when it is nearest to heavy particle is :

(A) $\frac{3q^2}{2\varepsilon_0 h}$ (B) $\frac{3q^2}{4\varepsilon_0 h}$ (C) $\frac{3q}{2\varepsilon_0 h}$ (D) $\frac{4q^2}{\varepsilon_0 h}$

2. A neutron collides head on with a stationary hydrogen atom in ground state :

(A) if kinetic energy of the neutron is less than 13.6 eV, collision must be elastic

(B) if kinetic energy of the neutron is less than 13.6 eV, collision may be inelastic

(C) inelastic collision takes place when initial kinetic energy of neutron is greater than 13.6 eV

(D) perfectly inelastic collision cannot take place

3. The magnitude of angular momentum, orbit radius and frequency of revolution of electron in hydrogen atom corresponding to quantum number n are L, r and f respectively. The according to Bohr's theory of hydrogen atom :

(A) $f\,r^2L$ is constant for all orbits

(B) $f\,r\,L$ is constant for all orbits

(C) $f^2 r L$ is constant for all orbits

(D) $f\,r\,L^2$ is constant for all orbits

4. A radioactive substance is being prouced at a constant rate of 10 nuclei/s. The decay constant of the substance is $1/2\ \text{sec}^{-1}$. After what time the number of radioactive nuclei will become 10? Initially there are no nuclei present. Assume decay law holds for the sample.

(A) 2.45 sec (B) 2.91 sec (C) 1.386 sec (D) 1.923 sec

5. The radioactivity of a sample is R_1 at time T_1 and R_2 at time T_2. The half life of the specimen is T. Number of atoms that have disintegrated in time $(T_2 - T_1)$ is proportional to :

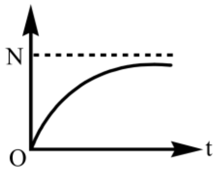
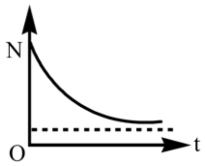
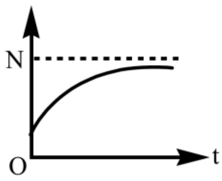
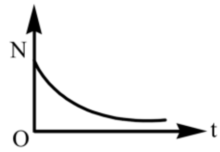
(A) $(R_1T_1 - R_2T_2)$

(B) $\frac{(R_1 - R_2)T}{\ln 2}$

(C) $\frac{(R_1 - R_2)}{T}$

(D) $(R_1 - R_2)(T_1 - T_2)$

6. In a certain nuclear reactor, a radioactive nucleus is being produced at a constant rate = 1000/s. The mean life of the radionuclide is 60 minutes, if there were 20×10^5 radionuclide at t = 0, then the graph of N vs t is :

(A)  (B)  (C)  (D) 

7. A radioactive source in the form of a metal sphere of diameter 3.2×10^{-3} m emits β-particle at a constant rate of 6.25×10^{10} particle/sec. The source is electrically insulated and all the β-particle are emitted from the surface. The potential of the spher will rise to 1 V in time (in μ sec)

8. The mass of ,$^{57}_{27}$Co: 56.936296u;$^{57}_{26}$Fe: 56.935399u are given. Two possible nuclear reactions are proposed

(i) $^{57}_{27}\text{Co}\to{}^{57}_{26}\text{Fe}+{}^{0}_{+1}e+v$ (positron emission)

(ii) $^{57}_{27}\text{Co}+{}^{0}_{+1}e\to{}^{57}_{26}\text{Fe}+v$ (K-shell capture) of these two reactions,

(A) (i) is possible but (ii) is not possible (B) (i) is not possible but (ii) is possible

(C) (i) is possible as well as (ii) is possible (D) (i) is not possible as well as (ii) is not possible

9. **Statement-1 :** Work function of aluminium is 4.2 eV. If two photons each of energy 2.5 eV strikes on a piece of aluminium, the photoelectric emission does not occur.

Statement-2 : In photoelectric effect a single photon interacts with a single electron and electron is emitted only if energy of each incident photon is greater than the work function.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

10. **Statement-1 :** If the accelerating potential of a X-Ray tube is increased then the characteristic wavelength decreases.

Statement-2 : The cut-off wavelength for a X-ray tube is given by $\lambda\frac{hc}{eV_{min}}$, where V is accelerating potential.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

11. Half life for certain radioactive element is 5 min. Four nuclei of that element are observed at a certain instant of time. After five minutes

Statement-1 : It can be definitely said that two nuclei will be left undecayed.

Statement-2 : After half life i.e., 5 minutes, half of total nuclei will disintegrate. So only two nuclei will be left undecayed.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

12. A particular hydrogen like atom has its ground state binding energy 122.4 eV. If it is in ground state. Then:

(A) its atomic number is 3

(B) an electron of 90 eV can exicte it

(C) an electron of kinetic energy nearly 90.8 eV can be brought to almost rest by this atom

(D) an electron of kinetic energy 2.6 eV may emerge from the atom when electron of kinetic energy 125 eV collides with this atom

13. A beam of ultraviolet light of all wavelengths passes thorugh hydrogen gas at room temperature, in the x-direction. Assume that all photons emitted due to eletron transition inside the gas emerge in the y-direction. Let A and B denote the lights emerging from the gas in the x and y directions respectively.

(A) Some of the incident wavelengths will be absent in A

(B) Only those wavelengths will be present in B which are absent in A

(C) B will contain some visible light

(D) B will contain some infrared light

14. In the hydrogen atom, if the reference level of potential energy is assumed to be zero at the ground state level. Choose the incorrect statement.

(A) The total energy of the shell increases with increase in the value of n

(B) The total energy of the shell decrease with increase in the value of n

(C) The difference in total energy of any two shells remains the same

(D) The total energy at the ground state becomes 13.6 eV

15. Choose the correct statement(s) for hydrogen and deuterium atoms (considering motion of nucleus) :

(A) The radius of first Bohr orbit of deuterium is less than that of hydrogen

(B) The speed off electron in the first Bohr orbit of deuterium is more than that of hydrogen

(C) The wavelength of first Balmer line of deuterium is more than that of hydrogen

(D) The angular momentum of electron in the first Bohr orbit of deuterium is more than that of hydrogen

16. A neutron collides head-on with a stationary hydrogen atom in ground state. Which of the following statements are correct (Assume that the hydrogen atom and neutron has same mass) :

(A) If kinetic enrgy of the neutron is less than 20.4 eV collision must be elastic

(B) If kinetic energy of the neutron is less than 20.4 eV collision may be inelastic

(C) Inelastic collision may take place only when initial kinetic energy of neutron is greater than 20.4 eV

(D) Perfectly inelastic collision cannot take place

17. A free hydrogen atom in ground state is at rest. Neutron of kinetic energy 'K' collides with the hydrogen atom. After collision hydrogen atom emits two photons in succession one of which has energy 2.55 eV. (Assume that the hydrogen atom and neutron has same mass)

(A) minimum value of 'K' is 28.5 eV

(B) minimum value of 'K' is 12.75 eV

(C) the other photon has energy 10.2 eV

(D) the upper energy level is of excitation energy 12.75 eV

18. The decay constant of a radioactive substance is 0.173 $(\text{years})^{-1}$. Therefore :

(A) Nearly 63% of the radioactive substance will decay in $\left(\frac{1}{0.173}\right)$ year

(B) half life of the radioactive substance is $\left(\frac{1}{0.173}\right)$ year

(C) one-fourth of the radioactive substance will be left after nearly 4 years

(D) all of the above statements are true

19. Which of the following statement(s) is (are) correct?

(A) The rest mass of a stable nucleus is less than the sum of the rest masses of its separated nucleons

(B) The rest mass of a stable nucleus is greater than the sum of the rest masses of its separated nucleons

(C) In nuclear fusion, energy is released by fusion two nuclei of medium mass (approximately 100 amu)

(D) In nuclear fission, energy is released by fragmentation of a very heavy nucleus

20. In β-decay, the Q-value of the process is E. Then :

(A) K.E. of a β-particle cannot exceed E

(B) K.E. of anti neutrino emitted lies between zero and E

(C) $\frac{N}{Z}$ ratio of the nucleus is altered

(D) Mass number (a) of the nucleus is altered

21. Consider the following nuclear reactions and select the correct statements from the options that follow.

Reaction I : $n \rightarrow p + e^- + \bar{v}$

Reaction II : $p \rightarrow n + e^+ + v$

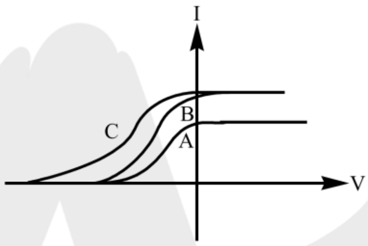
(A) Free neutron is unstable, therefore reaction I is possible

(B) Free proton is stable, therefore reaction II is not possible

(C) Inside a nucleus, both decays (reaction I and II)

(D) Inside a nucleus, reaction I is not possible but reaction II is possible

22. In a photoelectric experiment anode potential is plotted against plate current.



(A) A and B will have different intensities while B and C will have different frequencies

(B) B and C will have different intensities while A and C will have different frequencies

(C) A and B will have different intensities while A and C will have equal frequencies

(D) A and B will have equal intensities while B and C will have different frequencies

23. Highly excited states for hydrogen like atoms (also called Rydberg states) with nuclear charge Ze are defined by their principal quantum number n, where $n >> 1$. Which of the following statement(s) is(are) true?

(A) Relative change in the radii of two consecutive orbitals does not depend on Z

(B) Relative hange in the radii of two consecutive orbitals varies as $\frac{1}{n}$

(C) Relative change in the energy of two consecutive orbitals varies as $\frac{1}{n^3}$

(D) Relative change in the angular moemnt of two consecutive orbitals varies as $\frac{1}{n}$

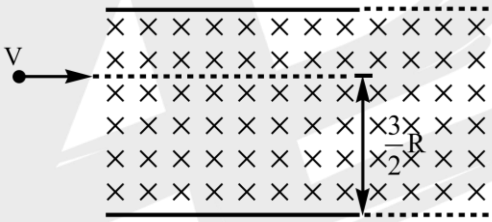
24. A cooling object was emitting radiations of time varying wavelength $\lambda = 3000 + 40t$, where λ is in $\overset{o}{A}$ and t is in second is incident on a metal sheet (of work function 2 eV) such that the power incident on sheet is constant at 100 watt. This signal is switched on and off for time intervals of 2 minutes and 1 minute respectively. Each time the signal is switched on, λ again starts from fresh value of $3000\overset{o}{A}$. If the metal plate is grounded so that it always remains neutral and electron clouding is negligible then find the maximum photocurrent. The photoemission efficiency is 0.01% and remains constant. (Take hc = 12400 eV-$\overset{o}{A}$)

(A) 2 mA (B) 5 mA (C) 3 mA (D) 4 mA

25. A light of wavelength 3540 $\overset{o}{A}$ falls on a metal having work function of 2.5 eV. If ejected electron collides with another target metal inelastically and its total kinetic energy is utilized to raise the temperature of target metal. The mass of target metal is $10^{-3} kg$ and its specific heat is 160 J/kg/ ^{o}C. If 10^{18} electrons are ejected per seond, then find the rate of raise of temperature of the metal [Assume there is no loss of energy of ejected electron by any other process, all the electron are reaching the target metal with max kinetic energy and take hc = 12400 eV- $\overset{o}{A}$]

(A) 1°C/sec (B) 2°C/sec (C) 3°C/sec (D) 4°C/sec

26. Light from a discharge tube containing hydrogen atoms falls on a piece of sodium due to the transition of electron from 4th orbit to 2nd orbit. Work function of sodium is 1.83 eV. The fastest moving photoelectron is allowed to enter in a magnetic field, which is perpendicular to the direction of motion of photoelectron as shown in figure. Find ditance covered by the electron in the magneitc field.

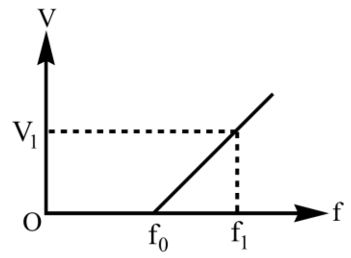


[B =1 Tesla, $\pi^2 = 10$, mass of electron $= 9\times10^{-31}$ kg] where R is the radius of the path that the most energetic electron takes in the presence of applied magnetic field.

(A) 2×10^{-6} m (B) 4×10^{-6} m (C) 6×10^{-6} m (D) 8×10^{-6} m

PROFICIENCY TEST-I

1. In a photoelectric experiment, the potential difference V that must be maintained between the illuminated surface and the collector so as just to prevent any electron from reaching the collector is determined for different frequencies f of the incident illumination. The graph obtained is shown.



The maximum kinetic energy of the electrons emitted at frequency f_1 is :

(A) $h f_1$ (B) $\frac{V_1}{(f_1-f_0)}$ (C) $h(f_1 - f_0)$ (D) $h(\phi_1 + \phi_0)$

2. Cut off potentials for a metal in photoelectric effect for light of wavelength λ_1, λ_2 and λ_3 is found to be V_1, V_2 and V_3 volts if V_1, V_2 and V_3 are in Arithmetic Progression and λ_1, λ_2 and λ_3 will be:

(A) Arithmetic Progression (B) Geometric Progression

(C) Harmonic Progression (D) None of the above

3. In a photoelectric experiment, the collector plate is at 2.0 V with respect to the emitter plate made of copper ($\phi = 4.5$eV). The emitter is illuminated by a source of monochromatic light of wavelength 100 nm.

(A) The minimum kinetic energy of the photoelectrons reaching the collector is 0

(B) The maximum kinetic energy of the photoelectrons reachingg the collector is 9.9 V

(C) If the polarity of the battery is reversed then answer to part A will be 0

(D) If the polarity of the battery is reversed then answer to part B will be 1.7 eV

4. By increasing the intensity of incident light keeping frequency $(v > v_0)$ fixed on the surface of metal :

(A) kinetic energy of the photoelectrons increases

(B) number of emitted electrons increases

(C) kinetic energy and number of electrons increases

(D) no effect

5. An image of the sun is formed by a lens of focal-length of 30 cm on the metal surface of a photoelectric cell and a photoelectric current I is produced. The lens forming the image is then replaced by another of the same diameter but of focal length 15 cm. The photoelectric current in this case is :

(A) $\frac{I}{2}$ (B) I (C) 2I (D) 4I

6. In a hydrogen atom, the electron is in n^{th} excited state. It may come down to second excited state by emitting ten different wavelengths. What is the value of n?

(A) 6 (B) 3 (C) 8 (D) 4

7. An electron in hydrogen atom after absorbing energy photons can jump between energy states n_1 and $n_2(n_2 > n_1)$. Then it may return to ground state after emitting six different wavelengths in emission spectrum. The energy of emitted photons is either equal to, less than or greater than the absorbed photons. Then n_1 and n_2 are :

(A) $n_2 = 6, n_1 = 3$ (B) $n_2 = 5, n_1 = 3$ (C) $n_2 = 4, n_1 = 2$ (D) $n_2 = 5, n_1 = 1$

8. The binding energy per nucleon for C^{12} is 7.68 MeV and that for C^{13} is 7.5 MeV. The energy required to remove a neutron from C^{13} is :

(A) 5.34 MeV (B) 5.5 MeV (C) 9.5 MeV (D) 9.34 MeV

9. The half-life of ^{131}I is 8 days. Given a simple 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 after t = 0

10. When a nucleus with atomic number Z and mass number A undergoes a radioactive decay process:

(A) both Z and A will decrease, if the process is α decay

(B) Z will decrease but A will not change, if the process is β^+ decay

(C) Z will decrease but A will not change, if the process is β^- decay

(D) Z and A will remain unchanged, if the process is γ decay

PROFICIENCY TEST-II

1. Monochromatic light with a frequency well above the cutoff frequency is incident on the emitter in a photoelectric effect apparatus. The frequency of the light is then doubled while the intensity is kept constant. How does this affect the photoelectric current?

(A) The photoelectric current will increase

(B) The photoelectric current will decrease

(C) The photoelectric current will remain the same

(D) None of the above

2. de-Broglie wavelength of an electron in the n^{th} Bohr orbit is λ_n and the angular momentum is J_n, then :

(A) $J_n \propto \lambda_n$ (B) $\lambda_n \propto \frac{1}{J_n}$ (C) $\lambda_n \propto J_n^2$ (D) None of these

3. Light coming from a discharge tube filled with hydrogen falls on the cathode of the photoelectric cell. The work function of the surface of cathode is 4 eV. Which one of the following values of the anode voltage (in Volts) with respect to the cathode is likely to make the photo current zero?

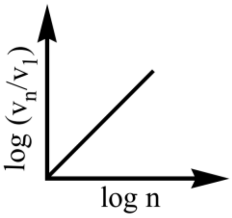
(A) -5 (B) -7 (C) -8 (D) -10

4. Difference between n^{th} and $(n+1)^{th}$ Bohr's radius of 'H' atom is equal to it's $(n-1)^{th}$ Bohr's radius. The value of n is :

(A) 5 (B) 6 (C) 3 (D) 4

5. Monochromatic radiation of wavelength λ is incident on a hydrogen sample containing electron in ground state. Hydrogen atoms absorb the light and subsequently emit radiations of ten different wavelengths. The value of λ (in nm) is

6. The frequency of revolution of electron in n^{th} Bohr orbit is ν_n. The graph between log n and $\log\left(\frac{\nu_n}{\nu_1}\right)$ may be :

(A)


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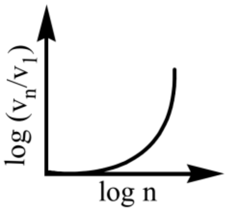

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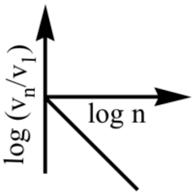

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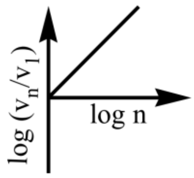


7. If each fission in a U^{235} nucleus releases 200 MeV, how many fissions must occur per second to produce a power of 1 KW?

(A) 1.325×10^{13} (B) 3.125×10^{13} (C) 1.235×10^{13} (D) 2.135×10^{13}

8. A certain radioactive nuclide of mass number m_x disintegrates, with the emission of an electron and γ radiation only, to give second nuclide of mass number m_y. Which one of the following equation correctly relates m_x and m_y?

(A) $m_y = m_x + 1$ (B) $m_y = m_x - 2$ (C) $m_y = m_x - 1$ (D) $m_y = m_x$

9. A fraction f_1 of a radioactive sample decay in one mean life, and a fraction f_2 decays in one half-life.

(A) $f_1 > f_2$

(B) $f_1 < f_2$

(C) $f_1 = f_2$

(D) May be (a), (b) or (c) depending on the values of the mean life and half life

10. At time t = 0, N_1 nuclei of decay constant λ_1 and N_2 nuclei of decay constant λ_2 are mixed. The decay rate of the mixture is :

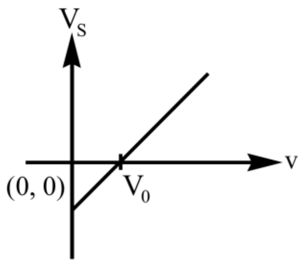
(A) $N_1N_2e^{-(\lambda_1+\lambda_2)t}$

(B) $+\left(\frac{N_1}{N_2}\right)e^{-(\lambda_1-\lambda_2)t}$

(C) $+\left(N_1\lambda_1e^{-\lambda_1 t} + N_2\lambda_2e^{-\lambda_2 t}\right)$

(D) $+N_1\lambda_1N_2\lambda_2e^{-(\lambda_1+\lambda_2)t}$

11. **Statement-1 :** Figure shows graph of stopping potential and frequency of incident light in photoelectric effect. For values of frequency less than threshold frequency (v_0) stopping potential is negative.



Statement-2 : Lower the value of frequency of incident light $(\text{for } v > v_0)$ the lower is the maxima of kinetic energy of emitted photoelectrons.

(A) Statement-1 is true, statement-2 is true and statement-2 is correct explanation for statement-1

(B) Statement-1 is true, statement-2 is true and statement-2 is NOT the correct explanation for statement-1

(C) Statement-1 is true, statement-2 is false

(D) Statement-1 is false, statement-2 is true

12. A small piece of caesium metal (work function $'\phi' = 1.9\ \text{eV}$) is kept at a distance of 20 cm from a large metal plate having a charge density of $1.0 \times 10^{-9}\ \text{C/m}^2$ on surface facing the caesium piece. A monochromatic light of wavelength 400 nm is incident kinetic energy of the photoelectron reaching the large metal plate is given by k. Then find nearest integral value of 'k'.

PROFICIENCY TEST-III

1. Imagine a Young's double slit interference experiment performed with waves associated with fast moving electrons produced from an electron gun. The distance between successive maxima will decrease if :

(A) The accelerating voltage in the electron gun is decreased

(B) The accelerating voltage is increased and the distance of the screen from the slits is decreased

(C) The distance of the screen from the slits is increased

(D) The distance between the slits is decreased

2. The total energy of a hydrogen atom in its ground state is $-13.6\ \text{eV}$. If the potential energy in the first excited state is taken as zero then the total energy in the ground state is $\frac{-68}{n}$. Find n?

3. The binding energies of the atom of elements A and B are E_a and E_b respectively. Three atoms of the element B fuse to give one atom of element A. This fusion process is accompained by release of energy e. Then E_a, E_b are related to each other as :

(A) $E_a + e = 3E_b$ (B) $E_a = 3E_b$ (C) $E_a - e = 3E_b$ (D) $E_a + 3E_b + e = 0$

4. A radioactive material of half-life T was produced in a nuclear reactor at different instants, the quantity produced second time was twice of that produced first time. If now their present activities are A_1 and A_2 respectively then their age difference equals :

(A) $\frac{T}{\ln 2}\left|\ln \frac{A_1}{A_2}\right|$ (B) $T\left|\ln \frac{A_1}{A_2}\right|$ (C) $\frac{T}{\ln 2}\left|\ln \frac{A_2}{2A_1}\right|$ (D) $T\left|\ln \frac{A_2}{2A_1}\right|$

5. The half life of a neutron is 800 sec. 10^8 neutrons at a certain instant are projected from one space station towards another space station, situated 3200 km away, with a velocity 2000 m/s. Their velocity remains constant during the journey. The number of neutrons reach the other station is $n \times 10^6$. Find n?

6. A radioactive sample S_1 having an activity of $5\mu\text{Ci}$ has twice the number of nuclei as another sample S_2 which has an activity of $10\mu\text{Ci}$. The half lives of S_1 and S_2 can be :

(A) 20 years and 5 years, respectively

(B) 20 yeards and 10 years, respectively

(C) 10 years each

(D) 5 years each

7. An electron in hydrogen atom first jumps from second excited state to first excited state and then, from first excited state to ground state. Let the ratio of wavelength, momentum and energy of photons in the two cases be x, y and z, then select the wrong answer/(s) :

(A) $z = \frac{1}{x}$ (B) $z = \frac{9}{4}$ (C) $y = \frac{13}{27}$ (D) $z = \frac{27}{5}$

8. The electron in a hydrogen atom makes a transition $n_1 \rightarrow n_2$, where n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. 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) $n_1 = 6, n_2 = 3$

9. When the atomic number A of the nucleus increases :

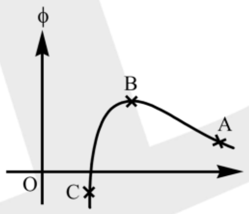
(A) initially the neutron-proton ratio is constant = 1

(B) initially neutron-proton ratio increases and later decreases

(C) initially binding energy per nucleon increases and later decreases

(D) the binding energy per nucleon increases when the neutron-proton ratio increases

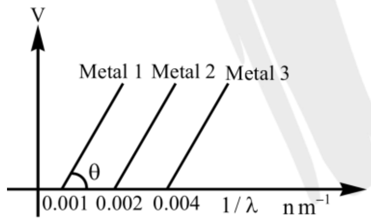
10. The graph shows the variation of potential energy ϕ of a proton with its distance 'r' from a fixed sodium nucleus, as it approaches the nucleus, placed at origin O. Then the portion :



(A) AB indicates nuclear repulsion (B) AB indicates electrostatic repulsion

(C) BC indicates nuclear attraction (D) BC represents electrostatic interaction

11. The graph between $\frac{1}{\lambda}$ and stopping potential (V) of three metals having work functions ϕ_1, ϕ_2 and ϕ_3 in an experiment of photo-electric effect is plotted as shown in the figure. Which of the following statement(s) is/are correct? [Here λ is the wavelength of the incident ray].



(A) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 1 : 2 : 4$

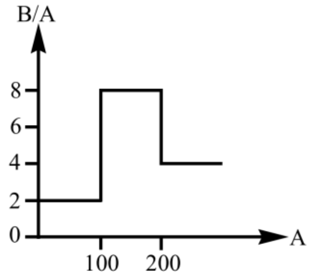
(B) Ratio of work functions $\phi_1 : \phi_2 : \phi_3 = 4 : 2 : 1$

(C) $\tan\theta$ is directly proportional to hc/e, where h is Planck's constant and c is the speed of light

(D) The violet colour light can eject photoelectrons from metals 2 and 3

12. Assume that the nuclear binding energy per nucleon (B/A) versus mass number (A) is as shown in the figure. Use this plot to choose the correct choice(s) given below :

Figure :



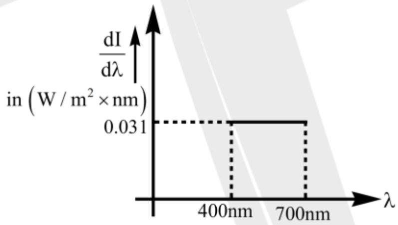
(A) Fusion of two nuclei with mass numbers lying in the range of 1 < A < 50 will release energy

(B) Fusion of two nuclei with mass numbers lying in the range of 51 < A < 100 will release energy

(C) Fission of a nucleus lying in the mass range of 100 < A < 200 will release energy when broken into two equal fragments

(D) Fission of a nucleus lying in the mass range of 200 < A < 260 will release energy when broken into two equal fragments

13. Scientists have made a light source whose spectral emissive power $\frac{dI}{d\lambda}$ is constant over visible range. Here I is intensity and λ is wavelength. In other words. $\frac{dI}{d\lambda}$ graph is shown below. This beam of area $1m^2$ is incident on emitter plate of photoelectric tube. The collector plate is sufficiently positive so that tube is in saturation mode. Assume that each capable photon liberates 1 electron. If work function is 2 eV, what is the current the tube?



(A) 1.4 A
(B) 2 A
(C) 2.4 A
(D) 2.8 A

ANSWER KEY

EXCERCISE-I_KEY

1	2	3	4	5	6	7	8	9	10
C	A	A	C	C	A	B	D	D	D
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
A	C	D	59	A	B	A	AD	D	B

EXCERCISE-II_KEY

1	2	3	4	5	6	7	8	9	10
D	C	D	B	C	C	10	A	C	79
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
C	160	B	D	A	B	C	D	A	B
21	**22**	**23**	**24**	**25**					
A	C	D	A	AC					

EXCERCISE-III_KEY

1	2	3	4	5	6	7	8	9	10
D	C	A	15	B	D	C	C	C	C
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
C	C	C	B	19	C	9	B	C	A
21	**22**	**23**	**24**	**25**	**26**	**27**			
D	BC	B	CD	AC	AC	D			

EXCERCISE-IV_KEY

1	2	3	4	5	6	7	8	9	10
C	D	C	2	D	D	D	10	B	D
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
100	C	135	D	A	D	A	A	A	BC
21									
D									

EXCERCISE-V_KEY

1	2	3	4	5	6	7	8	9	10
D	A	B	C	B	C	18	B	A	D
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
D	AD	ACD	B	A	AC	CD	A	AD	ABC
21	**22**	**23**	**24**	**25**	**26**				
ABC	AB	ABD	B	A	C				

PROFICIENCY TEST-I_KEY

1	2	3	4	5	6	7	8	9	10
C	C	B	B	B	A	C	A	D	ABD

PROFICIENCY TEST-II

1	2	3	4	5	6	7	8	9	10
B	A	D	D	95	C	B	D	A	C
11	**12**								
D	1								

PROFICIENCY TEST-III_KEY

1	2	3	4	5	6	7	8	9	10
B	10	C	C	25	A	BC	AD	AC	BC
11	**12**	**13**							
AC	BD	D							