Chapter

25

Electron, Photon, Photoelectric Effect and X-rays

Electric Discharge Through Gases

At normal atmospheric pressure, the gases are poor conductor of electricity. If we establish a potential difference (of the order of 30 *kV*) between two electrodes placed in air at a distance of few *cm* from each other, electric conduction starts in the form of sparks.

The discharge of electricity through gases can be systematically studied with the help of discharge tube shown below

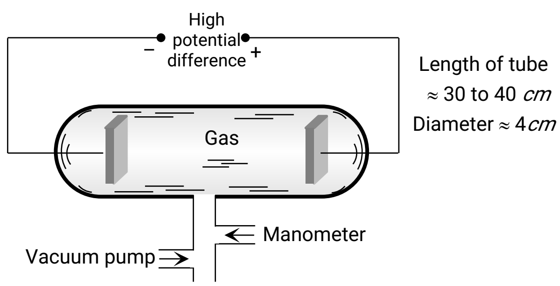


Fig. 25.1

As the pressure inside the discharge tube is gradually reduced, the following is the sequence of phenomenon that are observed.

(1) At normal pressure no discharge takes place.

(2) At the pressure 10 *mm* of *Hg*, a zig-zag thin red spark runs from one electrode to other and cracking sound is heard.

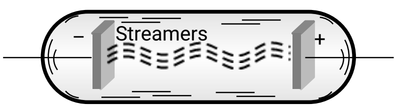


Fig. 25.2

(3) At the pressure 4 *mm.* of *Hg*, an illumination is observed at the electrodes and the rest of the tube appears dark. This type of discharge is called dark discharge.

(4) When the pressure falls below 4 *mm* of *Hg* then the whole tube is filled with bright light called positive column and colour of light depends upon the nature of gas in the tube as shown in the following table.

Table 25.1 : Colour for different gases

Gas	Air	H_2	N_2	Cl_2	CO_2	Neon
Colour	Purple red	Blue	Red	Green	Bluish white	Dark red

(5) At a pressure of 1.65 *mm* of *Hg* :

Sky colour light is produced at the cathode it is called as negative glow. Positive column shrinks towards the anode and the dark space between positive column and negative glow is called Faradays dark space (*FDS*).

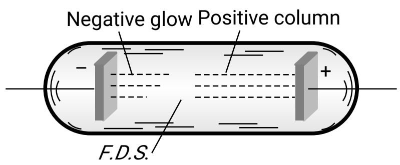


Fig. 25.3

(6) At a pressure of 0.8 *mm* of *Hg* : At this pressure, negative glow is detached from the cathode and moves towards the anode. The dark space created between cathode and negative glow is called as Crook's dark space. Length of positive column further reduced. A glow appear at cathode called cathode glow.

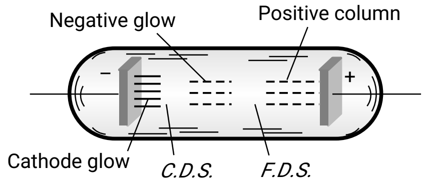


Fig. 25.4

(7) At a pressure of 0.05 *mm* of *Hg* : The positive column splits into dark and bright disc of light called striations.

(8) At the pressure of 0.01 or 10^{-2} *mm* of *Hg* some invisible

particles move from cathode which on striking with the glass tube on the opposite side of cathode cause the tube to glow. These invisible rays emerging from cathode are called cathode rays.

(9) Finally when pressure drops to nearly 10^{-4} *mm* of *Hg*, there is no discharge in tube.

Cathode Rays

(1) Cathode rays, discovered by Sir William Crooke

(2) They are streams of fast moving electrons.

(3) They can be produced by using a discharge tube containing gas at a low pressure of the order of 10^{-2} *mm* of *Hg*.

(4) The cathode rays in the discharge tube are the electrons produced due to ionisation of gas and that emitted by cathode due to collision of positive ions.

(5) Cathode rays travel in straight lines.

(6) Cathode rays are emitted normally from the cathode surface. Their direction is independent of the position of the anode.

(7) Cathode rays exert mechanical force on the objects they strike.

(8) Cathode rays produce heat when they strikes a metal surface.

(9) Cathode rays produce fluorescence.

(10) When cathode rays strike a solid object, specially a metal of high atomic weight and high melting point *X*-rays are emitted from the objects.

(11) Cathode rays are deflected by an electric field and also by a magnetic field.

(12) Cathode rays ionise the gases through which they are passed.

(13) Cathode rays can penetrate through thin foils of metal.

(14) Cathode rays are found to have velocity ranging $\frac{1}{30}th$ to $\frac{1}{10}th$ of velocity of light.

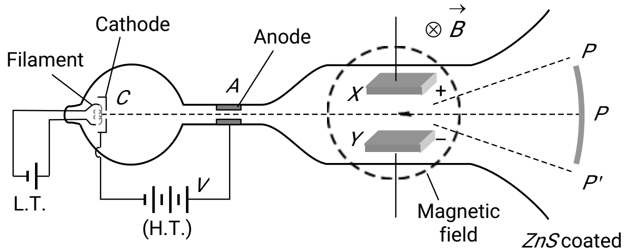
J.J. Thomson's Experiment

(1) It's working is based on the fact that if a beam of electron is subjected to the crossed electric field $\vec{E}$ and magnetic field $\vec{B}$, it experiences a force due to each field. In case the forces on the electrons in the electron beam due to these fields are equal and opposite, the beam remains undeflected.

(2) When no field is applied, the electron beam produces illuminations at point *P*.

(3) In the presence of any field (electric and magnetic) electron beam deflected up or down (illumination at P' or P'')

(4) If both the fields are applied simultaneously and adjusted such that electron beam passes undeflected and produces illumination at point *P*.



In this case; Electric force = Magnetic force ⇒ $eE = evB$

Fig. 25.5

$\Rightarrow \; v = \frac{E}{B}$; v = velocity of electron

(5) As electron beam accelerated from cathode to anode its loss in potential energy appears as gain in the K.E. at the anode. If suppose *V* is the potential difference between cathode and anode then, loss in potential energy = *eV*

And gain in kinetic energy at anode will be K.E. $= \frac{1}{2}mv^2$

i.e. $eV = \frac{1}{2}mv^2 \Rightarrow \frac{e}{m} = \frac{v^2}{2V} \Rightarrow \frac{e}{m} = \frac{E^2}{2VB^2}$

Thomson found, $\frac{e}{m} = 1.77 \times 10^{11}\ C/kg$.

If one includes the relativistic variation of mass with speed $(m = m_0/\sqrt{1 - v^2/c^2})$, then specific charge of an electron decreases with the increase in its velocity.

(6) The deflection of an electron in a purely electric field is given by $y = \frac{1}{2}\left(\frac{eE}{m}\right)\cdot\frac{l^2}{v^2}$; where l = Length of each plate, y = deflection of electron in the field region, v = speed of the electron.

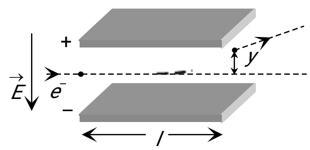


Fig. 25.6

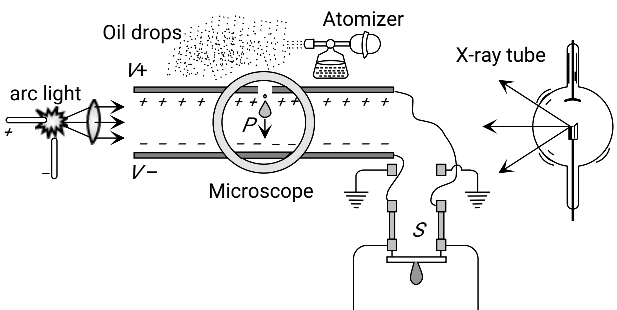
Millikans Oil Drop Experiment

(1) Millikan performed the pioneering oil drop experiment for the precise measurement of the charge on the electron.

(2) By applying suitable electric field across two metal plates, the charged oil droplets could be caused to rise or fall or even held stationary in the field of view for sufficiently long time. He found that the charge on an oil droplet was always an integral multiple of an elementary charge 1.602×10^{-19} *C*.

(3) In this experiment charge on the drop is given by

$$q = \frac{6\pi\eta(v_1 + v_2)d}{v}\left[\frac{9\eta v_1}{2g(\rho - \sigma)}\right]^{1/2}$$



where η = Coefficient of viscosity of air, v_1 = Terminal velocity of drop when no electric field is applied between the plates, v_2 = Terminal velocity of drop when electric field is applied between the plates.

V = Potential difference between the plates, d = Separation between plates, ρ = density of oil, σ = Density of air.

Positive Rays

When potential difference is applied across the electrodes of a discharge tube (10^{-3} *mm* of *Hg*), electrons are emitted from the perforated cathode. As they move towards anode, they gain energy. These energetic electrons when collide with the atoms of the gas in the discharge tube, they ionize the atoms. The positive ions so formed at various places between cathode and anode, travel towards the cathode. Since during their motion, the positive ions when reach the cathode, some pass through the holes in the cathode and a faint luminous glow comes out from each hole on the backside of the cathode. It is called positive rays, which are coming out from the holes.

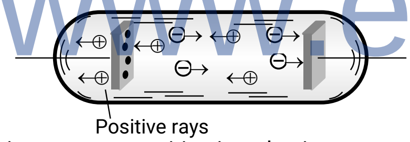


Fig. 25.8

(1) Positive rays are positive ions having same mass if the experimental gas does not have isotopes. However if the gas has isotopes then positive rays are group of positive ions having different masses.

(2) They travel in straight lines and cast shadows of objects placed in their path. But the speed of the positive rays is much smaller than that of cathode rays.

(3) They are deflected by electric and magnetic fields but the deflections are small as compared to that for cathode rays.

(4) They show a spectrum of velocities. Different positive ions move with different velocities. Being heavy, their velocity is much less than that of cathode rays.

(5) q/m ratio of these rays depends on the nature of the gas in the tube (while in case of the cathode rays q/m is constant and doesn't depend on the nature of gas in the tube). q/m for hydrogen is maximum.

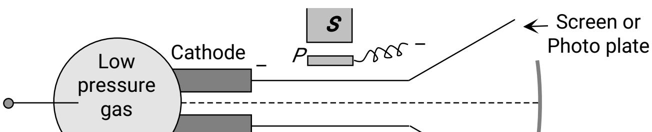
(6) They carry energy and momentum. The kinetic energy of positive rays is more than that of cathode rays.

(7) The value of charge on positive rays is an integral multiple of electronic charge.

(8) They cause ionisation (which is much more than that produced by cathode rays).

Thomson's Mass Spectrograph

It is used to measure atomic masses of various isotopes in



gas. This is done by measuring q/m of singly ionised positive ion of the gas.

(1) The positive ions are produced in the bulb at the left hand side. These ions are accelerated towards cathode. Some of the positive ions pass through the fine hole in the cathode. This fine ray of positive ions is subjected to electric field E and magnetic field B and then allowed to strike a fluorescent screen ($\vec{E} \parallel \vec{B}$ but $\vec{E}$ or $\vec{B} \perp \vec{v}$).

(2) If the initial motion of the ions is in $+x$ direction and electric and magnetic fields are applied along $+y$ axis then force due to electric field is in the direction of y-axis and due to magnetic field it is along z-direction.

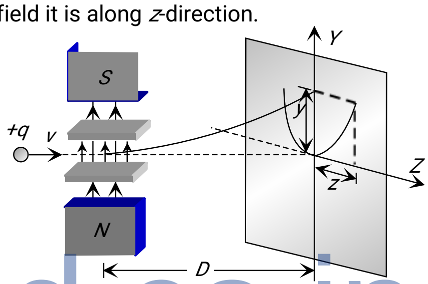


Fig. 25.10

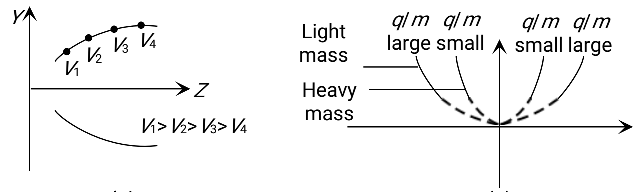
The deflection due to electric field alone $y = \frac{qELD}{mv^2}$ .....(i)

The deflection due to magnetic field alone $z = \frac{qBLD}{mv}$ .....(ii)

From equation (i) and (ii), $z^2 = k\left(\frac{q}{m}\right)y$

where $k = \frac{B^2LD}{E}$; This is the equation of parabola. It means all the charged particles moving with different velocities but of same q/m value will strike the screen placed in yz plane on a parabolic track as shown in the above figure.

(3) All the positive ions of same. q/m moving with different velocity lie on the same parabola. Higher is the velocity lower is the value of y and z. The ions of different specific charge will lie on different parabola.



(A) (B)

Fig. 25.11

(4) The number of parabola tells the number of isotopes present in the given ionic beam.

Bainbridge Mass Spectrograph

In Bainbridge mass spectrograph, field particles of same velocity are selected by using a velocity selector and then they are subjected to a uniform magnetic field perpendicular to the velocity of the particles. The particles corresponding to different isotopes follow different circular paths as shown in the figure.

(1) **Velocity selector :** The positive ions having a certain velocity v gets isolated from all other velocity particles. In this chamber the electric and magnetic fields are so balanced that the particle moves undeflected. For this the necessary condition is $v = \frac{E}{B}$ and E, B and v should be mutually perpendicular to each other.

(2) **Analysing chamber :** In this chamber magnetic field B is applied perpendicular to the direction of motion of the particle. As a result the particles move along a circular path of radius

$$r = \frac{mE}{qBB'} \Rightarrow \frac{q}{m} = \frac{E}{BB'r} \text{ also } \frac{r_1}{r_2} = \frac{m_1}{m_2}$$

In this way the particles of different masses gets deflected on circles of different radii and reach on different points on the photo plate.

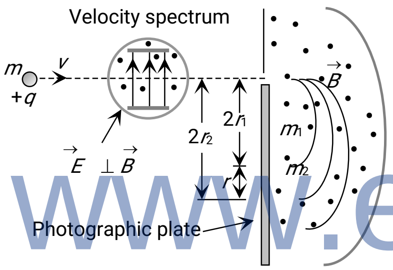


Fig. 25.12

Separation between two traces

$$= d = 2r_2 - 2r_1 = \frac{2v(m_2 - m_1)}{qB'}.$$

Matter Waves (de-Broglie Waves)

According to de-Broglie a moving material particle sometimes acts as a wave and sometimes as a particle.

The wave associated with moving particle is called matter wave or de-Broglie wave and it propagates in the form of wave packets with group velocity.

(1) **de-Broglie wavelength :** According to de-Broglie theory, the wavelength of de-Broglie wave is given by

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

Where h = Plank's constant, m = Mass of the particle, v = Speed of the particle, E = Energy of the particle.

The smallest wavelength whose measurement is possible is that of γ-rays.

The wavelength of matter waves associated with the microscopic particles like electron, proton, neutron, α-particle *etc*. is of the order of 10^{-10} *m*.

(2) **de-Broglie wavelength associated with the charged particles :** The energy of a charged particle accelerated through potential difference V is $E = \frac{1}{2}mv^2 = qV$

Hence de-Broglie wavelength $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2mqV}}$

$$\lambda_{Electron} = \frac{12.27}{\sqrt{V}} Å, \quad \lambda_{Proton} = \frac{0.286}{\sqrt{V}} Å,$$

$$\lambda_{Deutron} = \frac{0.202}{\sqrt{V}} Å, \quad \lambda_{\alpha-particle} = \frac{0.101}{\sqrt{V}} Å$$

(3) **de-Broglie wavelength associated with uncharged particles :** For *Neutron* de-Broglie wavelength is given as

$$\lambda_{Neutron} = \frac{0.286 \times 10^{-10}}{\sqrt{E \text{ (in } eV)}} m = \frac{0.286}{\sqrt{E \text{ (in } eV)}} Å$$

Energy of thermal neutrons at ordinary temperature

$\because$ $E = kT \Rightarrow \lambda = \frac{h}{\sqrt{2mkT}}$; where T = Absolute temperature, k = Boltzman's constant = 1.38×10^{-23} *Joule/kelvin*, So,

$$\lambda_{Thermal\ neutron} = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 1.67 \times 10^{-27} \times 1.38 \times 10^{-23} T}} = \frac{30.83}{\sqrt{T}} Å$$

(4) **Ratio of wavelength of photon and electron :** The wavelength of a photon of energy E is given by $\lambda_{ph} = \frac{hc}{E}$

While the wavelength of an electron of kinetic energy K is given by $\lambda_e = \frac{h}{\sqrt{2mK}}$. Therefore, for the same energy,

the ratio $\frac{\lambda_{ph}}{\lambda_e} = \frac{c}{E}\sqrt{2mK} = \sqrt{\frac{2mc^2K}{E^2}}$

Characteristics of Matter Waves

(1) Matter wave represents the probability of finding a particle in space.

(2) Matter waves are not electromagnetic in nature.

(3) de-Broglie or matter wave is independent of the charge on the material particle. It means, matter wave of de-Broglie wave is associated with every moving particle (whether charged or uncharged).

(4) Practical observation of matter waves is possible only when the de-Broglie wavelength is of the order of the size of the particles.

(5) Electron microscope works on the basis of de-Broglie waves.

(6) The phase velocity of the matter waves can be greater than the speed of the light.

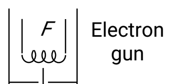
(7) Matter waves can propagate in vacuum, hence they are not mechanical waves.

(8) The number of de-Broglie waves associated with n^{th} orbital electron is n.

(9) Only those circular orbits around the nucleus are stable whose circumference is integral multiple of de-Broglie wavelength associated with the orbital electron.

Davision and Germer Experiment

(1) It is used to study the scattering of electron from a solid or to verify the wave nature of electron. A beam of electrons



emitted by electron gun is made to fall on nickel crystal cut along cubical axis at a particular angle. *Ni* crystal behaves like a three dimensional diffraction grating and it diffracts the electron beam obtained from electron gun.

(2) The diffracted beam of electrons is received by the detector which can be positioned at any angle by rotating it about the point of incidence. The energy of the incident beam of electrons can also be varied by changing the applied voltage to the electron gun.

(3) According to classical physics, the intensity of scattered beam of electrons at all scattering angle will be same but Davisson and Germer, found that the intensity of scattered beam of electrons was not the same but different at different angles of scattering. It is maximum for diffracting angle 50° at 54 *volt* potential difference.

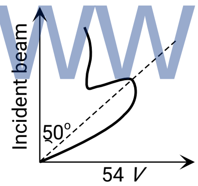


Fig. 25.14

(4) If the de-Broglie waves exist for electrons then these should be diffracted as *X*-rays. Using the Bragg's formula $2d\sin\theta = n\lambda$, we can determine the wavelength of these waves.

where d = distance between diffracting planes, $\theta = \frac{(180 - \phi)}{2}$ = glancing angle for incident beam = Bragg's angle.

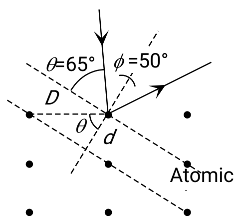


Fig. 25.15

The distance between diffracting planes in *Ni*-crystal for this experiment is $d = 0.91 Å$ and the Bragg's angle = 65°. This gives for $n = 1$, $\lambda = 2 \times 0.91 \times 10^{-10} \sin 65^{o} = 1.65\ Å$

Now the de-Broglie wavelength can also be determined by using the formula $\lambda = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{54}} = 1.67\ Å$. Thus the de-Broglie hypothesis is verified.

(5) The Bragg's formula can be rewritten in the form containing interatomic distance D and angle ϕ

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

Using $\sin\theta = \cos\frac{\phi}{2}$

$$2d\sin\theta = \lambda \Rightarrow 2(D\sin\frac{\phi}{2}).\cos\frac{\phi}{2} = \lambda \Rightarrow D\sin\phi = \lambda$$

Heisenberg Uncertainty Principle

(1) According to Heisenberg's uncertainty principle, it is impossible to measure simultaneously both the position and the momentum of the particle.

(2) Let Δx and Δp be the uncertainty in the simultaneous measurement of the position and momentum of the particle, then $\Delta x \Delta p = \hbar$; where $\hbar = \frac{h}{2\pi}$ and $h = 6.63 \times 10^{-34}$ *J-s* is the Planck's constant. $(\frac{h}{2\pi} = 1.05 \times 10^{-34}\ J\text{-}sec)$

A more rigorous treatment gives $\Delta x . \Delta p \ge \frac{\hbar}{2}\left(\text{or } \frac{h}{4\pi}\right)$.

(3) If $\Delta x = 0$ then $\Delta p = \infty$ and if $\Delta p = 0$ then $\Delta x = \infty$

i.e., if we are able to measure the exact position of the particle (say an electron) then the uncertainty in the measurement of the linear momentum of the particle is infinite. Similarly, if we are able to measure the exact linear momentum of the particle *i.e.,* $\Delta p = 0$, then we can not measure the exact position of the particle at that time.

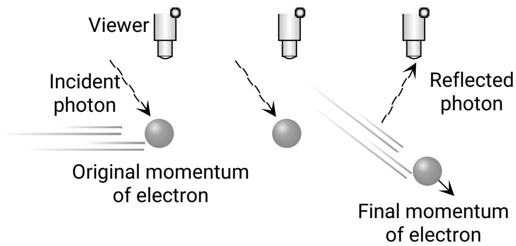


Fig. 25.16

An electron cannot be observed without changing it's momentum

(4) Uncertainty principle successfully explains

(i) Non-existence of electrons in the nucleus

(ii) Finite size of spectral lines.

(5) The Heisenberg uncertainty principle is also applicable to energy and time, angular momentum and angular displacement. Hence $\Delta E . \Delta t \ge \frac{h}{2\pi}$ and $\Delta L . \Delta\theta \ge \frac{h}{2\pi}$

(6) If the radius of the nucleus is r then the probability of finding the electron inside the nucleus is $\Delta x = 2r$ and uncertainty in momentum is $\Delta p = \frac{h}{4\pi r}$

Photon

According to Eienstein's quantum theory light propagates in the bundles (packets or quanta) of energy, each bundle being called a photon and possessing energy.

(1) **Energy of photon :** Energy of photon is given by

$E = h\nu = \frac{hc}{\lambda}$; where c = Speed of light, h = Plank's constant = 6.6 × 10^{-34} J-sec, ν = Frequency in Hz, λ = Wavelength of light.

In electron volt $E(eV) = \frac{hc}{e\lambda} = \frac{12375}{\lambda(\text{Å})} \approx \frac{12400}{\lambda(\text{Å})}$

(2) **Mass of photon :** Actually rest mass of the photon is zero. But it's effective mass is given as

$E = mc^2 = h\nu \Rightarrow m = \frac{E}{c^2} = \frac{h\nu}{c^2} = \frac{h}{c\lambda}$. This mass is also known as kinetic mass of the photon

(3) **Momentum of the photon**

Momentum $p = m \times c = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}$

(4) **Number of emitted photons :** The number of photons emitted per second from a source of monochromatic radiation of wavelength λ and power P is given as $(n) = \frac{P}{E} = \frac{P}{h\nu} = \frac{P\lambda}{hc}$; where E = energy of each photon

(5) **Intensity of light (I) :** Energy crossing per unit area normally per second is called intensity or energy flux

i.e. $I = \frac{E}{At} = \frac{P}{A}$ $\left(\frac{E}{t} = P = \text{radiation power}\right)$

At a distance r from a point source of power P intensity is given by $I = \frac{P}{4\pi r^2} \Rightarrow I \propto \frac{1}{r^2}$

(6) **Number of photons falling per second (n) :** If P is the power of radiation and E is the energy of a photon then $n = \frac{P}{E}$

Photo-Electric Effect

The photo-electric effect is the emission of electrons (called photo-electrons when light strikes a surface. To escape from the surface, the electron must absorb enough energy from the incident radiation to overcome the attraction of positive ions in the material of the surface.

The photoelectric effect was first observed by Heinrich Hertz and it was investigated in detail by Whilelm Hallwachs and Philipp Lenard.

The photoelectric effect is based on the principle of conservation of energy.

(1) **Work function (or threshold energy) (W_0) :** The minimum energy of incident radiation, required to eject the electrons from metallic surface is defined as work function of that surface.

$W_0 = h\nu_0 = \frac{hc}{\lambda_0}$ *Joules* ; ν_0 = Threshold frequency; λ_0 = Threshold wavelength

Work function in electron volt $W_0(eV) = \frac{hc}{e\lambda_0} = \frac{12375}{\lambda_0(\text{Å})}$

Table 25.2 : Work function of several elements

Element	Work function (eV)	Element	Work function (eV)
Platinum	6.4	Aluminum	4.3
Gold	5.1	Silver	4.3
Nickel	5.1	Sodium	2.7
Carbon	5.0	Lithium	2.5
Silicon	4.8	Potassium	2.2
Copper	4.7	Cesium	1.9

(2) **Threshold frequency (ν_0) :** The minimum frequency of incident radiations required to eject the electron from metal surface is defined as threshold frequency.

If incident frequency $\nu < \nu_0 \Rightarrow$ No photoelectron emission

For most metals the threshold frequency is in the ultraviolet (corresponding to wavelengths between 200 and 300 nm), but for potassium and cesium oxides it is in the visible spectrum (λ between 400 and 700 nm)

(3) **Threshold wavelength (λ_0) :** The maximum wavelength of incident radiations required to eject the electrons from a metallic surface is defined as threshold wavelength.

If incident wavelength $\lambda > \lambda_0 \Rightarrow$ No photoelectron emission

(4) **Einstein's photoelectric equation :** According to Einstein, photoelectric effect is the result of one to one inelastic collision between photon and electron in which photon is completely absorbed

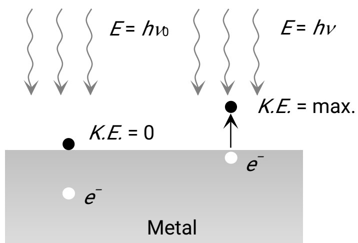


Figure 25.17

Einstein's photoelectric equation is $E = W_0 + K_{max}$

where $K_{max} = \frac{1}{2}mv_{max}^2$ = maximum kinetic energy of emitted electrons.

Experimental Setup for Photoelectric Effect

(1) Two conducting electrodes, the anode (Q) and cathode (P) are enclosed in an evacuated glass tube as shown

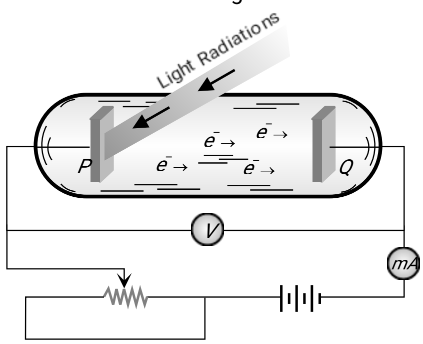


Fig. 25.18

(2) The battery or other source of potential difference creates an electric field in the direction from anode to cathode.

(3) Light of certain wavelength or frequency falling on the surface of cathode causes a current in the external circuit called photoelectric current.

(4) As potential difference increases, photo electric current also increases till saturation is reached.

(5) When polarity of battery is reversed (*i.e.* plate Q is at negative potential *w.r.t.* plate P) electrons start moving back towards the cathode.

(6) At a particular negative potential of plate Q no electron will reach the plate Q and the current will become zero, this negative potential is called **stopping potential** denoted by V_0. Maximum kinetic energy of photo electrons in terms of stopping potential will therefore be $K_{max} = (|V_0|)\ eV$

Effect of Intensity and Frequency of Light

(1) **Effect of intensity :** If the intensity of light is increased (while it's frequency is kept the same) the current levels off at a higher value, showing that more electrons are being emitted per unit time. But the stopping potential V_0 doesn't change *i.e.*

Intensity $\propto$ no. of incident photon $\propto$ no. of emitted photoelectron per time $\propto$ photo current

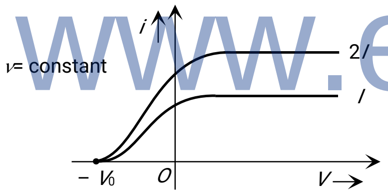


Fig. 25.19

(2) **Effect of frequency :** If frequency of incident light increases, (keeping intensity is constant) stopping potential increases but their is no change in photoelectric current

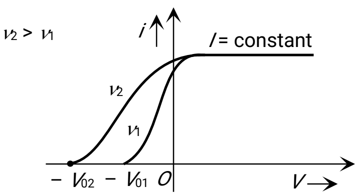


Fig. 25.20

Important Formulae for Photoelectric Effect

(1) $h\nu = h\nu_0 + K_{max}$ and $K_{max} = eV_0$

(2) $K_{max} = eV_0 = h(\nu - \nu_0) \Rightarrow \frac{1}{2}mv_{max}^2 = h(\nu - \nu_0)$

(3) $v_{max} = \sqrt{\frac{2h(\nu - \nu_0)}{m}}$

(4) $K_{max} = \frac{1}{2}mv_{max}^2 = eV_0 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)$

(5) $v_{max} = \sqrt{\frac{2hc}{m}\frac{(\lambda_0 - \lambda)}{\lambda\lambda_0}}$

(6) $V_0 = \frac{h}{e}(\nu - \nu_0) = \frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = 12375\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$

Compton Effect

(1) The scattering of a photon by an electron is called Compton effect.

(2) The energy and momentum is conserved.

(3) Scattered photon will have less energy (more wavelength) as compare to incident photon (less wavelength).

(4) The energy lost by the photon is taken by electron as kinetic energy.

(5) The change in wavelength due to Compton effect is called Compton shift. Compton shift

$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_0 c}(1 - \cos\phi)$

If $\phi = 0^\circ$, $\Delta\lambda = 0$

$\phi = 90^\circ$, $\Delta\lambda = \frac{h}{m_0 c} = 0.24\ nm$

$\phi = 180^\circ$, $\Delta\lambda = \frac{2h}{m_0 c} = 0.48\ nm$ (called Compton wave length)

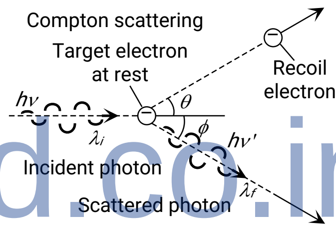


Fig. 25.21

X-Rays

(1) X-rays were discovered by scientist Rontgen thats why they are also called Rontgen rays.

(2) Rontgen discovered that when pressure inside a discharge tube is kept 10^{-3} *mm* of *Hg* and potential difference is kept 25 *kV*, then some unknown radiations (X-rays) are emitted by anode.

(3) There are three essential requirements for the production of X-rays.

(i) A source of electron

(ii) An arrangement to accelerate the electrons

(iii) A target of suitable material of high atomic weight and high melting point on which these high speed electrons strike.

Coolidge X-Ray Tube

(1) It consists of a highly evacuated glass tube containing cathode and target (also known as filament type X-ray tube). The cathode consist of a tungsten filament. The filament is coated with oxides of barium or strontium to have an emission of electrons even at low temperature. The filament is surrounded by a molybdenum cylinder kept at negative potential *w.r.t.* the target.

(2) The target (It is a material of high atomic weight, high melting point and high thermal conductivity) made of tungsten or molybdenum is embedded in a copper block.

(3) The face of the target is set at 45° to the incident electron stream.

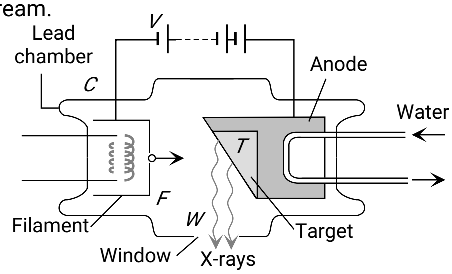


Fig. 25.22

(4) The filament is heated by passing the current through it. A high potential difference (≈ 10 *kV* to 80 *kV*) is applied between the target and cathode to accelerate the electrons which are emitted by filament. The stream of highly energetic electrons are focussed on the target.

(5) Most of the energy of the electrons is converted into heat (above 98%) and only a fraction of the energy of the electrons (about 2%) is used to produce X-rays.

(6) During the operation of the tube, a huge quantity of heat is produced in this target, this heat is conducted through the copper anode to the cooling fins from where it is dissipated by radiation and convection.

(7) **Control of intensity of X-rays** : Intensity implies the number of X-ray photons produced from the target. The intensity of X-rays emitted is directly proportional to the electrons emitted per second from the filament and this can be increased by increasing the filament current. So *intensity of X-rays* $\propto$ *Filament current*

(8) **Control of quality or penetration power of X-rays :** Quality of X-rays implies the penetrating power of X-rays, which can be controlled by varying the potential difference between the cathode and the target.

For large potential difference, energy of bombarding electrons will be large and hence larger is the penetration power of X-rays.

Table 25.3 : Types of X-rays

Hard X-rays	Soft X-rays
More penetration power	Less penetration power
More frequency of the order of $\approx 10^{19}$ *Hz*	Less frequency of the order of $\approx 10^{16}$ *Hz*
Lesser wavelength range (0.1Å – 4Å)	More wavelength range (4Å – 100Å)

Properties of X-Rays

(1) X-rays are electromagnetic waves with wavelength range 0.1Å – 100Å.

(2) The wavelength of X-rays is very small in comparison to the wavelength of light. Hence they carry much more energy (This is the only difference between X-rays and light)

(3) X-rays are invisible.

(4) They travel in a straight line with speed of light.

(5) X-rays are measured in Rontgen (measure of ionization power).

(6) X-rays carry no charge so they are not deflected in magnetic field and electric field.

(7) $\lambda_{Gama\ \ rays} < \lambda_{X\text{-}rays} < \lambda_{UV\ \ rays}$

(8) They used in the study of crystal structure.

(9) They ionise gases

(10) X-rays do not pass through heavy metals and bones.

(11) They affect photographic plates.

(12) Long exposure to X-rays is injurious for human body.

(13) Lead is the best absorber of X-rays.

(14) For X-ray photography of human body parts, $BaSO_4$ is the best absorber.

(15) They produce photoelectric effect and Compton effect

(16) X-rays are not emitted by hydrogen atom.

(17) These cannot be used in Radar because they are not reflected by the target.

(18) They show all the important properties of light rays like; reflection, refraction, interference, diffraction and polarization *etc*.

Absorption of X-Rays

X-rays are absorbed when they incident on substance.

Intensity of emergent X-rays $I = I_0 e^{-\mu x}$

So intensity of absorbed X-rays

$I' = I_0 - I = I_0(1 - e^{-\mu x})$

where x = thickness of absorbing medium, μ = absorption coefficient

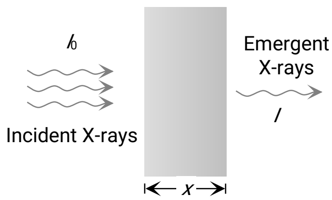


Fig. 25.23

$\mu \propto \lambda^3$; (λ = Wavelength of X-ray)

$\mu \propto \overline{\nu}^3$ ($\nu =$ Frequency of X-ray)

$\mu \propto Z^4$ ($Z =$ Atomic number of target)

Classification of X-Rays

In X-ray tube, when high speed electrons strikes the target, they penetrate the target. They loses their kinetic energy and comes to rest inside the metal. The electron before finally being stopped makes several collisions with the atoms in the target. At each collision one of the following two types of X-rays may get formed.

(1) Continuous X-rays

(2) Characteristic X-rays

Continuous X-Rays

As an electron passes close to the positive nucleus of atom of the target, the electron is deflected from it's path as shown in figure. This results in deceleration of the electron. The loss in energy of the electron during deceleration is emitted in the form of X-rays.

The X-ray photons so emitted form the continuous X-ray spectrum.

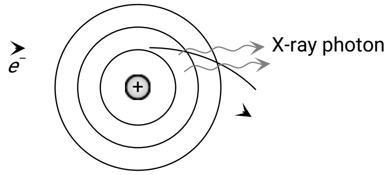


Fig. 25.24

(1) **Minimum wavelength :** When the electron looses whole of it's energy in a single collision with the atom, an X-ray photon of maximum energy $h\nu_{max}$ is emitted *i.e.*

$$\frac{1}{2}mv^2 = eV = h\nu_{max} = \frac{hc}{\lambda_{min}}$$

where v = velocity of electron before collision with target atom, V = potential difference through which electron is accelerated, c = speed of light = 3×10^8 *m/s*

Maximum frequency of radiations (X-rays) $\nu_{max} = \frac{eV}{h}$

Minimum wavelength = cut off wavelength of X-ray

$$\lambda_{min} = \frac{hc}{eV} = \frac{12375}{V} Å$$

(2) **Intensity wavelength graph :** The continuous X-ray spectra consist of all the wavelengths over a given range. These wavelength are of different intensities. Following figure shows the intensity variation of different wavelengths for various accelerating voltages applied to X-ray tube.

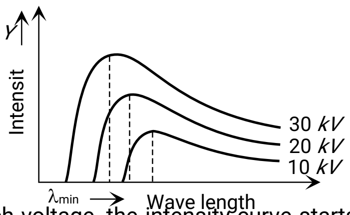


Fig. 25.25

For each voltage, the intensity curve starts at a particular minimum wavelength (λ_{min}). Rises rapidly to a maximum and then drops gradually.

The wavelength at which the intensity is maximum depends on the accelerating voltage, being shorter for higher voltage and vice-versa.

Characteristic X-Rays

Few of the fast moving electrons having high velocity penetrate the surface atoms of the target material and knock out the tightly bound electrons even from the inner most shells of the atom. Now when the electron is knocked out, a vacancy is created at that place.

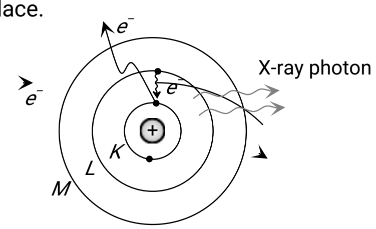


Fig. 25.26

To fill this vacancy electrons from higher shells jump to fill the created vacancies, we know that when an electron jumps from a higher energy orbit E_1 to lower energy orbit E_2, it radiates energy $(E_1 - E_2)$. Thus this energy difference is radiated in the form of X-rays of very small but definite wavelength which depends upon the target material. The X-ray spectrum consists of sharp lines and is called characteristic X-ray spectrum.

(1) ***K, L, M, …… series* :** If the electron striking the target eject an electron from the *K*-shell of the atom, a vacancy is created in the *K*-shell. Immediately an electron from one of the outer shell, say *L*-shell jumps to the *K*-shell, emitting an X-ray photon of energy equal to the energy difference between the two shells. Similarly, if an electron from the *M*-shell jumps to the *K*-shell, X-ray photon of higher energy is emitted. The X-ray photons emitted due to the jump of electron from the *L*, *M*, *N* shells to the K-shells gives K_α, K_β, K_γ lines of the *K*-series of the spectrum.

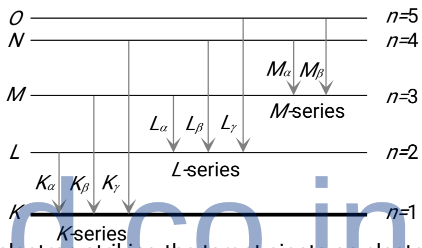


Fig. 25.27

If the electron striking the target ejects an electron from the *L*-shell of the target atom, an electron from the *M*, *N* ….. shells jumps to the *L*-shell so that X-rays photons of lesser energy are emitted.

These photons form the *L*-series of the spectrum. In a similar way the formation of *M* series, *N* series *etc*. may be explained.

(2) **Intensity-wavelength graph :** At certain sharply defined wavelengths, the intensity of X-rays is very large as marked K_α, K_β …. as shown in figure. These X-rays are known as characteristic X-rays. At other wavelengths the intensity varies gradually and these X-rays are called continuous X-rays.

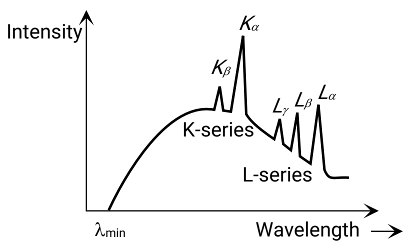


Fig. 25.28

Mosley's Law

Mosley studied the characteristic *X*-ray spectrum of a number of a heavy elements and concluded that the spectra of different elements are very similar and with increasing atomic number, the spectral lines merely shift towards higher frequencies.

He also gave the following relation $\sqrt{\nu} = a(Z-b)$

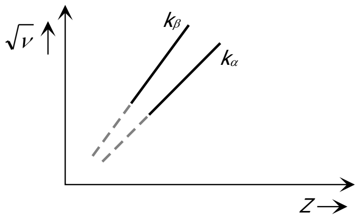


Fig. 25.29

where ν = Frequency of emitted line, Z = Atomic number of target, a = Proportionality constant, b = Screening constant or Shielding constant.

$(Z-b)$ = Effective atomic number

a and b doesn't depend on the nature of target. Different values of b are as follows

$b = 1$	for	K-series
$b = 7.4$	for	L-series
$b = 19.2$	for	M-series

(1) Mosley's law supported Bohr's theory

(2) It experimentally determined the atomic number (Z) of elements.

(3) This law established the importance of ordering of elements in periodic table by atomic number and not by atomic weight.

(4) Gaps in Moseley's data for A = 43, 61, 72, 75 suggested existence of new elements which were later discovered.

(5) The atomic numbers of Cu, Ag and Pt were established to be 29, 47 and 78 respectively.

(6) When a vacancy occurs in the K-shell, there is still one electron remaining in the K-shell. An electron in the L-shell will feel an effective charge of $(Z-1)e$ due to $+Ze$ from the nucleus and $-e$ from the remaining K-shell electron, because L-shell orbit is well outside the K-shell orbit.

(7) Wave length of characteristic spectrum $\frac{1}{\lambda} = R(Z-b)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ and energy of X-ray radiations.

$$\Delta E = h\nu = \frac{hc}{\lambda} = Rhc\,(Z-b)^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(8) If transition takes place from $n_2 = 2$ to $n_1 = 1$ (K_α - line)

(i) $a = \sqrt{\frac{3RC}{4}} = 2.47 \times 10^{15}\ Hz$

(ii) $\nu_{K\alpha} = RC\,(Z-1)^2\left(1 - \frac{1}{2^2}\right) = \frac{3RC}{4}(Z-1)^2$

$$= 2.47 \times 10^{15}(Z-1)^2\ Hz$$

(iii) In general the wavelength of all the K-lines are given by

$\frac{1}{\lambda_K} = R(Z-1)^2\left(1 - \frac{1}{n^2}\right)$ where n = 2, 3, 4, ...

While for K_α line $\lambda_{K\alpha} = \frac{1216}{(Z-1)^2}\ Å$

(iv) $E_{K\alpha} = 10.2(Z-1)^2\ eV$

Uses of X-Rays

(i) In study of crystal structure : Structure of DNA was also determined using X-ray diffraction.

(ii) In medical science

(iii) In radiography

(iv) In radio therapy

(v) In engineering

(vi) In laboratories

(vii) In detective department

(viii) In art the change occurring in old oil paintings can be examined by X-rays.

Tips & Tricks

✍ Discovery of positive rays helps in discovering of isotopes.

✍ The de-Broglie wavelength of electrons in first Bohr orbit of an atom is equal to circumference of orbit.

✍ A particle having zero rest mass and non zero energy and momentum must travels with a speed equal to speed of light.

✍ **de-Broglie wave length associates with gas molecules** is given as $\lambda = \frac{h}{mv_{rms}} = \frac{h}{\sqrt{3mkT}}$ (Energy of gas molecules at temperature T is $E = \frac{3}{2}kT$)

✍ A photon is not a material particle. It is a quanta of energy.

✍ When a particle exhibits wave nature, it is associated with a wave packet, rather then a wave.

✍ By coating the metal surface with a layer of barium oxide or strontium oxide it's work function is lowered.

✍ We must remember that intensity of incident light radiation is inversely proportional to the square of distance between source of light and photosensitive plate P *i.e.*, $I \propto \frac{1}{d^2}$ so $I \propto i \propto \frac{1}{d^2}$)

✍ The photoelectric current can be increased by filling some inert gas like Argon into the bulb. The photoelectrons emitted by cathode ionise the gas by collision and hence the current is increased.

✍ Compton effect shows that photon have momentum.

✍ Production of X-ray is the reverse phenomenon of photoelectric effect.

✍ The thickness of medium at which intensity of emergent X-rays becomes half *i.e.* $I' = \frac{I_0}{2}$ is called half value thickness ($x_{1/2}$) and it is given as $x_{1/2} = \frac{0.693}{\mu}$.

✍ Continuos X-rays are produced due to the phenomenon called "Bremsstrahlung". It means slowing down or braking radiation.

✍ The wavelength of characteristic X-ray doesn't depend on accelerating voltage. It depends on the atomic number (*Z*) of the target material.

✍ In characteristic X-ray spectrum $\lambda_{K\alpha} < \lambda_{L\alpha} < \lambda_{M\alpha}$ and $\nu_{K\alpha} > \nu_{L\alpha} > \nu_{M\alpha}$ also $\lambda_{K\alpha} > \lambda_{K\beta} > \lambda_{K\gamma}$

✍ Nearly all metals emits photoelectrons when exposed to UV light. But alkali metals like lithium, sodium, potassium, rubidium and cesium emit photoelectrons even when exposed to visible light.

✍ Oxide coated filament in vacuum tubes is used to emit electrons at relatively lower temperature.

✍ Conduction of electricity in gases at low pressure takes because colliding electrons acquire higher kinetic energy due to increase in mean free path.

✍ Kinetic energy of cathode rays depends on both voltage and work function of cathode.

✍ Photoelectric effect is due to the particle nature of light.

✍ Hydrogen atom does not emit X-rays because it's energy levels are too close to each other.

✍ The essential difference between X-rays and of γ-rays is that, γ-rays emits from nucleus while X-rays from outer part of atom.

✍ There is no time delay between emission of electron and incidence of photon *i.e.* the electrons are emitted out as soon as the light falls on metal surface.

✍ If light were wave (not photons) it will take about an year to eject a photoelectron out of the metal surface.

✍ Doze of X-ray are measured in terms of produced ions or free energy via ionisaiton.

✍ Safe doze for human body per week is one Rontgen (One Rontgon is the amount of X-rays which emits 2.5 × 10^4 *J* free energy through ionization of 1 *gm* air at NTP

✍ The photoelectrons emitted from the metallic surface have different kinetic energies even when the incident photons have same energy. This happens because all the electrons do not exist in the surface layer.

Those coming from below the surface loose more energy in getting themselves free.

✍ Einstein was awarded Nobel prize for explaining the photoelectric effect.

✍ Uncertainty in the measurement of momentum of photon within the nucleus is $\Delta p = \frac{h}{2\pi d}$

where *d* = diameter of the nucleus and Δx = *d* = uncertainty in the measurement of position of proton.

Ordinary Thinking

Objective Questions

Cathode Rays and Positive Rays

1. In the Millikan's experiment, the distance between two horizontal plates is 2.5 *cm* and the potential difference applied is 250 *V*. The electric field between the plates will be

(a) 900 *V/m* **(b)** 10000 *V/m*

(c) 625 *V/m* (d) 6250 *V/m*

2. The cathode rays have particle nature because of the fact that **[CPMT 1986; MNR 1986]**

(a) They can propagate in vacuum

(b) They are deflected by electric and magnetic fields

(c) They produced fluorescence

(d) They cast shadows

3. In Millikan's experiment for the determination of the charge on the electron, the reason for using the oil is

(a) It is a lubricant (b) Its density is higher

(c) It vapourises easily **(d)** It does not vapourise

4. The mass of a particle is 400 times than that of an electron and the charge is double. The particle is accelerated by 5 *V*. Initially the particle remained in rest, then its final kinetic energy will be **[MP PMT 1990]**

(a) 5 *eV* (b) 10 *eV*

(c) 100 *eV* (d) 2000 *eV*

5. An electron (charge = 1.6×10^{-19} *C*) is accelerated through a potential of 100,000 *V*. The energy acquired by the electron is **[MP PET 1989]**

(a) 1.6×10^{-24} *J* (b) 1.6×10^{-14} *erg*

(c) 0.53×10^{-17} *J* **(d)** 1.6×10^{-14} *J*

6. While doing his experiment, Millikan one day observed the following charges on a single drop

(i) 6.563×10^{-19} *C* (ii) 8.204×10^{-19} *C*

(iii) 11.50×10^{-19} *C* (iv) 13.13×10^{-19} *C*

(v) 16.48×10^{-19} *C* (vi) 18.09×10^{-19} *C*

From this data the value of the elementary charge (*e*) was found to be **[MP PMT 1993]**

(a) $1.641\times10^{-19}\,C$ (b) $1.630\times10^{-19}\,C$

(c) $1.648\times10^{-19}\,C$ (d) $1.602\times10^{-19}\,C$

7. When electron beam passes through an electric field, they gain kinetic energy. If the same beam passes through magnetic field, then

(a) Their energy increases

(b) Their momentum increases

(c) Their potential energy increases

(d) Energy and momentum both remains unchanged

8. Which of the following law is used in the Millikan's method for the determination of charge **[DPMT 2002]**

(a) Ampere's law **(b)** Stoke's law

(c) Fleming's left hand rule (d) Fleming's right hand rule

9. The mass of the electron varies with

(a) The size of the cathode ray tube

(b) The variation of *'g'*

(c) Velocity

(d) Size of the electron

10. When the speed of electrons increases, then the value of its specific charge **[MP PMT 1994]**

(a) Increases

(b) Decreases

(c) Remains unchanged

(d) Increases upto some velocity and then begins to decrease

11. An electron is accelerated through a potential difference of 1000 *volts*. Its velocity is nearly

[MP PMT 1985; Pb. PET 2003]

(a) $3.8\times10^{7}\,m/s$ (b) $1.9\times10^{6}\,m/s$

(c) $1.9\times10^{7}\,m/s$ (d) $5.7\times10^{7}\,m/s$

12. In an electron gun the control grid is given a negative potential relative to cathode in order to **[NCERT 1988]**

(a) Decelerate electrons

(b) Repel electrons and thus to control the number of electrons passing through it

(c) To select electrons of same velocity and to converge them along the axis

(d) To decrease the kinetic energy of electrons

13. The ratio of momenta of an electron and an $\alpha -$particle which are accelerated from rest by a potential difference of 100 V is

(a) 1 (b) $\sqrt{\frac{2m_e}{m_\alpha}}$

(c) $\sqrt{\frac{m_e}{m_\alpha}}$ (d) $\sqrt{\frac{m_e}{2m_\alpha}}$

14. When subjected to a transverse electric field, cathode rays move

(a) Down the potential gradient

(b) Up the potential gradient

(c) Along a hyperbolic path

(d) Along a circular path

15. The fact that electric charges are integral multiples of the fundamental electronic charge was proved experimentally by

(a) Planck (b) J.J. Thomson

(c) Einstein (d) Millikan

16. In Millikan oil drop experiment, a charged drop of mass $1.8 \times 10^{-14}\,kg$ is stationary between its plates. The distance between its plates is 0.90 *cm* and potential difference is 2.0 *kilo volts*. The number of electrons on the drop is

[MP PMT 1994, 2003; MP PET 1997]

(a) 500 (b) 50

(c) 5 (d) 0

17. The charge on electron was discovered by

[BHU 1995; RPMT 1999; DCE 2004]

(a) J.J. Thomson (b) Neil Bohr

(c) Millikan (d) Chadwick

18. From the following, what charges can be present on oil drops in Millikan's experiment [MP PET 1995]

(a) Zero, equal to the magnitude of charge on $\alpha -$particle

(b) $2e, 1.6 \times 10^{-18}\,C,$

(c) $1.6 \times 10^{-19}\,C, 2.5e$

(d) $1.5e, e$

(Here e is the electronic charge)

19. A narrow electron beam passes undeviated through an electric field $E = 3 \times 10^4\,volt/m$ and an overlapping magnetic field $B = 2 \times 10^{-3}\,Weber/m^2$. If electric field and magnetic field are mutually perpendicular. The speed of the electrons is

(a) 60 *m/s* (b) $10.3 \times 10^7\,m/s$

(c) $1.5 \times 10^7\,m/s$ (d) $0.67 \times 10^{-7}\,m/s$

20. In Thomson's method of determining *e/m* of electrons

[MP PMT 1997]

(a) Electric and magnetic fields are parallel to electrons beam

(b) Electric and magnetic fields are perpendicular to each other and perpendicular to electrons beam

(c) Magnetic field is parallel to the electrons beam

(d) Electric field is parallel to the electrons beam

21. Cathode rays enter into a uniform magnetic field perpendicular to the direction of the field. In the magnetic field their path will be [MNR 1994; RPET 1997]

(a) Straight line (b) Circle

(c) Parabolic (d) Ellipse

22. The specific charge of an electron is [MP PMT/PET 1998; J&K CET 2004; Pb. PET 2002; MH CET 1999]

[MP PET 1994]

(a) $1.6 \times 10^{-19}\,coulomb$

(b) $4.8 \times 10^{-10}\,statcoulomb$

(c) $1.76 \times 10^{11}\,coulomb/kg$

(d) $1.76 \times 10^{-11}\,coulomb/kg$

23. An electron is moving with constant velocity along $x -$axis. If a uniform electric field is applied along $y -$axis, then its path in the $x - y$ plane will be [MP PET 1994] [MP PMT 1999]

(a) A straight line (b) A circle

(c) A parabola (d) An ellipse

24. Cathode rays are similar to visible light rays in that

[SCRA 1994]

(a) They both can be deflected by electric and magnetic fields

(b) They both have a definite magnitude of wavelength

(c) They both can ionise a gas through which they pass

(d) They both can expose a photographic plate

25. Which one of the following devices makes use of the electrons to strike certain substances to produce fluorescence

[SCRA 1994]

(a) Thermionic valve (b) Photoelectric cell

(c) Cathode ray oscilloscope (d) Electron gun

26. An oxide coated filament is useful in vacuum tubes because essentially [SCRA 1994]

(a) It has high melting point

(b) It can withstand high temperatures

(c) It has good machanical strength

(d) It can emit electrons at relatively lower temperatures

27. Gases begin to conduct electricity at low pressure because

[CBSE PMT 1994]

(a) At low pressure, gases turn to plasma [MP PET 1995]

(b) Colliding electrons can acquire higher kinetic energy due to increased mean free path leading to ionisation of atoms

(c) Atoms break up into electrons and protons

(d) The electrons in atoms can move freely at low pressure

28. A beam of electrons is moving with constant velocity in a region having electric and magnetic fields of strength $20\ Vm^{-1}$ and 0.5 T at right angles to the direction of motion of the electrons. What is the velocity of the electrons

[CBSE PMT 1996]

(a) 20 ms^{-1} (b) 40 ms^{-1}

(c) 8 ms^{-1} (d) 5.5 ms^{-1}

29. Kinetic energy of emitted cathode rays is dependent on [CPMT 1996]

(a) Only voltage

(b) Only work function

(c) Both (a) and (b)

(d) It does not depend upon any physical quantity

30. The radius of the orbital of electron in the hydrogen atom 0.5 Å. The speed of the electron is $2\times10^6 m/s$. Then the current in the loop due to the motion of the electron is [RPMT 1996]

(a) 1 *mA* (b) 1.5 *mA*

(c) 2.5 *mA* (d) $1.5\times10^{-2} mA$

31. The kinetic energy of an electron which is accelerated through a potential of 100 *volts* is [MP PET 1986; CBSE PMT 1997; AIIMS 1998]

(a) $1.602\times10^{-17} J$ (b) 418.6 *calories*

(c) $1.16\times10^4 K$ (d) 6.626×10^{-34} *W- sec*

32. When a proton is accelerated with 1 *volt* potential difference, then its kinetic energy is [CPMT 1997; CBSE PMT 1999; RPET 2003]

(a) $\frac{1}{1840} eV$ (b) 1840 *eV*

(c) 1 *eV* (d) 1840 *c eV*

33. Energy of electrons can be increased by allowing them [JIPMER 1997]

(a) To fall through electric potential

(b) To move in high magnetic field

(c) To fall from great heights

(d) To pass through lead blocks

34. Cathode rays and canal rays produced in a certain discharge tube are deflected in the same direction if [SCRA 1998]

(a) A magnetic field is applied normally

(b) An electric field is applied normally

(c) An electric field is applied tangentially

(d) A magnetic field is applied tangentially

35. In a Millikan's oil drop experiment the charge on an oil drop is calculated to be $6.35\times10^{-19} C$. The number of excess electrons on the drop is [MNR 1998]

(a) 3.9 (b) 4

(c) 4.2 (d) 6

36. Cathode rays consist of [DCE 1999]

(a) Photons (b) Electrons

(c) Protons (d) α -particles

37. A metal plate gets heated, when cathode rays strike against, it due to [CPMT 2000; Pb. PET 2000]

(a) Kinetic energy of cathode rays

(b) Potential energy of cathode rays

(c) Linear velocity of cathode rays

(d) Angular velocity of cathode rays

38. Cathode rays are [RPET 2000]

(a) Positive rays (b) Neutral rays

(c) He rays (d) Electron waves

39. An electron of charge '*e*' coulomb passes through a potential difference of V *volts*. Its energy in '*joules*' will be [MP PET 2000]

(a) V/e (b) eV

(c) e/V (d) V

40. An electron is accelerated through a potential difference of 200 *volts*. If e/m for the electron be 1.6×10^{11} *coulomb/kg*, the velocity acquired by the electron will be [MP PET 2000]

(a) $8\times10^6 m/s$ (b) $8\times10^5 m/s$

(c) $5.9\times10^6 m/s$ (d) $5.9\times10^5 m/s$

41. Which is not true with respect to the cathode rays [Kerala PET 2001]

(a) A stream of electrons

(b) Charged particles

(c) Move with speed same as that of light

(d) Can be deflected by magnetic fields

42. In Milikan's experiment, an oil drop having charge q gets stationary on applying a potential difference V in between two plates separated by a distance 'd'. The weight of the drop is

(a) qVd (b) $q\frac{d}{V}$

(c) $\frac{q}{Vd}$ (d) $q\frac{V}{d}$

43. Electron volt is a unit of [MP PMT 2001]

(a) Potential (b) Charge

(c) Power (d) Energy

44. In Thomson experiment of finding e/m for electrons, beam of electron is replaced by that of muons (particle with same charge as of electrons but mass 208 times that of electrons). No deflection condition in this case satisfied if [Orissa (Engg.) 2002]

(a) B is increased 208 times

(b) E is increased 208 times

(c) B is increased 14.4 times

(d) None of these

45. The colour of the positive column in a gas discharge tube depends on [Kerala (Engg.) 2002]

(a) The type of glass used to construct the tube

(b) The gas in the tube

(c) The applied voltage

(d) The material of the cathode

46. Cathode rays are produced when the pressure is of the order of

(a) 2 *cm* of *Hg* (b) 0.1 *cm* of *Hg*

(c) 0.01 *mm* of *Hg* (d) 1 μm of *Hg*

47. The speed of an electron having a wavelength of $10^{-10}\ m$ is [AIIMS 2002]

(a) $7.25\times10^{6}\ m/s$ (b) $6.26\times10^{6}\ m/s$

(c) $5.25\times10^{6}\ m/s$ (d) $4.24\times10^{6}\ m/s$

48. Which of the following is not the property of a cathode ray [CBSE PMT 2002]

(a) It casts shadow

(b) It produces heating effect

(c) It produces flurosence

(d) It does not deflect in electric field

49. In a Thomson set-up for the determination of *e/m*, electrons accelerated by 2.5 kV enter the region of crossed electric and magnetic fields of strengths $3.6\times10^{4}\ Vm^{-1}$ and $1.2\times10^{-3}\ T$ respectively and go through undeflected. The measured value of e/m of the electron is equal to [AMU 2002]

(a) $1.0\times10^{11}\ C\text{-}kg^{-1}$ (b) $1.76\times10^{11}\ C\text{-}kg^{-1}$

(c) $1.80\times10^{11}\ C\text{-}kg^{-1}$ (d) $1.85\times10^{11}\ C\text{-}kg^{-1}$

50. The ratio of specific charge of an α -particle to that of a proton is

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

(c) 1 : 2 (d) 1 : 3

51. In Bainbridge mass spectrograph a potential difference of 1000 *V* is applied between two plates distant 1 *cm* apart and magnetic field in B = 1*T*. The velocity of undeflected positive ions in *m/s* from the velocity selector is [RPMT 1998]

(a) $10^{7}\ m/s$ (b) $10^{4}\ m/s$

(c) $10^{5}\ m/s$ (d) $10^{2}\ m/s$

52. When cathode rays (tube voltage ~ 10 *kV*) collide with the anode of high atomic weight then we get [MP PET 1985]

(a) Positive rays (b) *X*-rays

(c) Gamma rays (d) Canal rays

53. In Thomson's experiment if the value of *q/m* is the same for all positive ions striking the photographic plate, then the trace would be [RPMT 1986]

(a) Straight line (b) Parabolic

(c) Circular (d) Elliptical

54. In a discharge tube at 0.02 *mm*, there is a formation of [CBSE PMT 1996]

(a) FDS (b) CDS

(c) Both space (d) None of these

55. Electric field and magnetic field in Thomson mass spectrograph are applied [RPMT 1998]

(a) Simultaneously, perpendicular

(b) Perpendicular but not simultaneously

(c) Parallel but not simultaneously

(d) Parallel simultaneously

56. The current conduction in a discharged tube is due to [CBSE PMT 1999]

(a) Electrons only

(b) +*ve* ions and electrons

(c) – *ve* ions and electrons

(d) + *ve* ions, – *ve* ions and electrons

57. In Milikan's oil drop experiment, a charged drop falls with terminal velocity *V*. If an electric field *E* is applied in vertically upward direction then it starts moving in upward direction with terminal velocity $2V$. If magnitude of electric field is decreased to $\frac{E}{2}$, then terminal velocity will become [CBSE PMT 1999]

(a) $\frac{V}{2}$ (b) V

(c) $\frac{3V}{2}$ (d) $2V$

58. An electron is accelerated through a p.d. of 45.5 *volt*. The velocity acquired by it is (in *ms*) [AIIMS 2004]

(a) 4×10^{6} (b) 4×10^{4}

(c) 10^{6} (d) Zero

59. A cathode emits [BCECE 2003] 1.8×10^{14} electrons per second, when heated. When $400\,V$ is applied to anode all the emitted electrons reach the anode. The charge on electron is $1.6\times10^{-19}\ C$. The maximum anode current is [MP PMT 2004]

(a) $2.7\ \mu A$ (b) $29\ \mu A$

(c) $72\ \mu A$ (d) $29\ mA$

60. Order of q/m ratio of proton, α -particle and electron is [AFMC 2004]

(a) $e > p > \alpha$ (b) $p > \alpha > e$

(c) $e > \alpha > p$ (d) None of these

61. A charge of magnitude $3e$ and mass $2m$ is moving in an electric field $\vec{E}$. The acceleration imparted to the charge is [DCE 2004]

(a) $2Ee/3m$ (b) $3Ee/2m$

(c) $2m/3Ee$ (d) $3m/2Ee$

62. An electron initially at rest, is accelerated through a potential difference of 200 *volt*, so that it acquires a velocity $8.4\times10^{6}\ m/s$. The value of *e/m* of electron will be [DPMT 2003]

(a) $2.76\times10^{12}\ C/kg$ (b) $1.76\times10^{11}\ C/kg$

(c) $0.76\times10^{12}\ C/kg$ (d) None of these

63. An α particle is accelerated through a *p.d* of 10^{6} volt then *K.E.* of particle will be [Pb. PET 2003]

(a) 8 *MeV* (b) 4 *MeV*

(c) 2 *MeV* (d) 1 *MeV*

64. Positive rays consists of [RPMT 1996, 2003]

(a) Electrons (b) Neutrons

(c) Positive ions (d) Electro magnetic waves

65. O^{++}, C^{+}, He^{++} and H^{+} ions are projected on the photographic plate with same velocity in a mass spectrograph. Which one will strike farthest [RPMT 2003]

(a) O^{++} (b) C^{+}

(c) He^{++} (d) H_2^{+}

66. An electron beam is moving between two parallel plates having electric field $1.125\times10^{-6}\, N/m$. A magnetic field $3\times10^{-10}\, T$ is also applied so that beam of electrons do not deflect. The velocity of the electron is [MH CHT 2004]

(a) $4225\, m/s$ (b) $3750\, m/s$

(c) $2750\, m/s$ (d) $3200\, m/s$

67. Positive rays was discovered by [RPMT 1998]

(a) Thomson (b) Goldstem

(c) W. Crookes (d) Rutherford

68. An electron is moving in electric field and magnetic field it will gain energy from [DCE 1998]

(a) Electric field (b) Magnetic field

(c) Both of these (d) None of these

69. If an electron oscillates at a frequency of 1 *GHz* it gives [DCE 1999]

(a) *X*-rays (b) Mirowaves

(c) Infrared rays (d) None of these

70. In an electron gun, the electrons are accelerated by the potential *V*. If *e* is the charge and *m* is the mass of an electron, then the maximum velocity of these electrons will be

(a) $\frac{2eV}{m}$ (b) $\sqrt{\frac{2eV}{m}}$

(c) $\sqrt{\frac{2m}{eV}}$ (d) $\frac{V^2}{2em}$

71. Which of the following have highest specific charge [BHU 2005]

(a) Positron (b) Proton

(c) *He* (d) None of these

72. In Millikan's oil drop experiment, an oil drop of mass $16\times10^{-6}\, kg$ is balanced by an electric field of $10^{6}\, V/m$. The charge in coulomb on the drop, assuming $g=10\, m/s^2$ is

(a) 6.2×10^{-11} (b) 16×10^{-9}

(c) 16×10^{-11} (d) 16×10^{-13}

Matter Waves

1. The idea of matter waves was given by

(a) Davisson and Germer (b) de-Broglie

(c) Einstein (d) Planck

2. Wave is associated with matter

(a) When it is stationary

(b) When it is in motion with the velocity of light only

(c) When it is in motion with any velocity

(d) None of the above

3. The de-Broglie wavelength associated with the particle of mass *m* moving with velocity *v* is [CBSE PMT 1992]

(a) h/mv (b) mv/h

(c) mh/v (d) m/hv

4. A photon, an electron and a uranium nucleus all have the same wavelength. The one with the most energy [MP PMT 1992]

(a) Is the photon

(b) Is the electron

(c) Is the uranium nucleus

(d) Depends upon the wavelength and the properties of the particle.

5. A particle which has zero rest mass and non-zero energy and momentum must travel with a speed [MP PMT 1992; DPMT 2001; Kerala PMT 2004]

(a) Equal to *c*, the speed of light in vacuum

(b) Greater than *c*

(c) Less than *c*

(d) Tending to infinity

6. When the kinetic energy of an electron is increased, the wavelength of the associated wave will

(a) Increase

(b) Decrease

(c) Wavelength does not depend on the kinetic energy

(d) None of the above

[MP PMT 1987, 96; BHU 1995; MNR 1998]

7. If the de-Broglie wavelengths for a proton and for a α – particle are equal, then the ratio of their velocities will be

(a) 4 : 1 (b) 2 : 1

(c) 1 : 2 (d) 1 : 4

8. The de-Broglie wavelength λ associated with an electron having kinetic energy *E* is given by the expression [MP PMT 1990; CPMT 1996]

(a) $\frac{h}{\sqrt{2mE}}$ (b) $\frac{2h}{mE}$

(c) $2mhE$ (d) $\frac{2\sqrt{2mE}}{h}$

[UP SEAT 2005]

9. Dual nature of radiation is shown by [MP PET 1991]

(a) Diffraction and reflection

(b) Refraction and diffraction

(c) Photoelectric effect alone

(d) Photoelectric effect and diffraction

10. For the Bohr's first orbit of circumference $2\pi r$, the de-Broglie wavelength of revolving electron will be [MP PMT 1987]

(a) $2\pi r$ (b) πr

(c) $\frac{1}{2\pi r}$ (d) $\frac{1}{4\pi r}$

11. An electron of mass *m* when accelerated through a potential difference *V* has de-Broglie wavelength λ. The de-Broglie

wavelength associated with a proton of mass M accelerated through the same potential difference will be

[CBSE PMT 1995; EAMCET 2001; J & K CET 2004]

(a) $\lambda \frac{m}{M}$ (b) $\lambda \sqrt{\frac{m}{M}}$

(c) $\lambda \frac{M}{m}$ (d) $\lambda \sqrt{\frac{M}{m}}$

12. What will be the ratio of de-Broglie wavelengths of proton and $\alpha -$particle of same energy

[RPET 1991, 96; DCE 2002; Kerala PET 2005]

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

(c) 4 : 1 (d) 1 : 4

13. What is the de-Broglie wavelength of the $\alpha -$particle accelerated through a potential difference V [RPMT 1996]

(a) $\frac{0.287}{\sqrt{V}}$ Å (b) $\frac{12.27}{\sqrt{V}}$ Å

(c) $\frac{0.101}{\sqrt{V}}$ Å (d) $\frac{0.202}{\sqrt{V}}$ Å

14. de-Broglie hypothesis treated electrons as

[BHU 2000]

(a) Particles (b) Waves

(c) Both '*a*' and '*b*' (d) None of these

15. The energy that should be added to an electron, to reduce its de-Broglie wavelengths from 10^{-10} *m* to 0.5×10^{-10} *m*, will be [KCET (Engg./Med.) 2000]

(a) Four times the initial energy

(b) Thrice the initial energy

(c) Equal to the initial energy

(d) Twice the initial energy

16. The de-Broglie wavelength of an electron having $80 eV$ of energy is nearly

($1 eV$ = 1.6 × 10^{-19} *J*, Mass of electron = 9 × 10^{-31} *kg*

Plank's constant = 6.6 × 10^{-34} *J-sec*)

[EAMCET (Engg.) 2001]

(a) 140 Å (b) 0.14 Å

(c) 14 Å (d) 1.4 Å

17. If particles are moving with same velocity, then maximum de-Broglie wavelength will be for [CBSE PMT 2002]

(a) Neutron (b) Proton

(c) β-particle (d) α -particle

18. If an electron and a photon propagate in the form of waves having the same wavelength, it implies that they have the same [CBSE PMT 1995; DCE 2001; AIIMS 2003]

(a) Energy (b) Momentum

(c) Velocity (d) Angular momentum

19. The de-Broglie wavelength is proportional to [RPET 2003]

(a) $\lambda \propto \frac{1}{v}$ (b) $\lambda \propto \frac{1}{m}$

(c) $\lambda \propto \frac{1}{p}$ (d) $\lambda \propto p$

20. Particle nature and wave nature of electromagnetic waves and electrons can be shown by [AIIMS 2000]

(a) Electron has small mass, deflected by the metal sheet

(b) X-ray is diffracted, reflected by thick metal sheet

(c) Light is refracted and defracted

(d) Photoelectricity and electron microscopy

21. The de-Broglie wavelength of a particle moving with a velocity 2.25 × 10^{8} *m/s* is equal to the wavelength of photon. The ratio of kinetic energy of the particle to the energy of the photon is (velocity of light is 3 × 10^{8} *m/s*)

[EAMCET (Med.) 2003]

(a) 1/8 (b) 3/8

(c) 5/8 (d) 7/8

22. According to de-Broglie, the de-Broglie wavelength for electron in an orbit of hydrogen atom is 10^{-9} *m*. The principle quantum number for this electron is [RPMT 2003]

(a) 1 (b) 2

(c) 3 (d) 4

23. The speed of an electron having a wavelength of $10^{-10} m$ is

[Manipal 1997; AIIMS 2002]

(a) 7.25×10^{6} *m/s* (b) $6.26 \times 10^{6} m/s$

(c) $5.25 \times 10^{6} m/s$ (d) $4.24 \times 10^{6} m/s$

24. The kinetic energy of electron and proton is $10^{-32} J$. Then the relation between their de-Broglie wavelengths is

[CPMT 1999]

(a) $\lambda_p < \lambda_e$ (b) $\lambda_p > \lambda_e$

(c) $\lambda_p = \lambda_e$ (d) $\lambda_p = 2\lambda_e$

25. The de-Broglie wavelength of a particle accelerated with 150 *volt* potential is 10^{-10} *m*. If it is accelerated by 600 *volts* p.d., its wavelength will be [RPET 1988]

(a) 0.25 Å (b) 0.5 Å

(c) 1.5 Å (d) 2 Å

26. The de-Broglie wavelength associated with a hydrogen molecule moving with a thermal velocity of 3 *km/s* will be

(a) 1 Å (b) 0.66 Å

(c) 6.6 Å (d) 66 Å

27. When the momentum of a proton is changed by an amount P_0, the corresponding change in the de-Broglie wavelength is found to be 0.25%. Then, the original momentum of the proton was

(a) p_0 (b) 100 p_0

(c) 400 p_0 (d) 4 p_0

28. The de-Broglie wavelength of a neutron at 27°C is λ. What will be its wavelength at 927°C [DPMT 2002]

(a) $\lambda / 2$ (b) $\lambda / 3$

(c) $\lambda / 4$ (d) $\lambda / 9$

29. An electron and proton have the same de-Broglie wavelength. Then the kinetic energy of the electron is [Kerala PMT 2004]

(a) Zero

(b) Infinity

(c) Equal to the kinetic energy of the proton

(d) Greater than the kinetic energy of the proton

30. For moving ball of cricket, the correct statement about de-Broglie wavelength is [RPMT 2001]

(a) It is not applicable for such big particle

(b) $\frac{h}{\sqrt{2mE}}$

(c) $\sqrt{\frac{h}{2mE}}$

(d) $\frac{h}{2mE}$

31. Photon and electron are given same energy $(10^{-20}\,J)$. Wavelength associated with photon and electron are λ_{Ph} and λ_{el} then correct statement will be [RPMT 2001]

(a) $\lambda_{Ph} > \lambda_{el}$ (b) $\lambda_{Ph} < \lambda_{el}$

(c) $\lambda_{Ph} = \lambda_{el}$ (d) $\frac{\lambda_{el}}{\lambda_{Ph}} = C$

32. The kinetic energy of an electron with de-Broglie wavelength of 0.3 nanometer is [UPSEAT 2004]

(a) 0.168 eV (b) 16.8 eV

(c) 1.68 eV (d) 2.5 eV

33. A proton and an α-particle are accelerated through a potential difference of 100 V. The ratio of the wavelength associated with the proton to that associated with an α-particle is

(a) $\sqrt{2}:1$ (b) $2:1$

(c) $2\sqrt{2}:1$ (d) $\frac{1}{2\sqrt{2}}:1$

34. The wavelength of de-Broglie wave is $2\mu m$, then its momentum is ($h = 6.63 \times 10^{-34}$ J-s) [DCE 2004]

(a) 3.315×10^{-28} kg-m/s (b) 1.66×10^{-28} kg-m/s

(c) 4.97×10^{-28} kg-m/s (d) 9.9×10^{-28} kg-m/s

35. de-Broglie wavelength of a body of mass 1 kg moving with velocity of 2000 m/s is [Pb. PMT 2003]

(a) 3.32×10^{-27} Å (b) 1.5×10^{-7} Å

(c) 0.55×10^{-22} Å (d) None of these

36. The kinetic energy of an electron is 5 eV. Calculate the de-Broglie wavelength associated with it ($h = 6.6 \times 10^{-34}$ Js, $m_e = 9.1 \times 10^{-31}$ kg)

(a) 5.47 Å (b) 10.9 Å

(c) 2.7 Å (d) None of these

37. The wavelength associated with an electron accelerated through a potential difference of 100 V is nearly [RPMT 2003]

(a) 100 Å (b) 123 Å

(c) 1.23 Å (d) 0.123 Å

38. The de-Broglie wavelength λ [RPMT 2004]

(a) is proportional to mass

(b) is proportional to impulse

(c) Inversely proportional to impulse

(d) does not depend on impulse

39. Davission and Germer experiment proved [RPET 2002; DCE 2004]

(a) Wave nature of light (b) Particle nature of light

(c) Both (a) and (b) (d) Neither (a) nor (b)

40. If the kinetic energy of a free electron doubles, its de-Broglie wavelength changes by the factor [AIEEE 2005]

(a) $\frac{1}{\sqrt{2}}$ (b) $\sqrt{2}$

(c) $\frac{1}{2}$ (d) 2

41. The energy that should be added to an electron to reduce its de Broglie wavelength from one nm to 0.5 nm is [KCET 2005]

(a) Four times the initial energy

(b) Equal to the initial energy

(c) Twice the initial energy

(d) Thrice the initial energy

42. de-Broglie wavelength of a body of mass m and kinetic energy E is given by [BCECE 2005]

(a) $\lambda = \frac{h}{mE}$ (b) $\lambda = \frac{\sqrt{2mE}}{h}$

(c) $\lambda = \frac{h}{2mE}$ (d) $\lambda = \frac{h}{\sqrt{2mE}}$

43. The wavelength of the matter wave is independent of [Kerala PMT 2005]

[DCE 2002; DPMT 2003]

(a) Mass (b) Velocity

(c) Momentum (d) Charge

Photon and Photoelectric Effect

1. The momentum of a photon is $3.3 \times 10^{-29}\,kg - m/sec$. Its frequency will be [CPMT 1980; MP PET 1992; DPMT 1999]

(a) $3 \times 10^{3}\,Hz$ (b) $6 \times 10^{3}\,Hz$

(c) $7.5 \times 10^{12}\,Hz$ (d) $1.5 \times 10^{13}\,Hz$

2. The energy of a photon of wavelength λ is given by [CPMT 1974; CBSE PMT 1992; DCE 1998; BHU 2000; DPMT 2001]

(a) $h\lambda$ (b) $ch\lambda$

(c) λ / hc (d) hc / λ

3. The momentum of a photon is 2×10^{-16} gm-cm/sec. Its energy is [Pb. PMT 2004]

(a) $0.61 \times 10^{-26}\,erg$ (b) $2.0 \times 10^{-26}\,erg$

(c) $6 \times 10^{-6}\,erg$ (d) $6 \times 10^{-8}\,erg$

4. The rest mass of the photon is [MP PET 1994; CPMT 1996; RPMT 1999; JIPMER 2002]

(a) 0

(b) ∞

(c) Between 0 and ∞

(d) Equal to that of an electron

5. The momentum of the photon of wavelength 5000Å will be [CPMT 1987]

(a) $1.3\times10^{-27}\,kg\text{-}m/sec$ (b) $1.3\times10^{-28}\,kg\text{-}m/sec$

(c) $4\times10^{29}\,kg\text{-}m/sec$ (d) $4\times10^{-18}\,kg\text{-}m/sec$

6. The momentum of a photon of energy $h\nu$ will be [DCE 2000]

(a) $h\nu$ (b) $h\nu/c$

(c) $h\nu c$ (d) h/ν

7. A photon in motion has a mass [MP PMT 1992]

(a) $c/h\nu$ (b) h/ν

(c) $h\nu$ (d) $h\nu/c^2$

8. If the momentum of a photon is *p*, then its frequency is [MP PET 1989]

(a) $\frac{ph}{c}$ (b) $\frac{pc}{h}$

(c) $\frac{mh}{c}$ (d) $\frac{mc}{h}$

Where *m* is the rest mass of the photon

9. An AIR station is broadcasting the waves of wavelength 300 metres. If the radiating power of the transmitter is 10 *kW*, then the number of photons radiated per second is [MP PET 1989; RPMT 2000]

(a) 1.5×10^{29} (b) 1.5×10^{31}

(c) 1.5×10^{33} (d) 1.5×10^{35}

10. The energy of a photon is $E = h\nu$ and the momentum of photon $p = \frac{h}{\lambda}$, then the velocity of photon will be [CPMT 1991]

(a) *E/p* (b) *Ep*

(c) $\left(\frac{E}{p}\right)^2$ (d) $3\times10^{8}\,m/s$

11. The approximate wavelength of a photon of energy 2.48 *eV* is

(a) 500 Å (b) 5000 Å

(c) 2000 Å (d) 1000 Å

12. An important spectral emission line has a wavelength of 21 *cm*. The corresponding photon energy is [MP PMT 1993]

(a) $5.9\times10^{-4}\,eV$ (b) $5.9\times10^{-6}\,eV$

(c) $5.9\times10^{-8}\,eV$ (d) $11.8\times10^{-6}\,eV$

$(h = 6.62\times10^{-34}\,Js;\ c = 3\times10^{8}\,m/s)$

13. The momentum of a photon in an *X*-ray beam of 10^{-10} metre wavelength is [MP PET 1996]

(a) $1.5\times10^{-23}\,kg-m/sec$ (b) $6.6\times10^{-24}\,kg-m/sec$

(c) $6.6\times10^{-44}\,kg-m/sec$ (d) $2.2\times10^{-52}\,kg-m/sec$

14. The energy of a photon of light with wavelength 5000 Å is approximately 2.5 *eV*. This way the energy of an *X*-ray photon with wavelength 1Å would be [MP PET 1997]

(a) 2.5/5000 *eV* (b) $2.5/(5000)^2\,eV$

(c) $2.5\times5000\,eV$ (d) $2.5\times(5000)^2\,eV$

15. Energy of a quanta of frequency $10^{15}\,Hz$ and $h = 6.6\times10^{-34}\,J\text{-sec}$ will be [RPMT 1997]

(a) $6.6\times10^{-19}\,J$ (b) $6.6\times10^{-12}\,J$

(c) $6.6\times10^{-49}\,J$ (d) $6.6\times10^{-41}\,J$

16. Momentum of a photon of wavelength λ is [CBSE PMT 1993; JIPMER 2001, 02]

(a) $\frac{h}{\lambda}$ (b) Zero

(c) $\frac{h\lambda}{c^2}$ (d) $\frac{h\lambda}{c}$

17. Wavelength of a 1 *keV* photon is $1.24\times10^{-9}\,m$. What is the frequency of 1 *MeV* photon [CBSE PMT 1993; MP PET 2005]

(a) $1.24\times10^{15}\,Hz$ (b) $2.4\times10^{20}\,Hz$

(c) $1.24\times10^{18}\,Hz$ (d) $2.4\times10^{23}\,Hz$

18. What is the momentum of a photon having frequency $1.5\times10^{13}\,Hz$ [BHU 1997]

(a) $3.3\times10^{-29}\,kg\ m/s$ (b) $3.3\times10^{-34}\,kg\ m/s$

(c) $6.6\times10^{-34}\,kg\ m/s$ (d) $6.6\times10^{-30}\,kg\ m/s$

19. The energy of a photon of light of wavelength 450 *nm* is [BHU 1997; JIPMER 2000]

(a) $4.4\times10^{-19}\,J$ (b) $2.5\times10^{-19}\,J$

(c) $1.25\times10^{-17}\,J$ (d) $2.5\times10^{-17}\,J$

20. Frequency of photon having energy 66 *eV* is [CPMT PMT 1997]

(a) $8\times10^{-15}\,Hz$ (b) $12\times10^{-15}\,Hz$

(c) $16\times10^{15}\,Hz$ (d) None of these

21. Which of the following statement is not correct [AFMC 1999]

(a) Photographic plates are sensitive to infrared rays

(b) Photographic plates are sensitive to ultraviolet rays

(c) Infra-red rays are invisible but can cast shadows like visible light

(d) Infrared photons have more energy than photons of visible light [MP PMT 1987]

22. If we express the energy of a photon in *KeV* and the wavelength in angstroms, then energy of a photon can be calculated from the relation [AMU (Engg.) 1999]

(a) $E = 12.4\,h\nu$ (b) $E = 12.4\,h/\lambda$

(c) $E = 12.4/\lambda$ (d) $E = h\nu$

23. The frequency of a photon, having energy 100 *eV* is $(h = 6.6\,10^{-34}\ J\text{-}sec)$ [AFMC 2000]

(a) $2.42\times10^{26}\,Hz$ (b) $2.42\times10^{16}\,Hz$

(c) $2.42\times10^{12}\,Hz$ (d) $2.42\times10^{9}\,Hz$

24. A photon of wavelength 4400 Å is passing through vacuum. The effective mass and momentum of the photon are respectively

(a) $5\times10^{-36}\,kg,\ 1.5\times10^{-27}\,kg\text{-}m/s$

(b) $5\times10^{-35}\,kg,\ 1.5\times10^{-26}\,kg\text{-}m/s$

(c) Zero, $1.5\times10^{-26}\ kg\text{-}m/s$

(d) $5\times10^{-36}\ kg, 1.67\times10^{-43}\ kg\text{-}m/s$

25. Which of the following is true for photon [RPET 2001]

(a) $E=\frac{hc}{\lambda}$ (b) $E=\frac{1}{2}mu^2$

(c) $p=\frac{E}{2v}$ (d) $E=\frac{1}{2}mc^2$

26. Which of the following is incorrect statement regarding photon [MH CET (Med.) 2001]

(a) Photon exerts no pressure

(b) Photon energy is $h\nu$

(c) Photon rest mass is zero

(d) None of these

27. If a photon has velocity c and frequency ν, then which of following represents its wavelength [AIEEE 2002]

(a) $\frac{hc}{E}$ (b) $\frac{h\nu}{c}$

(c) $\frac{h\nu}{c^2}$ (d) $h\nu$

28. The mass of a photo electron is [MP PMT 2002]

(a) $9.1\times10^{-27}\ kg$ (b) $9.1\times10^{-29}\ kg$

(c) $9.1\times10^{-31}\ kg$ (d) $9.1\times10^{-34}\ kg$

29. Energy of photon whose frequency is $10^{12}\ MHz$, will be [MH CET 2002]

(a) $4.14\times10^{3}\ keV$ (b) $4.14\times10^{2}\ eV$

(c) $4.14\times10^{3}\ MeV$ (d) $4.14\times10^{3}\ eV$

30. There are n_1 photons of frequency γ_1 in a beam of light. In an equally energetic beam, there are n_2 photons of frequency γ_2. Then the correct relation is [KCET 2003]

(a) $\frac{n_1}{n_2}=1$ (b) $\frac{n_1}{n_2}=\frac{\gamma_1}{\gamma_2}$

(c) $\frac{n_1}{n_2}=\frac{\gamma_2}{\gamma_1}$ (d) $\frac{n_1}{n_2}=\frac{\gamma_1^2}{\gamma_2^2}$

31. Einstein's photoelectric equation states that $E_k=h\nu-\phi$. In this equation E_k refers to [CPMT 1982; MP PMT 1997]

(a) Kinetic energy of all the emitted electrons

(b) Mean kinetic energy of the emitted electrons

(c) Maximum kinetic energy of the emitted electrons

(d) Minimum kinetic energy of the emitted electrons

32. Kinetic energy with which the electrons are emitted from the metal surface due to photoelectric effect is [CPMT 1973]

(a) Independent of the intensity of illumination

(b) Independent of the frequency of light

(c) Inversely proportional to the intensity of illumination

(d) Directly proportional to the intensity of illumination

33. The threshold wavelength for photoelectric emission from a material is 5200 Å. Photo-electrons will be emitted when this material is illuminated with monochromatic radiation from a [IIT JEE 1982; MP PMT 1994; MP PET 1995; UPSEAT 2001; KCET 2004; J & K CET 2004; BHU 2004]

(a) 50 watt infrared lamp

(b) 1 watt infrared lamp

(c) 50 watt ultraviolet lamp

(d) 1 watt ultraviolet lamp

(e) Both (c) and (d)

34. Threshold frequency for a metal is $10^{15}\ Hz$. Light of $\lambda=4000\mathring{A}$ falls on its surface. Which of the following statements is correct

(a) No photoelectric emission takes place

(b) Photo-electrons come out with zero speed

(c) Photo-electrons come out with $10^{3}\ m/sec$ speed

(d) Photo-electrons come out with $10^{5}\ m/sec$ speed

35. Photo cells are used for the

(a) Reproduction of pictures from the cinema film

(b) Reproduction of sound from the cinema film

(c) Automatic switching of street light

(d) (b) and (c) both

36. Einstein got Nobel prize on which of the following works [DCE 1995]

(a) Mass-energy relation

(b) Special theory of relativity

(c) Photoelectric equation

(d) (a) and (b) both

37. The photo-electrons emitted from a surface of sodium metal are such that [MP PMT 1992]

(a) They all are of the same frequency

(b) They have the same kinetic energy

(c) They have the same de Broglie wavelength

(d) They have their speeds varying from zero to a certain maximum

38. A metal surface of work function 1.07 eV is irradiated with light of wavelength 332 nm. The retarding potential required to stop the escape of photo-electrons is [MP PMT 1992]

(a) 4.81 eV (b) 3.74 eV

(c) 2.66 eV (d) 1.07 eV

39. In a photo cell, the photo-electrons emission takes place

(a) After 10^{-1} *sec* on incident of light rays

(b) After 10^{-3} *sec* on incident of light rays

(c) After 10^{-6} *sec* on incident of light rays

(d) After 10^{-8} *sec* on incident of light rays

40. When light falls on a metal surface, the maximum kinetic energy of the emitted photo-electrons depends upon [MP PMT 1989; MP PET 1992, 93]

(a) The time for which light falls on the metal

(b) Frequency of the incident light

(c) Intensity of the incident light

(d) Velocity of the incident light

41. Electrons are emitted in the photoelectric effect from a metal surface [MP PET 1992]

(a) Only if the frequency of the incident radiation is above a certain threshold value

(b) Only if the temperature of the surface is high

(c) At a rate that is independent of the nature of the metal

(d) With a maximum velocity proportional to the frequency of the incident radiation

42. The work function of a metal is 4.2 *eV*, its threshold wavelength will be [BHU 2003; CPMT 2004]

(a) 4000 Å (b) 3500 Å

(c) 2955 Å (d) 2500 Å

43. The number of photo-electrons emitted per second from a metal surface increases when

[EAMCET (Med.) 1995; CBSE PMT 1993; MP PMT 1994, 2002; MH CET 1999; KCET 2003]

(a) The energy of incident photons increases

(b) The frequency of incident light increases

(c) The wavelength of the incident light increases

(d) The intensity of the incident light increases

44. The work function of metal is 1 *eV*. Light of wavelength 3000 Å is incident on this metal surface. The velocity of emitted photo-electrons will be [MP PMT 1990]

(a) 10 *m/sec* (b) 1×10^{3} *m/sec*

(c) 1×10^{4} *m/sec* (d) 1×10^{6} *m/sec*

45. The retarding potential for having zero photo-electron current

(a) Is proportional to the wavelength of incident light

(b) Increases uniformly with the increase in the wavelength of incident light

(c) Is proportional to the frequency of incident light

(d) Increases uniformly with the increase in the frequency of incident light wave

46. In a dark room of photography, generally red light is used. The reason is

(a) Most of the photographic films are not sensitive to red light

(b) The frequency for red light is low and hence the energy $h\nu$ of photons is less

(c) (a) and (b) both

(d) None of the above

47. The work function of a metal is 1.6×10^{-19} *J*. When the metal surface is illuminated by the light of wavelength 6400 Å, then the maximum kinetic energy of emitted photo-electrons will be

(Planck's constant $h = 6.4\times10^{-34}$ *Js*) [MP PMT 1989]

(a) 14×10^{-19} *J* (b) 2.8×10^{-19} *J*

(c) 1.4×10^{-19} *J* (d) 1.4×10^{-19} *eV*

48. Ultraviolet radiations of $6.2\,eV$ falls on an aluminium surface (work function $4.2\ eV$). The kinetic energy in joules of the fastest electron emitted is approximately

[MNR 1987; MP PET 1990; CBSE PMT 1993; Pb. PMT 2001; BVP 2003; Pb. PET 2004]

(a) 3.2×10^{-21} (b) 3.2×10^{-19}

(c) 3.2×10^{-17} (d) 3.2×10^{-15}

49. The work function for tungsten and sodium are 4.5 *eV* and 2.3 *eV* respectively. If the threshold wavelength λ for sodium is $5460Å$, the value of λ for tungsten is

[MP PET 1990]

(a) 5893 Å (b) 10683 Å

(c) 2791 Å (d) 528 Å

50. A photon of energy 3.4 *eV* is incident on a metal having work function 2 *eV*. The maximum K.E. of photo-electrons is equal to

(a) 1.4 *eV* (b) 1.7 *eV*

(c) 5.4 *eV* (d) 6.8 *eV*

51. The work function of a metallic surface is 5.01 *eV*. The photo-electrons are emitted when light of wavelength 2000Å falls on it. The potential difference applied to stop the fastest photo-electrons is $[h = 4.14\times10^{-15}\ eV\,\text{sec}]$

[MP PET 1991; DPMT 1999]

(a) 1.2 *volts* (b) 2.24 *volts*

(c) 3.6 *volts* (d) 4.8 *volts*

52. The photoelectric threshold wavelength for a metal surface is 6600 Å. The work function for this is [MP PET 1991]

(a) 1.87 *V* (b) 1.87 *eV*

(c) 18.7 *eV* (d) 0.18 *eV*

53. Photoelectric effect was successfully explained first by

(a) Planck (b) Hallwash

(c) Hertz (d) Einstein

[MP PMT/PET 1988]

54. The spectrum of radiation 1.0×10^{14} *Hz* is in the infrared region. The energy of one photon of this in joules will be

[MP PET 1982]

(a) 6.62×10^{-48} (b) 6.62×10^{-20}

(c) $\frac{6.62}{3}\times10^{-28}$ (d) $3\times6.62\times10^{-28}$

55. A radio transmitter operates at a frequency of 880 *kHz* and a power of 10 *kW*. The number of photons emitted per second are[CBSE PMT 1990; MP P

(a) 1.72×10^{31} (b) 1327×10^{34}

(c) 13.27×10^{34} (d) 0.075×10^{-34}

56. A photo cell is receiving light from a source placed at a distance of 1 *m*. If the same source is to be placed at a distance of 2 *m*, then the ejected electron

[MNR 1986; UPSEAT 2000, 01]

(a) Moves with one-fourth energy as that of the initial energy

(b) Moves with one-fourth of momentum as that of the initial momentum

(c) Will be half in number

(d) Will be one-fourth in number

57. In a photoelectric experiment for 4000 Å incident radiation, the potential difference to stop the ejection is 2 *V*. If the incident light is changed to 3000 Å, then the potential required to stop the ejection of electrons will be

[MP PET 1995]

(a) 2 *V* (b) Less than 2 *V*

(c) Zero (d) Greater than 2 *V*

58. Light of wavelength 4000 Å is incident on a sodium surface for which the threshold wave length of photo – electrons is 5420 Å. The work function of sodium is

[MP PMT 1993; Pb. PMT 2002]

(a) 4.58 eV (b) 2.29 eV

(c) 1.14 eV (d) 0.57 eV

59. Photo cell is a device to [MP PET 1993]

(a) Store photons

(b) Measure light intensity

(c) Convert photon energy into mechanical energy

(d) Store electrical energy for replacing storage batteries

60. If the work function for a certain metal is 3.2×10^{-19} *joule* and it is illuminated with light of frequency 8×10^{14} *Hz*. The maximum kinetic energy of the photo-electrons would be

[MP PET 1993]

(a) $2.1\times10^{-19}\,J$ (b) $8.5\times10^{-19}\,J$

(c) $5.3\times10^{-19}\,J$ (d) $3.2\times10^{-19}\,J$

$(h=6.63\times10^{-34}\,Js)$

61. Stopping potential for photoelectrons [MP PET 1994]

(a) Does not depend on the frequency of the incident light

(b) Does not depend upon the nature of the cathode material

(c) Depends on both the frequency of the incident light and nature of the cathode material

(d) Depends upon the intensity of the incident light

62. The maximum wavelength of radiation that can produce photoelectric effect in a certain metal is 200 *nm*. The maximum kinetic energy acquired by electron due to radiation of wavelength 100 *nm* will be [MP PMT 1994]

(a) 12.4 *eV* (b) 6.2 *eV*

(c) 100 *eV* (d) 200 *eV*

63. When the light source is kept 20 *cm* away from a photo cell, stopping potential 0.6 *V* is obtained. When source is kept 40 *cm* away, the stopping potential will be [MP PMT 1994]

(a) 0.3 *V* (b) 0.6 *V*

(c) 1.2 *V* (d) 2.4 *V*

64. The minimum energy required to remove an electron is called [AFMC 1995; DPMT 2001]

(a) Stopping potential (b) Kinetic energy

(c) Work function (d) None of these

65. Light of wavelength 4000 Å falls on a photosensitive metal and a negative 2 *V* potential stops the emitted electrons. The work function of the material (in *eV*) is approximately

$(h=6.6\times10^{-34}\,Js,\ e=1.6\times10^{-19}\,C,\ c=3\times10^{8}\,ms^{-1})$

[MP PMT 1995; MH CET 2004]

(a) 1.1 (b) 2.0

(c) 2.2 (d) 3.1

66. Assuming photoemission to take place, the factor by which the maximum velocity of the emitted photoelectrons changes when the wavelength of the incident radiation is increased four times, is

(a) 4 (b) $\frac{1}{4}$

(c) 2 (d) $\frac{1}{2}$

67. Work function of a metal is 2.51 *eV*. Its threshold frequency is

(a) 5.9×10^{14} *cycle/sec* (b) 6.5×10^{14} *cycle/sec*

(c) 9.4×10^{14} *cycle/sec* (d) 6.08×10^{14} *cycle/sec*

68. Energy conversion in a photoelectric cell takes place from

[AFMC 1993; MP PET 1996; MP PMT 1996]

(a) Chemical to electrical (b) Magnetic to electrical

(c) Optical to electrical (d) Mechanical to electrical

69. Which one of the following is true in photoelectric emission

[MP PMT 1996; JIPMER 2001, 02]

(a) Photoelectric current is directly proportional to the amplitude of light of a given frequency

(b) Photoelectric current is directly proportional to the intensity of light of a given frequency at moderate intensities

(c) Above the threshold frequency, the maximum K.E. of photoelectrons is inversely proportional to the frequency of incident light

(d) The threshold frequency depends upon the wavelength of incident light

70. When a point source of light is at a distance of one metre from a photo cell, the cut off voltage is found to be *V*. If the same source is placed at 2 *m* distance from photo cell, the cut off voltage will be

(a) *V* (b) *V*/2

(c) *V*/4 (d) $V/\sqrt{2}$

71. The work function of a photoelectric material is 3.3 *eV*. The threshold frequency will be equal to [UPSEAT 1999]

(a) $8\times10^{4}\,Hz$ (b) $8\times10^{56}\,Hz$

(c) $8\times10^{10}\,Hz$ (d) $8\times10^{14}\,Hz$

72. If the work function of a metal is 'ϕ' and the frequency of the incident light is 'ν', there is no emission of photoelectron if

(a) $\nu<\frac{\phi}{h}$ (b) $\nu=\frac{\phi}{h}$

(c) $\nu>\frac{\phi}{h}$ (d) $\nu>=<\frac{\phi}{h}$

73. A photoelectric cell is illuminated by a point source of light 1 *m* away. When the source is shifted to 2 *m* then

[CBSE PMT 2003]

(a) Number of electrons emitted is half the initial number

(b) Each emitted electron carries half the initial energy

(c) Number of electrons emitted is a quarter of the initial number

(d) Each emitted electron carries one quarter of the initial energy

74. Light of wavelength λ strikes a photo-sensitive surface and electrons are ejected with kinetic energy *E*. If the kinetic energy is to be increased to 2*E*, the wavelength must be changed to λ' where

(a) $\lambda'=\frac{\lambda}{2}$ (b) $\lambda'=2\lambda$

(c) $\frac{\lambda}{2}<\lambda'<\lambda$ (d) $\lambda'>\lambda$

[Haryana CEE 1996]

75. If in a photoelectric experiment, the wavelength of incident radiation is reduced from 6000 Å to 4000 Å then

[MP PMT 1999]

(a) Stopping potential will decrease

(b) Stopping potential will increase

(c) Kinetic energy of emitted electrons will decrease

(d) The value of work function will decrease

76. The photoelectric work function for a metal surface is 4.125 *eV*. The cut-off wavelength for this surface is [CBSE PMT 1999; KCET 2001]

(a) 4125 Å (b) 2062.5 Å

(c) 3000 Å (d) 6000 Å

77. As the intensity of incident light increases [CPMT 1999; CBSE PMT 1999; MH CET (Med.) 2000; KCET (Engg./Med.) 2001; Pb. PET 2001]

(a) Photoelectric current increases

(b) Photoelectric current decreases

(c) Kinetic energy of emitted photoelectrons increases

(d) Kinetic energy of emitted photoelectrons decreases

78. Light of wavelength 5000 Å falls on a sensitive plate with photoelectric work function of 1.9 *eV*. The kinetic energy of the photoelectron emitted will be [CBSE PMT 1998]

(a) 0.58 *eV* (b) 2.48 *eV*

(c) 1.24 *eV* (d) 1.16 *eV*

79. Which of the following is dependent on the intensity of incident radiation in a photoelectric experiment [AIIMS 1998]

(a) Work function of the surface

(b) Amount of photoelectric current

(c) Stopping potential will be reduced

(d) Maximum kinetic energy of photoelectrons

80. The work function of a substance is 4.0 *eV*. The longest wavelength of light that can cause photoelectron emission from this substance is approximately [IIT JEE 1998; UPSEAT 2002, 03; AIEEE 2004]

(a) 540 *nm* (b) 400 *nm*

(c) 310 *nm* (d) 220 *nm*

81. The maximum kinetic energy of photoelectrons emitted from a surface when photons of energy 6 *eV* fall on it is 4 *eV*. The stopping potential in *volts* is [IIT JEE 1997 Re-Exam]

(a) 2 (b) 4

(c) 6 (d) 10

82. Work function of a metal is 2.1 *eV*. Which of the waves of the following wavelengths will be able to emit photoelectrons from its surface [Bihar MEE 1995]

(a) 4000 Å, 7500 Å (b) 5500 Å, 6000 Å

(c) 4000 Å, 6000 Å (d) None of these

83. If mean wavelength of light radiated by 100 *W* lamp is 5000 Å, then number of photons radiated per second are [RPET 1997]

(a) 3×10^{23} (b) 2.5×10^{22}

(c) 2.5×10^{20} (d) 5×10^{17}

84. The frequency of the incident light falling on a photosensitive metal plate is doubled, the kinetic energy of the emitted photoelectrons is

(a) Double the earlier value (b) Unchanged

(c) More than doubled (d) Less than doubled

85. When light of wavelength 300 *nm* (nanometer) falls on a photoelectric emitter, photoelectrons are liberated. For another emitter, however light of 600 *nm* wavelength is sufficient for creating photoemission. What is the ratio of the work functions of the two emitters [CBSE PMT 1993; JIPMER 2000]

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

(c) 4 : 1 (d) 1 : 4

86. Threshold wavelength for photoelectric effect on sodium is 5000 Å. Its work function is [CBSE PMT 1993]

(a) 15 *J* (b) 16×10^{-14} *J*

(c) 4×10^{-19} *J* (d) 4×10^{-81} *J*

87. The cathode of a photoelectric cell is changed such that the work function changes from W_1 to W_2 ($W_2 > W_1$). If the current before and after change are I_1 and I_2, all other conditions remaining unchanged, then (assuming $h\nu > W_2$) [CBSE PMT 1992]

(a) $I_1 = I_2$ (b) $I_1 < I_2$

(c) $I_1 > I_2$ (d) $I_1 < I_2 < 2I_1$

88. A beam of light of wavelength λ and with illumination L falls on a clean surface of sodium. If N photoelectrons are emitted each with kinetic energy E, then [BHU 1994]

(a) $N \propto L$ and $E \propto L$ (b) $N \propto L$ and $E \propto \frac{1}{\lambda}$

(c) $N \propto \lambda$ and $E \propto L$ (d) $N \propto \frac{1}{\lambda}$ and $E \propto \frac{1}{L}$

89. Which of the following statements is correct [CBSE PMT 1997]

(a) The current in a photocell increases with increasing frequency of light

(b) The photocurrent is proportional to applied voltage

(c) The photocurrent increases with increasing intensity of light

(d) The stopping potential increases with increasing intensity of incident light

90. What is the stopping potential when the metal with work function 0.6 *eV* is illuminated with the light of 2 *eV* [BHU 1998; MH CET 2003]

(a) 2.6 *V* (b) 3.6 *V*

(c) 0.8 *V* (d) 1.4 *V*

91. When yellow light is incident on a surface, no electrons are emitted while green light can emit. If red light is incident on the surface, then [MNR 1998; MP PET 2000; MH CET 2000]

(a) No electrons are emitted

(b) Photons are emitted

(c) Electrons of higher energy are emitted

(d) Electrons of lower energy are emitted

92. The photoelectric threshold wavelength of a certain metal is 3000Å. If the radiation of 2000Å is incident on the metal [MNR 1998; KCET 1994]

(a) Electrons will be emitted

(b) Positrons will be emitted

[Roorkee 1992]

(c) Protons will be emitted

(d) Electrons will not be emitted

93. A photocell stops emission if it is maintained at 2 *V* negative potential. The energy of most energetic photoelectron is [JIPMER 1999]

(a) $2eV$ (b) $2J$
(c) $2kJ$ (d) $2keV$

94. The work functions for sodium and copper are $2eV$ and $4eV$. Which of them is suitable for a photocell with 4000 Å light

(a) Copper (b) Sodium
(c) Both (d) Neither of them

95. For intensity I of a light of wavelength 5000Å the photoelectron saturation current is 0.40 μA and stopping potential is 1.36 V, the work function of metal is [RPET 1999]

(a) 2.47 eV (b) 1.36 eV
(c) 1.10 eV (d) 0.43 eV

96. The work function of aluminium is 4.2 eV. If two photons, each of energy 3.5 eV strike an electron of aluminium, then emission of electrons will be [AFMC 1999]

(a) Possible
(b) Not possible
(c) Data is incomplete
(d) Depend upon the density of the surface

97. In photoelectric effect if the intensity of light is doubled then maximum kinetic energy of photoelectrons will become [RPMT 1999]

(a) Double (b) Half
(c) Four time (d) No change

98. Energy required to remove an electron from aluminium surface is 4.2 eV. If light of wavelength 2000 $\AA$ falls on the surface, the velocity of the fastest electron ejected from the surface will be

(a) $8.4\times10^5\ m/sec$ (b) $7.4\times10^5\ m/sec$
(c) $6.4\times10^5\ m/sec$ (d) $8.4\times10^6\ m/sec$

99. Mercury violet light $(\lambda = 4558\AA)$ is falling on a photosensitive material $(\phi = 2.5eV)$. The speed of the ejected electrons is in ms^{-1}, about [AMU (Engg.) 1999]

(a) 3×10^5 (b) 2.65×10^5
(c) 4×10^4 (d) 3.65×10^7

100. The work functions of metals A and B are in the ratio 1 : 2. If light of frequencies f and $2f$ are incident on the surfaces of A and B respectively, the ratio of the maximum kinetic energies of photoelectrons emitted is (f is greater than threshold frequency of A, $2f$ is greater than threshold frequency of B)

(a) 1 : 1 (b) 1 : 2
(c) 1 : 3 (d) 1 : 4

101. Light of frequency ν is incident on a substance of threshold frequency ν_0 $(\nu_0 < \nu)$. The energy of the emitted photo-electron will be

(a) $h(\nu-\nu_0)$ (b) h/ν
(c) $he(\nu-\nu_0)$ (d) h/ν_0

102. The stopping potential (V_0) [BHU 2000]

(a) Depends upon the angle of incident light
(b) Depends upon the intensity of incident light
(c) Depends upon the surface nature of the substance
(d) Is independent of the intensity of the incident light

103. If work function of metal is $3\,eV$ then threshold wavelength will be [RPMT 2000]

(a) 4125 $\AA$ (b) 4000 $\AA$
(c) 4500 $\AA$ [RPET 1999] (d) 5000 $\AA$

104. When wavelength of incident photon is decreased then [RPET 2000]

(a) Velocity of emitted photo-electron decreases
(b) Velocity of emitted photoelectron increases
(c) Velocity of photoelectron do not charge
(d) Photo electric current increases

105. Quantam nature of light is explained by which of the following phenomenon [RPET 2000]

(a) Huygen wave theory
(b) Photoelectric effect
(c) Maxwell electromagnetic theory
(d) de-Broglie theory

106. When a metal surface is illuminated by light of wavelengths 400 nm and 250 nm, the maximum velocities of the photoelectrons ejected are v and $2v$ respectively. The work function of the metal is (h = Planck's constant, c = velocity of light in air)

(a) $2hc\times10^6\ J$ (b) $1.5hc\times10^6\ J$
(c) $hc\times10^6\ J$ (d) $0.5\ hc\times10^6\ J$

107. 4 eV is the energy of the incident photon and the work function in $2eV$. What is the stopping potential [AMU 1999] [DCE 2000; AIIMS 2004]

(a) $2V$ (b) $4V$
(c) $6V$ (d) $2\sqrt{2}V$

108. Light of frequency ν is incident on a certain photoelectric substance with threshold frequency ν_0. The work function for the substance is

(a) $h\nu$ (b) $h\nu_0$
(c) $h(\nu-\nu_0)$ (d) $h(\nu+\nu_0)$

109. If threshold wavelength for sodium is 6800Å then the work function will be [RPET 2001]

(a) $1.8eV$ (b) $2.5eV$
(c) $2.1eV$ (d) $1.4eV$

110. If intensity of incident light is increased in PEE then which of the following is true [RPET 2001]

(a) Maximum $K.E.$ of ejected electron will increase
(b) Work function will remain unchanged [EAMCET (Med.) 2000]
(c) Stopping potential will decrease
(d) Maximum $K.E.$ of ejected electron will decrease

111. Light of frequency $8\times10^{15}\ Hz$ is incident on a substance of photoelectric work function $6.125\,eV$. The maximum kinetic energy of the emitted photoelectrons is [MP PET 2000; 03] [AFMC 2001]

(a) 17 eV (b) 22 eV
(c) 27 eV (d) 37 eV

112. The photoelectric threshold wavelength for potassium (work function being $2eV$) is [CPMT 2001]

(a) 310 nm (b) 620 nm
(c) 1200 nm (d) 2100 nm

113. Photons of energy 6 eV are incident on a metal surface whose work function is 4 eV. The minimum kinetic energy of the emitted photo-electrons will be [MP PET 2001]

(a) 0 eV (b) 1 eV

(c) 2 eV (d) 10 eV

114. According to photon theory of light which of the following physical quantities associated with a photon do not/does not change as it collides with an electron in vacuum [AMU (Engg.) 2001]

(a) Energy and momentum (b) Speed and momentum

(c) Speed only (d) Energy only

115. The lowest frequency of light that will cause the emission of photoelectrons from the surface of a metal (for which work function is 1.65 eV) will be [JIPMER 2002]

(a) $4\times10^{10}\,Hz$ (b) $4\times10^{11}\,Hz$

(c) $4\times10^{14}\,Hz$ (d) $4\times10^{-10}\,Hz$

116. Light of two different frequencies whose photons have energies $1eV$ and $2.5eV$ respectively, successively illuminates a metal of work function $0.5eV$. The ratio of maximum kinetic energy of the emitted electron will be [AIEEE 2002]

(a) 1 : 5 (b) 1 : 4

(c) 1 : 2 (d) 1 : 1

117. Sodium and copper have work functions 2.3 eV and 4.5 eV respectively. Then the ratio of their threshold wavelengths is nearest to [AIEEE 2002]

(a) 1: 2 (b) 4 : 1

(c) 2 : 1 (d) 1 : 4

118. Photon of 5.5 eV energy fall on the surface of the metal emitting photoelectrons of maximum kinetic energy 4.0 eV. The stopping voltage required for these electrons are [Orissa (Engg.) 2002; DPMT 2004]

(a) 5.5 V (b) 1.5 V

(c) 9.5 V (d) 4.0 V

119. A caesium photocell, with a steady potential difference of 60 V across, is illuminated by a bright point source of light 50 cm away. When the same light is placed 1m away the photoelectrons emitted from the cell [KCET 2002]

(a) Are one quarter as numerous

(b) Are half as numerous

(c) Each carry one quarter of their previous momentum

(d) Each carry one quarter of their previous energy

120. A radio transmitter radiates 1 kW power at a wavelength 198.6 *metres*. How many photons does it emit per second [Kerala (Engg.) 2002]

(a) 10^{10} (b) 10^{20}

(c) 10^{30} (d) 10^{40}

121. The number of photons of wavelength 540 nm emitted per second by an electric bulb of power 100 W is (taking $h = 6\times10^{-34}\ J$ - sec) [Kerala (Engg.) 2002; Pb. PET 2001]

(a) 100 (b) 1000

(c) 3×10^{20} (d) 3×10^{18}

122. When radiation is incident on a photoelectron emitter, the stopping potential is found to be 9 volts. If e/m for the electron is $1.8\times10^{11}\,C\,kg^{-1}$ the maximum velocity of the ejected electrons is [Kerala (Engg.) 2002]

(a) $6\times10^5\,ms^{-1}$ (b) $8\times10^5\,ms^{-1}$

(c) $1.8\times10^6\,ms^{-1}$ (d) $1.8\times10^5\,ms^{-1}$

123. Two identical metal plates show photoelectric effect by a light of wavelength λ_A falls on plate A and λ_B on plate B $(\lambda_A = 2\lambda_B)$. The maximum kinetic energy is [CPMT 2002]

(a) $2K_A = K_B$ (b) $K_A < K_B/2$

(c) $K_A = 2K_B$ (d) $K_A = K_B/2$

124. The threshold wavelength for photoelectric effect of a metal is 6500 Å. The work function of the metal is approximately [MP PMT 2002]

(a) 2 eV (b) 1 eV

(c) 0.1 eV (d) 3 eV

125. When ultraviolet rays are incident on metal plate, then photoelectric effect does not occurs. It occurs by the incidence of [CBSE PMT 2002; DCE 1997;

(a) X-rays (b) Radio wave

(c) Infrared rays (d) Green house effect

126. Light of frequency 4ν is incident on the metal of the threshold frequency ν. The maximum kinetic energy of the emitted photoelectrons is [MP PET 2002]

(a) $3h\nu_0$ (b) $2h\nu_0$

(c) $\frac{3}{2}h\nu_0$ (d) $\frac{1}{2}h\nu_0$

127. By photoelectric effect, Einstein, proved [MP PET 2003]

(a) $E = hv$ (b) $K.E. = \frac{1}{2}mv^2$

(c) $E = mc^2$ (d) $E = \frac{Rhc^2}{n^2}$

128. The work function of sodium is 2.3 eV. The threshold wavelength of sodium will be [BHU 2003]

(a) 2900 Å (b) 2500 Å

(c) 5380 Å (d) 2000 Å

129. Which of the following shown particle nature of light [AFMC 2003; CBSE PMT 2001]

(a) Refraction (b) Interference

(c) Polarization (d) Photoelectric effect

130. Two identical photo-cathodes receive light of frequencies f_1 and f_2. If the velocities of the photo electrons (of mass m) coming out are respectively v_1 and v_2, then [AIEEE 2003]

(a) $v_1 - v_2 = \left[\frac{2h}{m}(f_1 - f_2)\right]^{1/2}$ (b) $v_1^2 - v_2^2 = \frac{2h}{m}(f_1 - f_2)$

(c) $v_1 + v_2 = \left[\frac{2h}{m}(f_1 + f_2)\right]^{1/2}$ (d) $v_1^2 + v_2^2 = \frac{2h}{m}(f_1 + f_2)$

131. Consider the two following statements A and B and identify the correct choice given in the answers;

(A) In photovlotaic cells the photoelectric current produced is not proportional to the, intensity of incident light.

(B) In gas filled photoemissive cells, the velocity of photoelectrons depends on the wavelength of the incident radiation.

(a) Both A and B are true (b) Both A and B are false

(c) A is true but B is false (d) A is false B is true

132. When radiation of wavelength λ is incident on a metallic surface, the stopping potential is 4.8 volts. If the same surface is illuminated with radiation of double the wavelength, then the stopping potential becomes 1.6 *volts*. Then the threshold wavelength for the surface is [EAMCET (Engg.) 2003]

(a) 2λ (b) 4λ

(c) 6λ (d) 8λ

133. The frequency and work function of an incident photon are ν and ϕ_0. If ν is the threshold frequency then necessary condition for the emission of photo electron is [RPET 2003]

(a) $\nu < \nu_0$ (b) $\nu = \frac{\nu_0}{2}$

(c) $\nu \geq \nu_0$ (d) None of these

134. Light of wavelength 1824 Å, incident on the surface of a metal, produces photo-electrons with maximum energy 5.3 eV. When light of wavelength 1216 $\mathring{A}$ is used, the maximum energy of photoelectrons is 8.7 eV. The work function of the metal surface is

(a) 3.5 eV (b) 13.6 eV

(c) 6.8 eV (d) 1.5 eV

135. If the energy of a photon corresponding to a wavelength of 6000 $\mathring{A}$ is $3.32 \times 10^{-19} J$, the photon energy for a wavelength of 4000 $\mathring{A}$ will be [DPMT 2004]

(a) 1.4 eV (b) 4.9 eV

(c) 3.1 eV (d) 1.6 eV

136. If the wavelength of light is 4000 $\mathring{A}$, then the number of waves in 1 *mm* length will be [J & K CET 2004]

(a) 25 (b) 0.25

(c) 0.25×10^4 (d) 25×10^4

137. The velocity of photon is proportional to (where ν is frequency)

(a) $\frac{\nu^2}{2}$ (b) $\frac{1}{\sqrt{\nu}}$

(c) $\sqrt{\nu}$ (d) ν

138. If the work function of a photometal is 6.825 eV. Its threshold wavelength will be $(c = 3 \times 10^8\ m/s)$

[Pb. PET 2000; BHU 2004]

(a) 1200 $\mathring{A}$ (b) 1800 $\mathring{A}$

(c) 2400 $\mathring{A}$ (d) 3600 $\mathring{A}$

139. A photon of energy 8 eV is incident on a metal surface of threshold frequency $1.6 \times 10^{15}\ Hz$, then the maximum kinetic energy of photoelectrons emitted is $(h = 6.6 \times 10^{-34}\ Js)$

(a) 4.8 eV (b) 2.4 eV

(c) 1.4 eV (d) 0.8 eV

140. If the energy of the photon is increased by a factor of 4, then its momentum [UPSEAT 2004]

(a) Does not change

(b) Decreases by a factor of 4

(c) Increases by a factor of 4

(d) Decreases by a factor of 2

141. The ratio of the energy of a photon with $\lambda = 150\,nm$ to that with $\lambda = 300\,nm$ is [DCE 2003]

(a) 2 [EAMCET (Engg.) 2003] (b) 1/4

(c) 4 (d) 1/2

142. Photo-electric effect can be explained by [DCE 2003]

(a) Corpusular theory of light (b) Wave nature of light

(c) Bohr's theory (d) Quantum theory of light

143. In photoelectric effect, the K.E. of electrons emitted from the metal surface depends upon [DCE 2003]

(a) Intensity of light

(b) Frequency of incident light

(c) Velocity of incident light

(d) Both intensity and velocity of light

144. The photoelectric effect can be understood on the basis of

[Pb. PET 2004]

(a) The principle of superposition

(b) The electromagnetic theory of light

(c) The special theory of relativity

(d) Line spectrum of the atom

145. If the threshold wavelength for sodium is 5420 $\mathring{A}$, then the work function of sodium is [RPMT 2003]

(a) 4.58 eV [MP PMT 2004] (b) 2.28 eV

(c) 1.14 eV (d) 0.23 eV

146. The work function of a metal is [RPMT 2004]

(a) The energy for the electron to enter into the metal

(b) The energy for producing X-ray

(c) The energy for the electron to come out from metal surface

(d) None of these

147. The minimum wavelength of photon is 5000 $\mathring{A}$, its energy will be

(a) 2.5 eV (b) 50 V

(c) 5.48 eV (d) 7.48 eV

148. Which of one is correct [DCE 1998]

(a) $E^2 = p^2c^2$ (b) $E^2 = p^2c$

(c) $E^2 = pc^2$ [Pb. PMT 2004] (d) $E^2 = p^2/c^2$

149. The work function for metals A, B and C are respectively 1.92 eV, 2.0 eV and 5 eV. According to Einstein's equation, the metals which will emit photo electrons for a radiation of wavelength 4100 $\mathring{A}$ is/are[CBSE PMT

(a) None of these (b) A only

(c) A and B only (d) All the three metals

150. A photosensitive metallic surface has work function $h\nu_0$. If photons of energy $2h\nu_0$ fall on this surface the electrons come out with a maximum velocity of $4 \times 10^6\ m/s$. When the photon energy is increases to $5h\nu_0$ then maximum velocity of photo electron will be[CBSE PMT

(a) $2 \times 10^6\ m/s$ [Pb. PET 2002] (b) $2 \times 10^7\ m/s$

(c) $8 \times 10^5\ m/s$ (d) $8 \times 10^6\ m/s$

151. A photocell is illuminated by a small bright source placed 1 *m* away. When the same source of light is placed $\frac{1}{2}m$ away, the number of electrons emitted by photo cathode would[CBSE PMT 2001; AIEEE 2005]

(a) Decrease by a factor of 2 (b) Increase by a factor of 2

(c) Decrease by a factor of 4 (d) Increase by a factor of 4

152. The magnitude of saturation photoelectric current depends upon[AFMC 2005]

(a) Frequency (b) Intensity
(c) Work function (d) Stopping potential

153. For photoelectric emission, tungsten requires light of 2300 Å. If light of 1800 Å wavelength is incident then emission [AFMC 2005]
(a) Takes place
(b) Don't take place
(c) May or may not take place
(d) Depends on frequency

154. The light rays having photons of energy 1.8 eV are falling on a metal surface having a work function 1.2 eV. What is the stopping potential to be applied to stop the emitting electrons
(a) 3 eV (b) 1.2 eV
(c) 0.6 eV (d) 1.4 eV

155. The incident photon involved in the photoelectric effect experiment.
(a) Completely disappears
(b) Comes out with an increased frequency
(c) Comes out with a decreased frequency
(d) Comes out without change in frequency

156. A photon of energy 8 eV is incident on metal surface of threshold frequency $1.6 \times 10^{15} \, Hz$. The maximum kinetic energy of the photoelectrons emitted (in eV) (Take $h = 6 \times 10^{-34} \, Js$).
(a) 1.6 (b) 6
(c) 2 (d) 1.2

X-Rays

1. An X-ray tube is operated at 50 kV. The minimum wavelength produced is [CPMT 1996]
(a) 0.5 Å (b) 0.75 Å
(c) 0.25 Å (d) 1 Å

2. Which of the following wavelength falls in X-ray region [CPMT 1975; MP PMT 1984]
(a) 10000 Å (b) 1000 Å
(c) 1 Å (d) 10^{-2} Å

3. A metal block is exposed to beams of X-ray of different wavelength. X-rays of which wavelength penetrate most [NCERT 1980; JIPMER 2002]
(a) 2 Å (b) 4 Å
(c) 6 Å (d) 8 Å

4. X-rays and gamma rays are both electromagnetic waves. Which of the following statements is true [NCERT 1973]
(a) In general X-rays have larger wavelength than of gamma rays
(b) X-rays have smaller wavelength than that of gamma rays
(c) Gamma rays have smaller frequency than that of X-rays
(d) Wavelength and frequency of X-rays are both larger than that of gamma rays

5. In producing X-rays a beam of electrons accelerated by a potential difference V is made to strike a metal target. For what value of V, X-rays will have the lowest wavelength of 0.3094 Å [CPMT 1982; NCERT 1986, 87]
(a) 10 kV (b) 20 kV
(c) 30 kV (d) 40 kV

6. In radio theraphy, X-rays are used to [CPMT 1972; BHU 2005]
(a) Detect bone fractures
(b) Treat cancer by controlled exposure
(c) Detect heart diseases
(d) Detect fault in radio receiving circuits

7. Hydrogen atom does not emit X-rays because [NCERT 1979; CPMT 1980, 90; RPET 1999]
(a) Its energy levels are too close to each other
(b) Its energy levels are too apart
(c) It is too small in size
(d) It has a single electron

8. X-rays were discovered by [NCERT 1977; BHU 2005]
(a) Becquerel (b) Roentgen
(c) Marie Curie (d) Von Laue
[BHU 2005]

9. X-rays are [CPMT 1975; EAMCET 1995; RPET 2000; SCRA 1994]
(a) Stream of electrons
[EAMCET 2005]
(b) Stream of positively charged particles
(c) Electromagnetic radiations of high frequency
(d) Stream of uncharged particles

10. The voltage applied across an X-rays tube is nearly [CPMT 1983]
(a) 10 V (b) 100 V
(c) 1000 V [MP PET 2005] (d) 10^{6} V

11. The characteristic X-ray radiation is emitted, when [CPMT 1975, 80, 90; RPET 1999]
(a) The electrons are accelerated to a fixed energy
(b) The source of electrons emits a monoenergetic beam
(c) The bombarding electrons knock out electrons from the inner shell of the target atoms and one of the outer electrons falls into this vacancy
(d) The valence electrons in the target atoms are removed as a result of the collision

12. Molybdenum is used as a target element for production of X-rays because it is [CPMT 1980; RPET 1999]
(a) A heavy element and can easily absorb high velocity electrons
(b) A heavy element with a high melting point
(c) An element having high thermal conductivity
(d) Heavy and can easily deflect electrons

13. Mosley's law relates the frequencies of line X-rays with the following characteristics of the target element [CPMT 1980; NCERT 1985]
(a) Its density
(b) Its atomic weight
(c) Its atomic number
(d) Interplaner spacing of the atomic planes

14. Compton effect is associated with [CPMT 1971]
(a) $\alpha -$ rays (b) $\beta -$ rays
(c) X-rays (d) Positive rays

15. X-rays are in nature similar to
(a) Beta rays (b) Gamma rays
(c) de-Broglie waves (d) Cathode rays

16. If the cathode–anode potential difference in an X-ray tube be 10^{5} V, then the maximum energy of X-ray photon can be
(a) 10^{5} J (b) 10^{5} MeV
(c) 10^{-1} MeV (d) 10^{5} KeV

17. The shortest wavelength of X-rays emitted from an X-ray tube depends on the

[MP PMT 1987; CPMT 1988, 92; IIT 1982]

(a) Current in the tube
(b) Voltage applied to the tube
(c) Nature of gas in the tube
(d) Atomic number of target material

18. The wavelength of X-rays is of the order of

[CPMT 1983; MP PMT 1987; KCET 1994; JIPMER 1997]

(a) *Centimetre* (b) *Micron* (10^{-6} *m*)
(c) *Angstrom* (10^{-10} *m*) (d) *Metre*

19. X – rays and γ – rays of the same energies may be distinguished by

(a) Their velocity (b) Their ionising power
(c) Their intensity (d) Method of production

20. When a beam of accelerated electrons hits a target, a continuous X-ray spectrum is emitted from the target. Which of the following wavelength is absent in the X-ray spectrum, if the X-ray tube is operating at 40,000 *volts*

[MP PMT 1993; NCERT 1984; MNR 1995; RPMT 2002]

(a) 0.25 Å (b) 0.5 Å
(c) 1.5 Å (d) 1.0 Å

21. For continuous X-rays produced wavelength is

(a) Inversely proportional to the energy of the electrons hitting the target
(b) Inversely proportional to the intensity of the electron beam
(c) Proportional to intensity of the electron beam
(d) Proportional to target temperature

22. An X-ray has a wavelength of 0.010 Å. Its momentum is

[AFMC 1980; RPMT 1995; Pb. PMT 2004]

(a) 2.126 $\times 10^{-23}$ *kg-m/sec* (b) 6.626 $\times 10^{-22}$ *kg-m/sec*
(c) 3.456 $\times$ 20^{-25} *kg-m/sec* (d) 3.313 $\times 10^{-22}$ *kg-m/sec*

23. X-rays are not used for radar purpose because

(a) They are not reflected by the target
(b) They are not electromagnetic waves
(c) They are completely absorbed by the air
(d) They sometimes damage the target

24. A direct X-ray photograph of the intestines is not generally taken by the radiologists because [CPMT 1986, 88]

(a) Intestines would burst on exposure to X-rays
(b) The X-rays would not pass through the intestines
(c) The X-rays will pass through the intestines without causing a good shadow for any useful diagnosis
(d) A very small exposure of X-rays causes cancer in the intestines

25. The patient is asked to drink $BaSO_4$ for examining the stomach by *X*-rays because *X*-rays are

(a) Reflected by heavy atoms
(b) Refracted by heavy atoms
(c) Less absorbed by heavy atoms
(d) More absorbed by heavy atoms

26. X-rays can be used to study crystal structure, if the wavelength lies in the range

(a) 2 Å to 0.1 Å (b) 10 Å to 5 Å
(c) 50 Å to 10 Å (d) 100 Å to 50 Å

27. When the accelerating voltage applied on the electrons increased beyond a critical value [CPMT 1975]

(a) Only the intensity of the various wavelengths is increased
(b) Only the wavelength of characteristic relation is affected
(c) The spectrum of white radiation is unaffected
(d) The intensities of characteristic lines relative to the white spectrum are increased but there is no change in their wavelength

28. The *X*-ray beam coming from an *X*-ray tube will be

[IIT 1985; SCRA 1996; MP PET 1999]

(a) Monochromatic [CPMT 1985]
(b) Having all wavelengths smaller than a certain maximum wavelength
(c) Having all wavelengths larger than a certain minimum wavelength
(d) Having all wavelengths lying between a minimum and a maximum wavelength

29. The continuous X-rays spectrum produced by an X-ray machine at constant voltage has [DPMT 1999]

(a) A maximum wavelength (b) A minimum wavelength
(c) A single wavelength (d) A minimum frequency

30. The penetrating power of X-rays increases with the

[MP PMT 1984]

(a) Increase in its velocity (b) Increase in its frequency
(c) Increase in its intensity (d) Decrease in its velocity

31. If λ_1 and λ_2 are the wavelengths of characteristic X-rays and gamma rays respectively, then the relation between them is

(a) $\lambda_1 = \dfrac{1}{\lambda_2}$ (b) $\lambda_1 = \lambda_2$
(c) $\lambda_1 > \lambda_2$ (d) $\lambda_1 < \lambda_2$

32. The wavelength λ of the K_α line of characteristic *X*-ray spectra varies with atomic number approximately

[MP PMT 1987]

(a) $\lambda \propto Z$ (b) $\lambda \propto \sqrt{Z}$
(c) $\lambda \propto \dfrac{1}{Z^2}$ (d) $\lambda \propto \dfrac{1}{\sqrt{Z}}$

33. The minimum frequency ν of continuous *X*-rays is related to the applied potential difference *V* as

(a) $\nu \propto \sqrt{V}$ (b) $\nu \propto V$
(c) $\nu \propto V^{3/2}$ (d) $\nu \propto V^2$

34. If *V* be the accelerating voltage, then the maximum frequency of continuous *X*-rays is given by

[NCERT 1971; CPMT 1991;
MP PET 2000; RPMT 2001; MP PMT 2002]

(a) $\dfrac{eh}{V}$ (b) $\dfrac{hV}{e}$
(c) $\dfrac{eV}{h}$ (d) $\dfrac{h}{eV}$

35. The minimum wavelength of *X*-rays produced by electrons accelerated by a potential difference of *volts* is equal to

[CPMT 1986, 88, 91; RPMT 1997; RPMT 1997, 98;
MP PET 1997, 98; MP PMT 1996, 98, 2003; UPSEAT 2005]

(a) $\frac{eV}{hc}$ (b) $\frac{eh}{cV}$

(c) $\frac{hc}{eV}$ (d) $\frac{cV}{eh}$

36. The potential difference applied to an *X*-ray tube is increased. As a result, in the emitted radiation [IIT 1988; ISM Dhanbad 1994; AIIMS 1997; MP PMT 1995, 2004]

(a) The intensity increases
(b) The minimum wavelength increases
(c) The intensity decreases
(d) The minimum wavelength decreases

37. A potential difference of 42,000 *volts* is used in an *X*-ray tube to accelerate electrons. The maximum frequency of the *X*–radiations produced is [MP PMT 1993]

(a) 10^{19} *Hz* (b) 10^{18} *Hz*

(c) 10^{16} *Hz* (d) 10^{20} *Hz*

$(1eV = 1.6\times10^{-19}\,J$ and $h = 6.63\times10^{-34}\,J-\text{sec})$

38. Which of the following is accompanied by the characteristic *X*-ray emission [MP PET 1993]

(a) $\alpha-$particle emission (b) Electron emission

(c) Positron emission (d) *K*–electron capture

39. *X*-rays are known to be electromagnetic radiations. Therefore the *X*-ray photon has [MP PET 1993]

(a) Electric charge
(b) Magnetic moment
(c) Both electric charge and magnetic moment
(d) Neither electric charge nor magnetic moment

40. *X*-rays of which of the following wavelengths are hardest

(a) 4 Å (b) 1 Å

(c) 0.1 Å (d) 2 Å

41. *X*-ray beam can be deflected by [CPMT 2000; BHU 2001; Pb. PMT 2002]

(a) Magnetic field (b) Electric field

(c) Both (a) and (b) (d) None of these

42. *X*-rays are produced due to [CPMT 1985; JIPMER 2002]

(a) Break up of molecules
(b) Changing in atomic energy level
(c) Changing in nuclear energy level
(d) Radioactive disintegration

43. *X*-rays region lies between [CPMT 1990]

(a) Short radiowave and visible region
(b) Visible and ultraviolet region
(c) Gamma rays and ultraviolet region
(d) Short radiowave and long radiowave

44. The structure of solid crystals is investigated by using [CPMT 1992; NCERT 1975; CBSEPMT 1992]

(a) Cosmic rays (b) *X*-rays

(c) Infrared radiations (d) $\gamma-$ rays

45. In an *X*-rays tube, the intensity of the emitted *X*-rays beam is increased by [MNR 1992; RPMT 1996; UPSEAT 2000]

(a) Increasing the filament current
(b) Decreasing the filament current
(c) Increasing the target potential
(d) Decreasing the target potential

46. The binding energy of the innermost electron in tungsten is 40 *keV*. To produce characteristic *X*-rays using a tungsten target in an *X*-rays tube the potential difference *V* between the cathode and the anti-cathode should be [IIT 1985]

(a) V< 40 *kV* (b) V ≤ 40 *kV*

(c) V > 40 *kV* (d) V >/< 40 *kV*

47. In above question the energy of the characteristic *X*-rays given out is

(a) Less than 40 *keV* (b) More than 40 *keV*

(c) Equal to 40 *keV* (d) ≥ 40 *keV*

48. The wavelength of most energetic *X*-rays emitted when a metal target is bombarded by 40*KeV* electrons, is approximately

$(h = 6.62\times10^{-34}$ *J-sec*; 1 *eV* = 1.6×10^{-19} *J*; *c* = $3\times10^{8}\ m/s)$

[MNR 1991; MP PMT 1999; UPSEAT 2000; Pb. PET 2004]

(a) 300 Å (b) 10 Å

(c) 4 Å (d) 0.31 Å

49. *X*-rays which can penetrate through longer distances in substance are called [EAMCET 1983]

(a) Soft *X*-rays (b) Continuous *X*-rays

(c) Hard *X*-rays (d) None of the above

50. An *X*-ray machine has an accelerating potential difference of 25,000 volts. By calculation the shortest wavelength will be obtained as

$(h = 6.62\times10^{-34}$ *J–sec*, e = 1.6×10^{-19} *coulomb*)

[MP PET 1994]

(a) 0.25 Å (b) 0.50 Å

(c) 1.00 Å (d) 2.50 Å

51. For the production of *X*-rays of wavelength 0.1 Å the minimum potential difference will be [MP PMT 1994; RPMT 1995]

(a) 12.4 *kV* (b) 24.8 *kV*

(c) 124 *kV* (d) 248 *kV*

52. Mosley measured the frequency (*f*) of the characteristic *X*-rays from many metals of different atomic number (Z) and represented his results by a relation known as Mosley's law. This law is (a, b are constants) [MP PMT 1994; RPMT 1996]

(a) $f = a(Z-b)^2$ (b) $Z = a(f-b)^2$

(c) $f^2 = a(Z-b)$ (d) $f = a(Z-b)^{1/2}$

53. Penetrating power of *X*-rays depends on [MP PMT 1994]

(a) Current flowing in the filament
(b) Applied potential difference
(c) Nature of the target
(d) All the above

54. The energy of a photon of characteristic *X*-rays from a Coolidge tube comes from [MP PET 1995]

(a) The kinetic energy of the striking electron
(b) The kinetic energy of the free electrons of the target
(c) The kinetic energy of the ions of the target
(d) An electronic transition of the target atom

55. An *X*-ray tube operates on 30 *kV*. What is the minimum wavelength emitted

$(h = 6.6\times10^{-34}$ *Js*, $e = 1.6\times10^{-19}$ *Coulomb*, $c = 3\times10^{8}$ *ms*)

[MP PMT 1995; DPMT 2001, 03]

(a) 0.133 Å (b) 0.4 Å

(c) 1.2 Å (d) 6.6 Å

56. The wavelength of the most energetic X–ray emitted when a metal target is bombarded by 100 *KeV* electrons is approximately

(a) 12 Å (b) 4

(c) 0.31 Å (d) 0.124 Å

57. An electron beam in an *X*-ray tube is accelerated through a potential difference of 50000 *volts*. These are then made to fall on a tungsten target. The shortest wavelength of the *X*-ray emitted by the tube is

(a) 2.5 Å (b) 0.25 *nm*

(c) 0.25 *cm* (d) 0.025 *nm*

58. For harder *X*-rays [MP PET 1997]

(a) The wavelength is higher

(b) The intensity is higher

(c) The frequency is higher

(d) The photon energy is lower

59. When cathode rays strike a metal target of high melting point with very high velocity, then

[MP PMT 1997; AIIMS 1999]

(a) *X*-rays are produced

(b) Ealpha-rays are produced

(c) TV waves are produced

(d) Ultrasonic waves are produced

60. Penetrating power of *X*-rays can be increased by

[MP PMT 1997, 2000]

(a) Increasing the potential difference between anode and cathode

(b) Decreasing the potential difference between anode and cathode

(c) Increasing the cathode filament current

(d) Decreasing the cathode filament current

61. K_α characteristic *X*-ray refers to the transition

[MP PMT 1999]

(a) $n = 2$ to $n = 1$ (b) $n = 3$ to $n = 2$

(c) $n = 3$ to $n = 1$ (d) $n = 4$ to $n = 2$

62. *X*-rays are produced in *X*-ray tube operating at a given accelerating voltage. The wavelength of the continuous *X*-rays has values from

(a) 0 to ∞

(b) λ_{min} to ∞, where $\lambda_{min} > 0$

(c) 0 to λ_{max} where $\lambda_{max} < \infty$

(d) λ_{min} to λ_{max}, where $0 < \lambda_{min} < \lambda_{max} < \infty$

63. The wavelength of *X*-rays is [EAMCET (Med.) 1995]

(a) 2000 Å (b) 2 Å

(c) 1 *mm* (d) 1 *cm*

64. The ratio of the energy of an *X*-ray photon of wavelength 1 Å to that of visible light of wavelength 5000 Å is

[EAMCET (Med.) 1995]

(a) 1: 5000 (b) 5000 : 1

(c) $1 : 25 \times 10^6$ (d) 25×10^6

65. According to Mosley's law, the frequency of a spectral line in *X*-ray spectrum varies as

[EAMCET (Med.) 1995; Pb. PMT 1999]

(a) Atomic number of the element

(b) Square of the atomic number of the element

(c) Square root of the atomic number of the element

(d) Fourth power of the atomic number of the element

66. For the structural analysis of crystals, *X*-rays are used because

(a) *X*-rays have wavelength of the order of interatomic spacing

(b) *X*-rays are highly penetrating radiations

(c) Wavelength of *X*-rays is of the order of nuclear size

(d) *X*-rays are coherent radiations

[MP PET 1996]

67. The essential distinction between *X*-rays and γ – rays is that

[BHU 1994; RPMT 1991; JIPMER 2001, 02]

(a) γ – rays have smaller wavelength than *X*-rays

(b) γ [MP PET 1997] – rays emanate from nucleus while *X*-rays emanate from outer part of the atom

(c) γ – rays have greater ionizing power than *X*-rays

(d) γ – rays are more penetrating than *X*-rays

68. The minimum wavelength of the *X*-rays produced by electrons accelerated through a potential difference of V *volts* is directly proportional to [CBSE PMT 1996]

(a) $\sqrt{V}$ (b) V^2

(c) $1/\sqrt{V}$ (d) $1/V$

69. What determines the hardness of the *X*-rays obtained from the Coolige tube [RPMT 1996]

(a) Current in the filament

(b) Pressure of air in the tube

(c) Nature of target

(d) Potential difference between cathode and target

70. The most penetrating radiation out of the following is

[CBSE PMT 1997]

(a) *X*-rays (b) β -rays

(c) α – particles (d) γ – rays

71. On increasing the number of electrons striking the anode of an *X*-ray tube, which one of the following parameters of the resulting *X*-rays would increase [IIT 1998; BVP 2003] [SCRA 1998; DPMT 2000]

(a) Penetration power (b) Frequency

(c) Wavelength (d) Intensity

72. What kV potential is to be applied on *X*-ray tube so that minimum wavelength of emitted *X*-rays may be 1Å ($h = 6.625 \times 10^{-34}$ *J-sec*)

(a) $12.42 kV$ (b) $12.84 kV$

(c) $11.98 kV$ (d) $10.78 kV$

73. *X*-rays cannot be deflected by means of an ordinary grating due to [Pb. PMT 19

(a) Large wavelength (b) High speed

(c) Short wavelength (d) None of these

74. Consider the following two statements *A* and *B* and identify the correct choice in the given answer

A: The characteristic *X*-ray spectrum depends on the nature of the material of the target.

B: The short wavelength limit of continuous *X*-ray spectrum varies inversely with the potential difference applied to the *X*-rays tube [EAMCET (Med.) 2000]

(a) *A* is true and *B* is false (b) *A* is false and *B* is true

(c) Both *A* and *B* are true (d) Both *A* and *B* are false

75. [IIT 1992; JIPMER 2000] The energy of an *X*- ray photon of wavelength 1.65 Å is

($h = 6.6 \times 10^{-34}$ *J-sec*, $c = 3 \times 10^8 ms^{-1}$, $1 eV = 1.6 \times 10^{-19} J$)

[EAMCET (Engg.) 2000]

(a) 3.5 keV (b) 5.5 keV
(c) 7.5 keV (d) 9.5 keV

76. If λ =10Å, then it corresponds to [DCE 2000]
(a) Infra-red (b) Microwave
(c) Ultra-violet (d) X-rays

77. Bragg's law for X-rays is [UPSEAT 2001]
(a) $d\sin\theta = 2n\lambda$ (b) $2d\sin\theta = n\lambda$
(c) $n\sin\theta = 2\lambda d$ (d) None of these

78. The X-rays produced in a coolidge tube of potential difference 40 V have minimum wavelength of
[MH CET (Med.) 2001]
(a) $3.09\times10^{-8}m$ (b) $5.09\times10^{8}m$
(c) $4.09\times10^{-8}m$ (d) $1.09\times10^{8}m$

79. For the production of X-rays, the target should be made of
(a) Steel (b) Copper
(c) Aluminum (d) Tungsten

80. Intensity of X-rays depends upon the number of
[SCRA 1998; DPMT 2000; AFMC 2001]
(a) Electrons (b) Protons
(c) Neutrons (d) Positrons

81. In an X-ray tube electrons bombarding the target produce X-rays of minimum wavelength 1 Å. What must be the energy of bombarding electrons [KCET 2001]
(a) 13375 eV (b) 12375 eV
(c) 14375 eV (d) 15375 eV

82. If energy of K-shell electron is – 40000 eV and If 60000 V potential is applied at coolidge tube then which of the following X-ray will get form [RPET 2001]
(a) Continuous
(b) White X-rays
(c) Continuous and all series of characteristic
(d) None of these

83. For production of characteristic K_β X-rays, the electron transition is [MP PET 2001]
(a) $n=2$ to $n=1$ (b) $n=3$ to $n=2$
(c) $n=3$ to $n=1$ (d) $n=4$ to $n=2$

84. Penetrating power of X-rays does not depend on
[MP PET 2001]
(a) Wavelength (b) Energy
(c) Potential difference (d) Current in the filament

85. The potential difference applied to an X-ray tube is 5kV and the current through it is 3.2 mA. Then the number of electrons striking the target per second is
[IIT-JEE (Screening) 2002]
(a) 2×10^{16} (b) 5×10^{16}
(c) 1×10^{17} (d) 4×10^{15}

86. For the production of characteristic K_γ, X-ray, the electron transition is [BHU 2002]
(a) $n=2$ to $n=1$ (b) $n=3$ to $n=2$
(c) $n=3$ to $n=1$ (d) $n=4$ to $n=1$

87. When X rays pass through a strong uniform magnetic field, Then they [MP PET 2002; RPMT 2002, 03]
(a) Do not get deflected at all
(b) Get deflected in the direction of the field
(c) Get deflected in the direction opposite to the field
(d) Get deflected in the direction perpendicular to the field

88. If the potential difference applied across X-ray tube is V volts, then approximately minimum wavelength of the emitted X-rays will be
RPMT 1995; CBSE PMT 1996]
(a) $\frac{1227}{\sqrt{V}}Å$ (b) $\frac{1240}{V}Å$
(c) $\frac{2400}{V}Å$ (d) $\frac{12400}{V}Å$

89. What is the difference between soft and hard X-rays
[MP PMT 2002; AIIMS 2002]
[BHU 2000; CPMT 2001]
(a) Velocity (b) Intensity
(c) Frequency (d) Polarization

90. X-ray will travel minimum distance in [MP PET 2003]
(a) Air (b) Iron
(c) Wood (d) Water

91. The minimum wavelength of X-ray emitted by X-rays tube is 0.4125 Å. The accelerating voltage is
[BHU 2003; CPMT 2004; MP PMT 2005]
(a) 30 kV (b) 50 kV
(c) 80 kV (d) 60 kV

92. Characteristic X-rays are produced due to [AIIMS 2003]
(a) Transfer of momentum in collision of electrons with target atoms
(b) Transition of electrons from higher to lower electronic orbits in an atom
(c) Heating of the target
(d) Transfer of energy in collision of electrons with atoms in the target

93. X-rays when incident on a metal [BCECE 2003; RPMT 2003]
(a) Exert a force on it (b) Transfer energy to it
(c) Transfer pressure to it (d) All of the above

94. The minimum wavelength of X-rays produced in a coolidge tube operated at potential difference of 40 kV is
[BCECE 2003; RPET 2002, 03]
(a) 0.31 Å (b) 3.1 Å
(c) 31 Å (d) 311 Å

95. The potential difference between the cathode and the target in a Collidge tube is 100 kV. The minimum wavelength of the X-rays emitted by the tube is [Pb. PMT 2004]
(a) 0.66 Å (b) 9.38 Å
(c) 0.246 Å (d) 0.123 Å

96. X-rays are produced by accelerating electrons by voltage V and let they strike a metal of atomic number Z. The highest frequency of X-rays produced is proportional to
[UPSEAT 2004]
(a) V (b) Z
(c) $(Z-1)$ (d) $(Z-1)^2$

97. If the operating potential of an X-ray tube is 50 kV, the velocity of X-rays coming out of it is [RPMT 2003]
(a) $4\times10^{4}\ m/s$ (b) $3\times10^{8}\ m/s$
(c) $10^{8}\ m/s$ (d) $3\ m/s$

98. If the voltage of X-ray tube is doubled, the intensity of X-rays will become [RPMT 2003]

(a) Half (b) Unchanged

(c) Double (d) Four times

99. If the minimum wavelength obtained in an X-ray tube is $2.5 \times 10^{-10} m$, the operating potential of the tube will be [RPMT 2003]

(a) 2 kV (b) 3 kV

(c) 4 kV (d) 5 kV

100. The wavelength of X-rays decreases, when [RPMT 2002]

(a) Temperature of target is increased

(b) Intensity of electron beam is increased

(c) K.E. of electrons striking the target is increased

(d) K.E. of electrons striking the target is decreased

101. X-rays are produced in laboratory by [RPMT 1998]

(a) Radiation

(b) Decomposition of the atom

(c) Bombardment of high energy electron on heavy metal

(d) None of these

102. In vacuum an electron of energy 10 keV hits tungsten target, then emitted radiation will be [RPMT 2001]

(a) Cathode rays (b) X-rays

(c) Infrared rays (d) Visible spectrum

103. X-rays of $\lambda = 1\,Å$ have frequency [DCE 1998]

(a) $3 \times 10^{8}\ Hz$ (b) $3 \times 10^{18}\ Hz$

(c) $3 \times 10^{10}\ Hz$ (d) $3 \times 10^{15}\ Hz$

104. Solid targets of different elements are bombarded by highly energetic electron beams. The frequency (f) of the characteristic X-rays emitted from different targets varies with atomic number Z as [AIIMS 2005]

(a) $f \propto \sqrt{Z}$ (b) $f \propto Z^2$

(c) $f \propto Z$ (d) $f \propto Z^{3/2}$

105. Compton effect shows that [DPMT 1995]

(a) X-rays are waves

(b) X-rays have high energy

(c) X-rays can penetrate matter

(d) Photons have momentum

106. An X-ray tube with a copper target emits $Cu\ K_\alpha$ line of wavelength 1.50 $Å$. What should be the minimum voltage through which electrons are to be accelerated to produce this wavelength of X rays

$(h = 6.63 \times 10^{-34}$ J-sec, $c = 3 \times 10^{8} m/s)$ [Orissa JEE 1996]

(a) 8280 V (b) 828 V

(c) 82800 V (d) 8.28 V

107. In X-ray spectrum wavelength λ of line K_α depends on atomic number Z as [RPMT 1995; DCE 2002]

(a) $\lambda \propto Z^2$ (b) $\lambda \propto (Z-1)^2$

(c) $\lambda \propto \frac{1}{(Z-1)}$ (d) $\lambda \propto \frac{1}{(Z-1)^2}$

108. Absorption of X-ray is maximum in which of the following different sheets [RPMT 1995]

(a) Copper (b) Gold

(c) Beryllium (d) Lead

109. The wavelength of K_α line in copper is 1.54 $Å$. The ionisation energy of K electron in copper in *Joule* is [EAMCET 1984]

(a) 11.2×10^{-27} (b) 12.9×10^{-16}

(c) 1.7×10^{-15} (d) 10×10^{-16}

110. The wavelength of K_α line for an element of atomic number 43 is λ. Then the wavelength of K_α line for an element of atomic number 29 is

(a) $\frac{43}{29}\lambda$ (b) $\frac{42}{28}\lambda$

(c) $\frac{9}{4}\lambda$ (d) $\frac{4}{9}\lambda$

111. In X-ray experiment K_α, K_β denotes [DCE 2005]

(a) Characteristic

(b) Continuous wavelength

(c) α, β-emissions respectively

(d) None of these

Critical Thinking

Objective Questions

1. A $1\mu A$ beam of protons with a cross-sectional area of 0.5 *sq. mm* is moving with a velocity of $3\times10^4 ms^{-1}$. Then charge density of beam is [CPMT 2002]
   (a) $6.6\times10^{-4} C/m^3$ (b) $6.6\times10^{-5} C/m^3$
   (c) $6.6\times10^{-6} C/m^3$ (d) None of these

2. A particle of mass M at rest decays into two particles of masses m_1 and m_2 having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles, λ_1/λ_2 is [IIT-JEE 1999; KCET 2003]
   (a) m_1/m_2 (b) m_2/m_1
   (c) 1.0 (d) $\sqrt{m_2}/\sqrt{m_1}$

3. A photon and an electron have equal energy E. $\lambda_{photon}/\lambda_{electron}$ is proportional to [UPSEAT 2003; IIT-JEE (Screening) 2004]
   (a) $\sqrt{E}$ (b) $1/\sqrt{E}$
   (c) $1/E$ (d) Does not depend upon E

4. When photon of energy 4.25 *eV* strike the surface of a metal *A*, the ejected photoelectrons have maximum kinetic energy T_A *eV* and de-Brolie wavelength λ_A. The maximum kinetic energy of photoelectrons liberated from another metal *B* by photon of energy 4.70 *eV* is $T_B=(T_A-1.50)\,eV$. If the de-Broglie wavelength of these photoelectrons is $\lambda_B=2\lambda_A$, then
   (a) The work function of *A* is 2.25 *eV*
   (b) The work function of *B* is 4.20 *eV*
   (c) $T_A=2.00\,eV$
   (d) $T_B=2.75\,eV$

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) 2*I* (d) 4*I*

6. When an inert gas is filled in the place vacuum in a photo cell, then
   (a) Photo-electric current is decreased
   (b) Photo-electric current is increased
   (c) Photo-electric current remains the same
   (d) Decrease or increase in photo-electric current does not depend upon the gas filled

7. A photon of 1.7×10^{-13} *Joules* is absorbed by a material under special circumstances. The correct statement is [MP PET 1999; JIPMER 2000]
   (a) Electrons of the atom of absorbed material will go the higher energy states
   (b) Electron and positron pair will be created
   (c) Only positron will be produced
   (d) Photoelectric effect will occur and electron will be produced

8. The maximum velocity of an electron emitted by light of wavelength λ incident on the surface of a metal of work function ϕ, is[MP PMT/PET 1998]
   (a) $\left[\frac{2(hc+\lambda\phi)}{m\lambda}\right]^{1/2}$ (b) $\frac{2(hc-\lambda\phi)}{m}$
   (c) $\left[\frac{2(hc-\lambda\phi)}{m\lambda}\right]^{1/2}$ (d) $\left[\frac{2(h\lambda-\phi)}{m}\right]^{1/2}$

   Where h = Planck's constant, m = mass of electron and c = speed of light.

9. When a point source of monochromatic light is at a distance of 0.2 *m* from a photoelectric cell, the cut-off voltage and the saturation current are 0.6 *volt* and 18 *mA* respectively. If the same source is placed 0.6 *m* away from the photoelectric cell, then[IIT JEE 1992; MP PMT 1999]
   (a) The stopping potential will be 0.2 *V*
   (b) The stopping potential will be 0.6 *V*
   (c) The saturation current will be 6 *mA*
   (d) The saturation current will be 18 *mA*

10. In a photoemissive cell with executing wavelength λ, the fastest electron has speed *v*. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be
    (a) $v(3/4)^{1/2}$ (b) $v(4/3)^{1/2}$
    (c) Less than $v(4/3)^{1/2}$ (d) Greater than $v(4/3)^{1/2}$

11. Ultraviolet light of wavelength 300 *nm* and intensity 1.0 *watt/m* falls on the surface of a photosensitive material. If 1% of the incident photons produce photoelectrons, then the number of photoelectrons emitted from an area of 1.0 *cm* of the surface is nearly [IIT-JEE 1994]
    (a) 9.61×10^{14} *per sec* (b) 4.12×10^{13} *per sec*
    (c) 1.51×10^{12} *per sec* (d) 2.13×10^{11} *per sec*

12. Photoelectric emission is observed from a metallic surface for frequencies ν_1 and ν_2 of the incident light rays $(\nu_1>\nu_2)$. If the maximum values of kinetic energy of the photoelectrons emitted in the two cases are in the ratio of $1:k$, then the threshold frequency of the metallic surface is [EAMCET (Engg.) 2001]
    (a) $\frac{\nu_1-\nu_2}{k-1}$ (b) $\frac{k\nu_1-\nu_2}{k-1}$
    (c) $\frac{k\nu_2-\nu_1}{k-1}$ (d) $\frac{\nu_2-\nu_1}{k}$

    [Manipal MEE 1995]

13. Light from a hydrogen discharge tube is incident on the cathode of a photoelectric cell the work function of the cathode surface is 4.2 *eV*. In order to reduce the photo-current to zero the voltage of the anode relative to the cathode must be made [MP PMT 1997]
    (a) – 4.2 *V* (b) – 9.4 *V*
    (c) – 17.8 *V* (d) +9.4 *V*

14. Work function of lithium and copper are respectively 2.3 *eV* and 4.0 *eV*. Which one of the metal will be useful for the photoelectric cell working with visible light ? (h = 6.6 × 10^{-34} *J-s*, c = 3 × 10^{8} *m/s*)
    (a) Lithium (b) Copper
    (c) Both (d) None of these

15. X-rays of wavelength 0.1 Å allowed to fall on a metal get scattered. The wavelength of scattered radiation is 0.111 Å. If h = 6.624 × 10^{-34} *J-s* and m_0 = 9 × 10^{-31} *kg*, then the direction of the scattered photons will be
    (a) $\cos^{-1}(0.547)$ (b) $\cos^{-1}(0.4484)$

(c) $\cos^{-1}(0.5)$ (d) $\cos^{-1}(0.3)$

16. The largest distance between the interatomic planes of a crystal is 10^{-7} *cm*. The upper limit for the wavelength of *X*-rays which can be usefully studied with this crystal is [CPMT 1984]

(a) 1 Å (b) 2 Å

(c) 10 Å (d) 20 Å

17. An *X*-ray tube is operating at 50 *kV* and 20 *mA*. The target material of the tube has a mass of 1.0 *kg* and specific heat 495 $J\ kg^{-1}\ {}^{o}C^{-1}$. One percent of the supplied electric power is converted into *X*-rays and the entire remaining energy goes into heating the target. Then

(a) A suitable target material must have a high melting temperature

(b) A suitable target material must have low thermal conductivity

(c) The average rate of rise of temperature of target would be 2 °*C/s*

(d) The minimum wavelength of the *X*-rays emitted is about $0.25\times10^{-10}\ m$

18. The wavelength of K_α *X*-rays produced by an *X*-ray tube is 0.76 Å. The atomic number of the anode material of the tube is

(a) 20 (b) 60

(c) 40 (d) 80

19. *X*-ray beam of intensity I_0 passes through an absorption plate of thickness *d*. If absorption coefficient of material of plate is μ, the correct statement regarding the transmitted intensity *I* of *X*-ray is

(a) $I = I_0(1-e^{-\mu d})$ (b) $I = I_0e^{-\mu d}$

(c) $I = I_0(1-e^{-\mu/d})$ (d) $I = I_0e^{-\mu/d}$

20. The K_α *X*-ray emission line of tungsten occurs at $\lambda = 0.021\ nm$. The energy difference between *K* and *L* levels in this atom is about

(a) 0.51 *MeV* (b) 1.2 *MeV*

(c) 59 *KeV* (d) 13.6 eV

21. Electrons with energy 80 *keV* are incident on the tungsten target of an *X*-ray tube. *K* shell electrons of tungsten have ionization energy 72.5 *keV*. *X*-rays emitted by the tube contain only

(a) A continuous *X*-ray spectrum (Bremsstrahlung) with a minimum wavelength of ~ 0.155Å

(b) A continuous *X*-ray spectrum (Bremsstrahlung] with all wavelengths

(c) The characteristic *X*-rays spectrum of tungsten

(d) A continuous *X*-ray spectrum (Bremsstrahlung) with a minimum wavelength of ~ 0.155Å and the characteristic *X*-ray spectrum of tungsten

22. The *X*-ray wavelength of L_α line of platinum (Z=78) is $1.30 Å$. The X–ray wavelength of L_α line of Molybdenum (Z=42) is

(a) 5.41Å (b) 4.20Å

(c) 2.70Å (d) 1.35 Å

23. The ratio of de-Broglie wavelengths of molecules of hydrogen and helium which are at temperature 27°*C* and 127°*C* respectively is

(a) $\frac{1}{2}$ (b) $\sqrt{\frac{3}{8}}$

(c) $\sqrt{\frac{8}{3}}$ (d) 1

24. A silver ball of radius 4.8 *cm* is suspended by a thread in the vacuum chamber. *UV* light of wavelength 200 *nm* is incident on the ball for some times during which a total energy of 1×10^{-7} *J* falls on the surface. Assuming on an average one out of 10^3 photons incident is able to eject electron. The potential on sphere will be

(a) 1 *V* (b) 2 *V*

(c) 3 *V* (d) Zero

25. A photon of wavelength 6630 Å is incident on a totally reflecting surface. The momentum delivered by the photon is equal to [IIT 1995]

(a) 6.63×10^{-27} *kg-m/sec* (b) 2×10^{-27} *kg-m/sec*

(c) 10^{-27} *kg-m/sec* (d) None of these

26. The ratio of de-Broglie wavelength of a α-particle to that of a proton being subjected to the same magnetic field so that the radii of their path are equal to each other assuming the field induction vector $\vec{B}$ is perpendicular to the velocity vectors of the α-particle and the proton is [IIT 1996]

(a) 1 (b) $\frac{1}{4}$

(c) $\frac{1}{2}$ (d) 2

27. K_α wavelength emitted by an atom of atomic number *Z* = 11 is λ. Find the atomic number for an atom that emits K_α radiation with wavelength 4λ [MP PET 1999] [IIT-JEE (Screening) 2005]

(a) *Z* = 6 (b) *Z* = 4

(c) *Z* = 11 (d) *Z* = 44

28. The potential energy of a particle of mass *m* is given by

$$U(x) = \begin{cases} E_0; & 0 \le x \le 1 \\ 0; & x > 1 \end{cases}$$

[IIT 1997 Cancelled]

λ_1 and λ_2 are the de-Broglie wavelengths of the particle, when 0 ≤ *x* ≤ 1 and *x* > 1 respectively. If the total energy of particle is $2E_0$, the ratio $\frac{\lambda_1}{\lambda_2}$ will be

[IIT-JEE (Screening) 2000]

[Based on IIT-JEE (Mains) 2005]

(a) 2 (b) 1

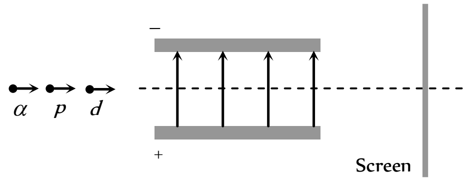
(c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

29. Rest mass energy of an electron is 0.51 *MeV*. If this electron is moving with a velocity 0.8 *c* (where *c* is velocity of light in vacuum), then kinetic energy of the electron should be. [EAMCET (Eng.) 2000]

(a) 0.28 *MeV* (b) 0.34 *MeV*

(c) 0.39 *MeV* (d) 0.46 *MeV*

30. A proton, a deutron and an α-particle having the same momentum, enters a region of uniform electric field between the parallel plates of a capacitor. The electric field is perpendicular to the initial path of the particles. Then the ratio of deflections suffered by them is



(a) 1 : 2 : 8 (b) 1 : 2 : 4

(c) 1 : 1 : 2 (d) None of these

31. In order to coincide the parabolas formed by singly ionised ions in one spectrograph and doubly ionized ions in the other Thomson's mass spectrograph, the electric fields and magnetic fields are kept in the ratios 1 : 2 and 3 : 2 respectively. Then the ratio of masses of the ions is

(a) 3 : 4 (b) 1 : 3

(c) 9 : 4 (d) None of these

32. Let λ_α, λ_β and λ'_α denote the wavelengths of the X-rays of the K_α, K_β and L_α lines in the characteristic X-rays for a metal

(a) $\lambda_\alpha > \lambda'_\alpha > \lambda_\beta$ (b) $\lambda'_\alpha > \lambda_\beta > \lambda_\alpha$

(c) $\frac{1}{\lambda_\beta} = \frac{1}{\lambda_\alpha} + \frac{1}{\lambda'_\alpha}$ (d) $\frac{1}{\lambda_\alpha} + \frac{1}{\lambda_\beta} = \frac{1}{\lambda'_\alpha}$

33. The minimum intensity of light to be detected by human eye is $10^{-10} W/m^2$. The number of photons of wavelength $5.6 \times 10^{-7} m$ entering the eye, with pupil area $10^{-6} m^2$, per second for vision will be nearly

(a) 100 (b) 200

(c) 300 (d) 400

34. In X-ray tube when the accelerating voltage V is halved, the difference between the wavelength of K_α line and minimum wavelength of continuous X-ray spectrum

(a) Remains constant

(b) Becomes more than two times

(c) Becomes half

(d) Becomes less than two times

35. In a photocell bichromatic light of wavelength 2475 Å and 6000 Å are incident on cathode whose work function is 4.8 eV. If a uniform magnetic field of 3 × 10· *Tesla* exists parallel to the plate, the radius of the path describe by the photoelectron will be (mass of electron = 9 × 10· *kg*)

(a) 1 *cm* (b) 5 *cm*

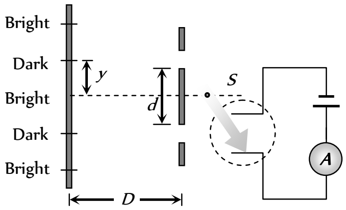
(c) 10 *cm* (d) 25 *cm*

36. Two metallic plates A and B, each of area 5 × 10·m are placed parallel to each other at a separation of 1 *cm*. Plate B carries a positive charge of 33.7 *pc*. A monochromatic beam of light, with photons of energy 5 eV each, starts falling on plate A at t = 0, so that 10· photons fall on it per square meter per second. Assume that one photoelectron is emitted for every 10· incident photons. Also assume that all the emitted photoelectrons are collected by plate B and the work function of plate A remains constant at the value 2 eV. Electric field between the plates at the end of 10 seconds is

(a) 2 × 10· *N/C* (b) 10· *N/C*

(c) 5 × 10· *N/C* (d) Zero

37. In the following arrangement y = 1.0 *mm*, d = 0.24 *mm* and D = 1.2 *m*. The work function of the material of the emitter is 2.2 eV. The stopping potential V needed to stop the photo current will be



(a) 0.9 V (b) 0.5 V

(c) 0.4 V (d) 0.1 V

38. The eye can detect 5 × 10· photons per square metre per sec of green light (λ = 5000 Å) while the ear can detect $10^{-13} (W/m^2)$. The factor by which the eye is more sensitive as a power detector than the ear is close to

(a) 5 (b) 10

(c) 10· (d) 15

39. A photon collides with a stationary hydrogen atom in ground state inelastically. Energy of the colliding photon is 10.2 eV. After a time interval of the order of micro second another photon collides with same hydrogen atom inelastically with an energy of 15 eV. What will be observed by the detector [IIT-JEE (Screening) 2005]

(a) 2 photon of energy 10.2 eV

(b) 2 photon of energy of 1.4 eV

(c) One photon of energy 10.2 eV and an electron of energy 1.4 eV

(d) One photon of energy 10.2 eV and another photon of 1.4 eV

GQ Graphical Questions

1. The curve drawn between velocity and frequency of photon in vacuum will be a [MP PET 2000]

(a) Straight line parallel to frequency axis

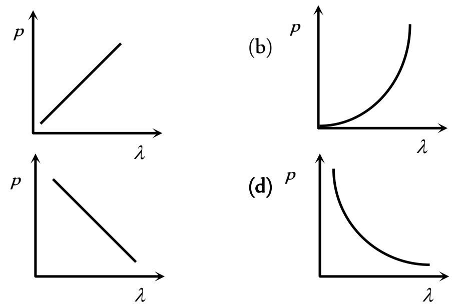
(b) Straight line parallel to velocity axis

(c) Straight line passing through origin and making an angle of 45· with frequency axis

(d) Hyperbola

2. Which of the following figure represents the variation of particle momentum and the associated de-Broglie wavelength

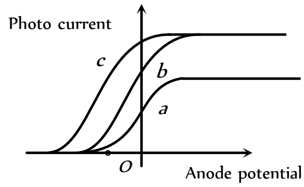
(a) (b) (c) (d)



3. The figure shows the variation of photocurrent with anode potential for a photo-sensitive surface for three different radiations. Let I_a, I_b and I_c be the intensities and f_a, f_b and f_c be the frequencies for the curves a, b and c respectively [IIT-JEE (Screening) 2004]

(a) $f_a = f_b$ and $I_a \neq I_b$

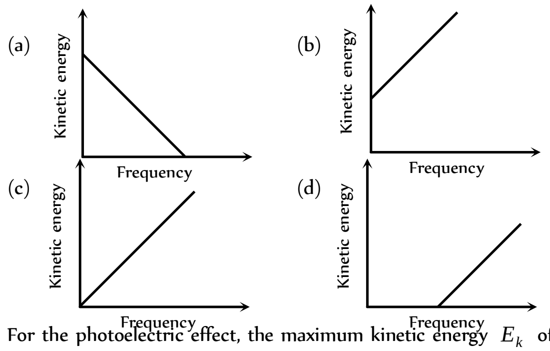
(b) $f_a = f_c$ and $I_a = I_c$



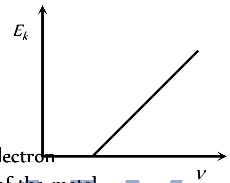
(c) $f_a = f_b$ and $l_a = l_b$

(d) $f_a = f_b$ and $l_a = l_b$

4. According to Einstein's photoelectric equation, the graph between the kinetic energy of photoelectrons ejected and the frequency of incident radiation is [MP PMT 1994; CBSE PMT 1996; CBSE PMT 2004]



5. For the photoelectric effect, the maximum kinetic energy E_k of the emitted photoelectrons is plotted against the frequency ν of the incident photons as shown in the figure. The slope of the curve gives [CPMT 1987; MP PET 2001; DPMT 2002]



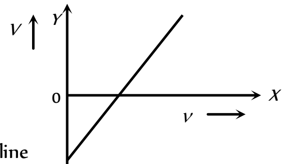
(a) Charge of the electron

(b) Work function of the metal

(c) Planck's constant

(d) Ratio of the Planck's constant to electronic charge

6. The stopping potential V for photoelectric emission from a metal surface is plotted along Y-axis and frequency ν of incident light along X-axis. A straight line is obtained as shown. Planck's constant is given by [CPMT 1987; Similar to MP PMT 2000; Kerala PET 2001]



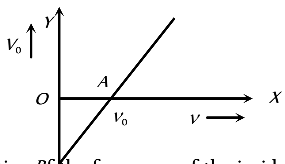
(a) Slope of the line

(b) Product of slope on the line and charge on the electron

(c) Product of intercept along Y-axis and mass of the electron

(d) Product of Slope and mass of electron

7. In an experiment on photoelectric effect the frequency f of the incident light is plotted against the stopping potential V_0. The work function of the photoelectric surface is given by (e is electronic charge) [CPMT 1987]



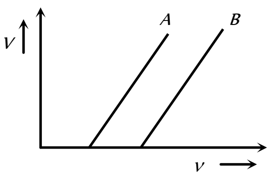
(a) $OB \times e$ in eV

(b) OB in *volt*

(c) OA in eV

(d) The slope of the line AB

8. The stopping potential as a function of the frequency of the incident radiation is plotted for two different photoelectric surfaces A and B. The graphs show that work function of A is



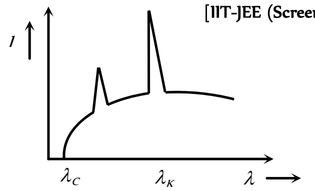
(a) Greater than that of B

(b) Smaller than that of B

(c) Equal to that of B

(d) No inference can be drawn about their work functions from the given graphs

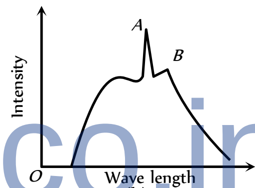
9. The intensity of X-rays from a Coolidge tube is plotted against wavelength as shown in the figure. The minimum wavelength found is λ_c and the wavelength of the K_α line is λ_k. As the accelerating voltage is increased [IIT-JEE (Screening) 2001]



(a) $(\lambda_K - \lambda_C)$ increases (b) $(\lambda_K - \lambda_C)$ decreases

(c) λ_K increases (d) λ_K decreases

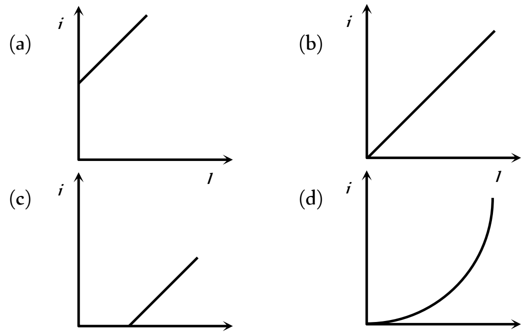
10. The figure represents the observed intensity of X-rays emitted by an X-ray tube as a function of wavelength. The sharp peaks A and B denote [CBSE PMT 1995]



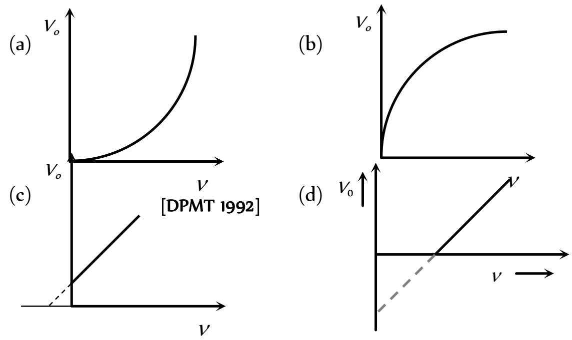
(a) Band spectrum (b) Continuous spectrum

(c) Characteristic radiations (d) White radiations

11. The graph between intensity of light falling on a metallic plate (I) with the current (i) generated is [DCE 2001]

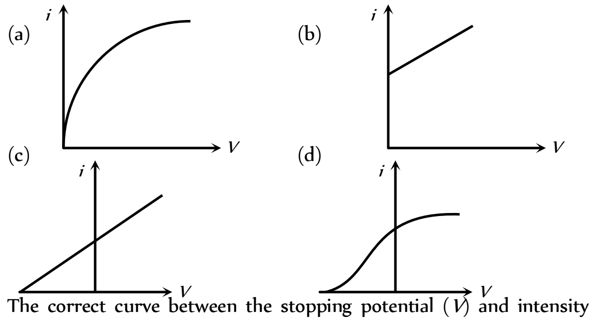


12. For a photoelectric cell the graph showing the variation of cut of voltage (V_0) with frequency (ν) of incident light is best represented by [DCE 2001; MP PET 2003]

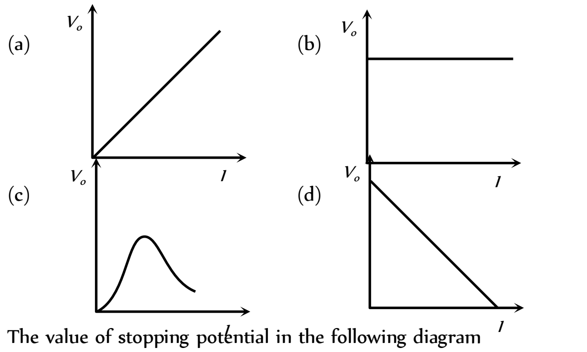


[DPMT 1992]

13. The curve between current (i) and potential difference (V) for a photo cell will be

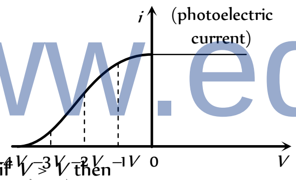


14. The correct curve between the stopping potential (V) and intensity of incident light (I) is



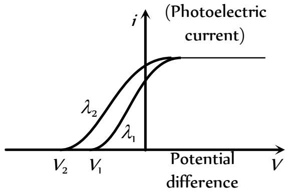
15. The value of stopping potential in the following diagram

(a) $-4\,V$
(b) $-3\,V$
(c) $-2\,V$
(d) $-1\,V$



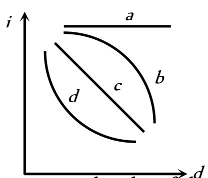
16. In the following diagram if $V_2 > V_1$ then

(a) $\lambda_1 = \sqrt{\lambda_2}$
(b) $\lambda_1 < \lambda_2$
(c) $\lambda_1 = \lambda_2$
(d) $\lambda_1 > \lambda_2$



17. A point source of light is used in an experiment on photoelectric effect. Which of the following curves best represents the variation of photo current (i) with distance (d) of the source from the emitter

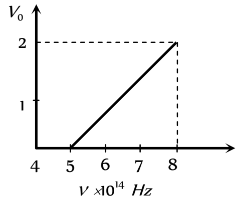
(a) a
(b) b
(c) c
(d) d



18. According to Einstein's photoelectric equation, the plot of the kinetic energy of the emitted photo electrons from a metal versus the frequency, of the incident radiation gives a straight line whose slope

(a) Is the same for all metals and independent of the intensity of the radiation
(b) Depends on the intensity of the radiation
(c) Depends both on the intensity of the radiation and the metal used
(d) Depends on the nature of the metals used

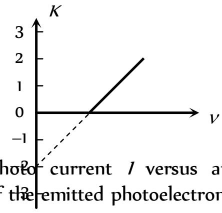
19. The stopping potential (V_0) versus frequency (ν) plot of a substance is shown in figure the threshold wave length is



(a) $5 \times 10^{14}\,m$
(b) 6000Å
(c) 5000 Å
(d) Can not be estimated from given data

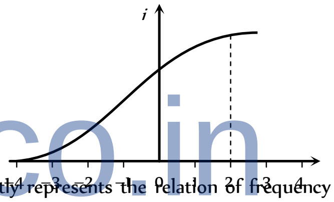
20. Figure represents a graph of kinetic energy (K) of photoelectrons (in eV) and frequency (ν) for a metal used as cathode in photoelectric experiment. The work function of metal is

(a) 1 eV
(b) 1.5 eV
(c) 2 eV
(d) 3 eV

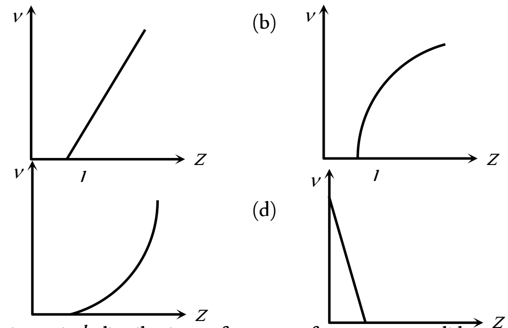


21. Figure represents the graph of photo current I versus applied voltage (V). The maximum energy of the emitted photoelectrons is

(a) $2eV$
(b) 4 eV
(c) 0 eV
(d) 4 J

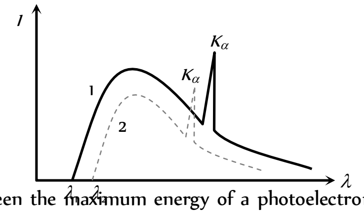


22. The graph that correctly represents the relation of frequency ν of a particular characteristic X-ray with the atomic number Z of the material is

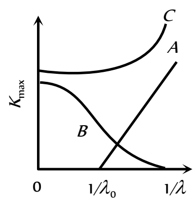


23. The intensity I distribution of X-rays from two coolidge tubes operated on different voltages V_1 and V_2 and using different target materials of atomic numbers Z_1 and Z_2 is shown in the figure. Which one of the following inequalities is true?

(a) $V_1 > V_2, Z_1 < Z_2$
(b) $V_1 > V_2, Z_1 > Z_2$ [AIEEE 2004]
(c) $V_1 < V_2, Z_1 > Z_2$
(d) $V_1 = V_2, Z_1 < Z_2$

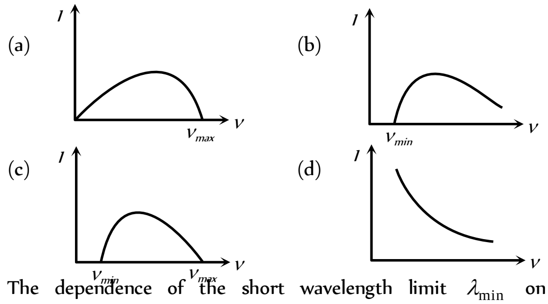


24. The correct graph between the maximum energy of a photoelectron and the inverse of wavelength of the incident radiation is given by the curve

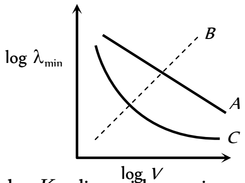


(a) A
(b) B
(c) C
(d) None of the above

25. The continuous *x*-ray spectrum obtained from a Coolidge tube is of the form

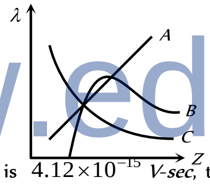


26. The dependence of the short wavelength limit λ_{min} on the accelerating potential *V* is represented by the curve of figure



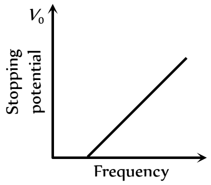
(a) A
(b) B
(c) C
(d) None of these

27. The variation of wavelength λ of the K_α line with atomic number *Z* of the target is shown by the following curve of



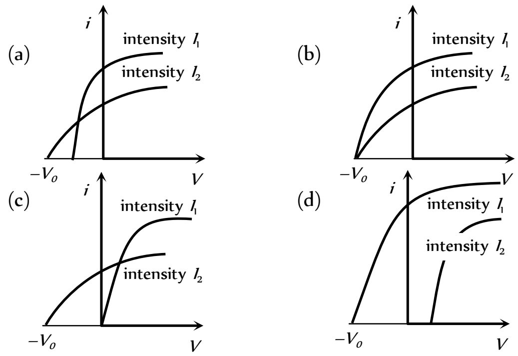
(a) A
(b) B
(c) C
(d) None of these

28. In the graph given below. If the slope is 4.12×10^{-15} *V-sec*, then value of '*h*' should be

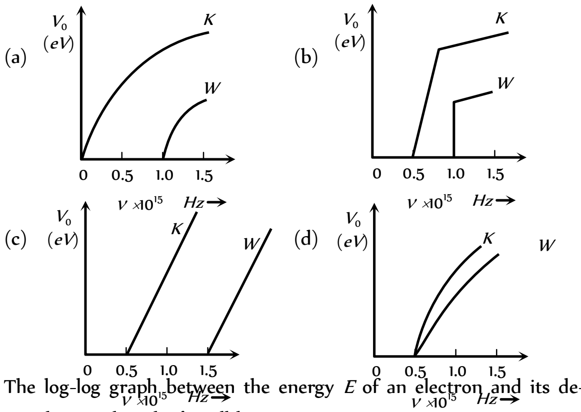


(a) 6.6×10^{-31} *J-sec*
(b) 6.6×10^{-34} *J-sec*
(c) $9.1\times10-31$ *J-sec*
(d) None of these

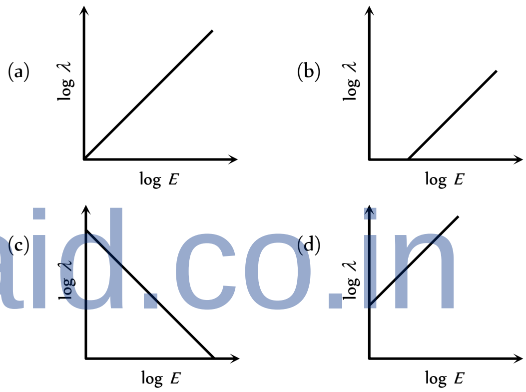
29. The curves (*a*), (*b*) (*c*) and (*d*) show the variation between the applied potential difference (*V*) and the photoelectric current (*i*), at two different intensities of light ($I_1 > I_2$). In which figure is the correct variation shown



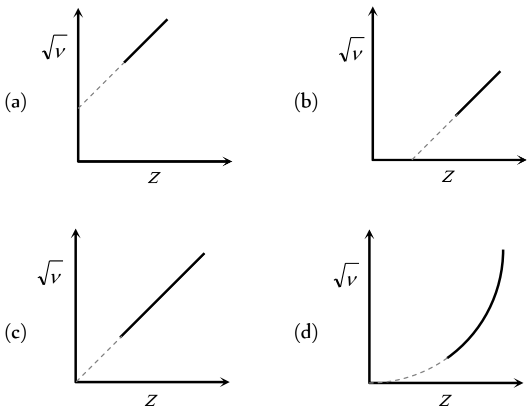
30. The figure showing the correct relationship between the stopping potential V_0 and the frequency ν of light for potassium and tungsten is



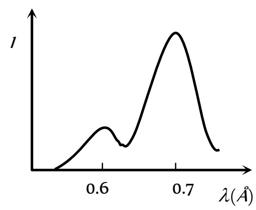
31. The log-log graph between the energy *E* of an electron and its de-Broglie wavelength λ will be



32. The graph between the square root of the frequency of a specific line of characteristic spectrum of *X*-rays and the atomic number of the target will be



33. In the diagram a graph between the intensity of *X*-rays emitted by a molybdenum target and the wavelength is shown, when electrons of 30 *keV* are incident on the target. In the graph one peak is of K_α line and the other peak is of K_β line



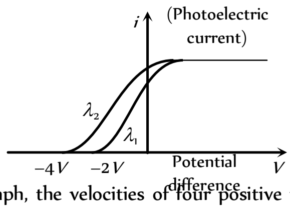
(a) First peak is of K_α line at 0.6 Å

(b) Highest peak is of K_α line at 0.7 Å

(c) If the energy of incident particles is increased, then the peaks will shift towards left

(d) If the energy of incident particles is increased, then the peaks will shift towards right

34. The maximum value of stopping potential in the following diagram is



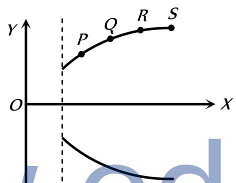
(a) $-4V$

(b) $-1V$

(c) $-3V$

(d) $-2V$

35. In a parabola spectrograph, the velocities of four positive ions P, Q, R and S are v_1, v_2, v_3 and v_4 respectively



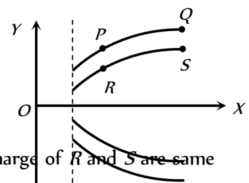
(a) $v_1 > v_2 > v_3 > v_4$

(b) $v_1 < v_2 < v_3 < v_4$

(c) $v_1 = v_2 = v_3 = v_4$

(d) $v_1 << v_2 > v_3 < v_4$

36. In Thomson spectrograph experiment, four positive ions P, Q, R and S are situated on Y-X curve a shown in the figure



(a) The specific charge of R and S are same

(b) The masses of P and S are same

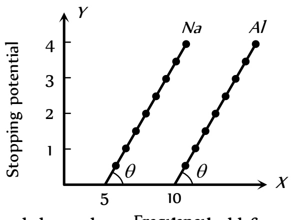
(c) The specific charges of Q and R are same

(d) The velocities of R and S are same

37. The slope of frequency of incident light and stopping potential graph for a given surface will be [MP PET 1999; MP PMT 2000; JIPMER 2001, 02; UPSEAT 2003]

(a) h
(b) h/e
(c) eh
(d) e

38. From the figure describing photoelectric effect we may infer correctly that [KCET 2005]



(a) Na and Al both have the same threshold frequency

(b) Maximum kinetic energy for both the metals depend linearly on the frequency

(c) The stopping potentials are different for Na and Al for the same change in frequency

(d) Al is a better photo sensitive material than Na

AR Assertion & Reason

For AIIMS Aspirants

Read the assertion and reason carefully to mark the correct option out of the options given below:

(a) If both assertion and reason are true and the reason is the correct explanation of the assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of the assertion.
(c) If assertion is true but reason is false.
(d) If the assertion and reason both are false.
(e) If assertion is false but reason is true.

1. Assertion : The energy (E) and momentum (p) of a photon are related by $p = E/c$.

Reason : The photon behaves like a particle.

[AIIMS 2005]

2. Assertion : Photoelectric effect demonstrates the wave nature of light.

Reason : The number of photoelectrons is proportional to the frequency of light. [AIIMS 2004]

3. Assertion : When the speed of an electron increases its specific charge decreases.

Reason : Specific charge is the ratio of the charge to mass. [AIIMS 2001]

4. Assertion : X-ray travel with the speed of light.

Reason : X-rays are electromagnetic rays.

[AIIMS 2001]

5. Assertion : Mass of moving photon varies inversely as the wavelength.

Reason : Energy of the particle $= \text{Mass} \times (\text{Speed of light})^2$

[AIIMS 2000]

6. Assertion : Kinetic energy of photo electrons emitted by a photosensitive surface depends upon the intensity of incident photon.

Reason : The ejection of electrons from metallic surface is possible with frequency of incident photon below the threshold frequency. [AIIMS 1999]

7. Assertion : Separation of isotope is possible because of the difference in electron numbers of isotope.

Reason : Isotope of an element can be separated by using a mass spectrometer. [AIIMS 1999]

8. Assertion : The specific charge of positive rays is not constant.

Reason : The mass of ions varies with speed.

[AIIMS 1999]

9. Assertion : Photosensitivity of a metal is high if its work function is small.

Reason : Work function $= hf_0$ where f_0 is the threshold frequency. [AIIMS 1997]

10. Assertion : The de-Broglie wavelength of a molecule varies inversely as the square root of temperature.

Reason : The root mean square velocity of the molecule depends on the temperature.

[AIIMS 1997]

11. Assertion : An electron is not deflected on passing through certain region of space. This observation confirms that there is no magnetic field in that region.

Reason : The deflection of electron depends on angle between velocity of electron and direction of magnetic field.

12. Assertion : Electric conduction in gases is possible at normal pressure.

Reason : The electric conduction in gases depends only upon the potential difference between the electrodes.

13. Assertion : Light is produced in gases in the process of electric discharge through them at high pressure.

Reason : At high pressure electrons of gaseous atoms collide and reach and excited state.

14. Assertion : If different gases are filled turn by turn at the same pressure in the discharge tube the discharge in them takes place at the same potential.

Reason : The discharge depends only on the pressure of discharge tube and not on the ionisation potential of gas.

15. Assertion : An electric field is preferred in comparison to magnetic field for detecting the electron beam in a television picture tube.

Reason : Electric field require low voltage.

16. Assertion : The specific charge for positive rays is a characteristic constant.

Reason : The specific charge depends on charge and mass of positive ions present in positive rays.

17. Assertion : In Millikan's experiment for the determination of charge on an electron, oil drops of any size can be used.

Reason : Millikan's experiment determine the charge on electron, by simply measuring the terminal velocity.

18. Assertion : In the process of photoelectric emission, all the emitted photoelectrons have the same kinetic energy.

Reason : The photon transfers its whole energy to the electron of the atom in photoelectric effect.

19. Assertion : In photoelectric effect, on increasing the intensity of light, both the number of electrons emitted and kinetic energy of each of them get increased but photoelectric current remains unchanged.

Reason : The photoelectric current depends only on wavelength of light.

20. Assertion : Though light of a single frequency (monochromatic) is incident on a metal, the energies of emitted photoelectrons are different.

Reason : The energy of electrons emitted from inside the metal surface is lost in collision with the other atoms in the metal.

21. Assertion : The threshold frequency of photoelectric effect supports the particle nature of sunlight.

Reason : If frequency of incident light is less than the threshold frequency, electrons are not emitted from metal surface.

22. Assertion : In photoemissive cell inert gas is used.

Reason : Inert gas in the photoemissive cell gives greater current.

23. Assertion : *X*-rays cannot be diffracted by means of grating.

Reason : *X*-rays does not obey Bragg's law.

24. Assertion : *X*-rays can penetrate through the flesh but not through the bones.

Reason : The penetrating power of *X*-rays depends on voltage.

25. Assertion : Intensity of *X*-rays can be controlled by adjusting the filament current and voltage.

Reason : The intensity of *X*-rays does not depend on number of *X*-ray photons emitted per second from the target.

26. Assertion : Anode of Coolidge tube gets heated up at time of emission of *X*-rays.

Reason : The anode of Coolidge tube is made of a material of high melting point.

27. Assertion : Penetrating power of *X*-rays increases with the increasing the wavelength.

Reason : The penetrating power of *X*-rays increases with the frequency of *X*-rays.

28. Assertion : *X*-rays are used for studying the structure of crystals.

Reason : The distance between the atoms of crystals is of the order of wavelength of *X*-rays.

29. Assertion : The phenomenon of *X*-ray production is basically inverse of photoelectric effect.

Reason : *X*-rays are electromagnetic waves.

30. Assertion : Soft and hard *X*-rays differ in frequency as well as velocity.

Reason : The penetrating power of hard *X*-rays is more than the penetrating power of soft *X*-rays.

Answers

Cathode Rays and Positive Rays

1	b	2	b	3	d	4	b	5	d
6	a	7	d	8	b	9	c	10	b
11	c	12	b	13	d	14	b	15	d
16	c	17	c	18	b	19	c	20	b
21	b	22	c	23	c	24	d	25	c
26	d	27	b	28	b	29	c	30	a
31	a	32	c	33	a	34	a	35	b
36	b	37	a	38	d	39	b	40	a
41	c	42	d	43	d	44	c	45	b
46	c	47	a	48	d	49	c	50	c
51	c	52	b	53	b	54	b	55	d
56	d	57	c	58	a	59	b	60	a

61	b	62	b	63	c	64	c	65	b
66	b	67	a	68	a	69	d	70	b
71	a	72	c						

Matter Waves

1	b	2	c	3	a	4	a	5	a
6	b	7	a	8	a	9	d	10	a
11	b	12	a	13	c	14	b	15	b
16	d	17	c	18	b	19	c	20	d
21	b	22	c	23	a	24	a	25	b
26	b	27	c	28	a	29	d	30	b
31	a	32	b	33	c	34	a	35	a
36	a	37	c	38	c	39	d	40	a
41	d	42	d	43	d				

Photon and Photoelectric Effect

1	d	2	d	3	c	4	a	5	a
6	b	7	d	8	b	9	b	10	a
11	b	12	b	13	b	14	c	15	a
16	a	17	b	18	a	19	a	20	c
21	d	22	c	23	b	24	a	25	a
26	a	27	a	28	c	29	d	30	c
31	c	32	a	33	e	34	a	35	d
36	c	37	d	38	c	39	d	40	b
41	a	42	c	43	d	44	d	45	d
46	c	47	c	48	b	49	c	50	a
51	a	52	b	53	d	54	b	55	a
56	d	57	d	58	b	59	b	60	a
61	c	62	b	63	b	64	c	65	a
66	d	67	d	68	c	69	b	70	a
71	d	72	a	73	c	74	c	75	b
76	c	77	a	78	a	79	b	80	c
81	b	82	d	83	c	84	c	85	b
86	c	87	a	88	b	89	c	90	d
91	a	92	a	93	a	94	b	95	c
96	b	97	d	98	a	99	b	100	b
101	a	102	d	103	a	104	b	105	b
106	a	107	a	108	b	109	a	110	b
111	c	112	b	113	a	114	c	115	c
116	b	117	c	118	d	119	a	120	c
121	c	122	c	123	b	124	a	125	a
126	a	127	a	128	c	129	d	130	b
131	d	132	b	133	c	134	d	135	c
136	c	137	d	138	b	139	c	140	c
141	a	142	d	143	b	144	d	145	b
146	c	147	a	148	a	149	c	150	d
151	d	152	b	153	a	154	c	155	a
156	a								

X-Rays

1	c	2	c	3	a	4	a	5	d
6	b	7	a	8	b	9	c	10	c
11	c	12	b	13	c	14	c	15	b
16	c	17	b	18	c	19	d	20	a
21	a	22	b	23	a	24	c	25	d
26	a	27	d	28	c	29	b	30	b
31	c	32	c	33	b	34	c	35	c
36	d	37	a	38	d	39	d	40	c
41	d	42	b	43	c	44	b	45	a
46	c	47	a	48	d	49	c	50	b
51	c	52	a	53	b	54	d	55	b
56	d	57	d	58	c	59	a	60	a
61	a	62	b	63	b	64	b	65	b
66	a	67	b	68	d	69	d	70	d
71	d	72	a	73	c	74	c	75	c
76	d	77	b	78	a	79	d	80	a
81	b	82	c	83	c	84	d	85	a
86	d	87	a	88	d	89	c	90	b
91	a	92	b	93	d	94	a	95	d
96	d	97	b	98	b	99	d	100	c
101	c	102	b	103	b	104	b	105	d
106	a	107	d	108	d	109	b	110	c
111	a								

Critical Thinking Questions

1	b	2	c	3	b	4	abc	5	d
6	b	7	b	8	c	9	b	10	d
11	c	12	b	13	b	14	a	15	a
16	d	17	acd	18	c	19	b	20	c
21	d	22	a	23	c	24	c	25	b
26	c	27	a	28	c	29	b	30	a
31	c	32	c	33	c	34	d	35	b
36	a	37	a	38	a	39	c		

Graphical Questions

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

16	d	17	d	18	a	19	b	20	c
21	b	22	c	23	a	24	a	25	a
26	a	27	c	28	b	29	b	30	c
31	c	32	b	33	b	34	a	35	a
36	a	37	b	38	b				

Assertion and Reason

1	a	2	d	3	b	4	a	5	b
6	d	7	e	8	b	9	b	10	a
11	e	12	d	13	d	14	d	15	d
16	b	17	e	18	e	19	d	20	a
21	b	22	a	23	c	24	b	25	c
26	b	27	e	28	a	29	b	30	e

Answers and Solutions

Cathode Rays and Positive Rays

1. (b) Electric field $=\frac{V}{d}=\frac{250}{2.5\times10^{-2}}=10000\ V/m$.

2. (b)

3. (d) In Millikan's experiment, drops of non-volatile liquid (cloak oil) are used to prevent evaporation.

4. (b) $E=eV=2e\times5=10\ eV$

5. (d) $E=eV=1.6\times10^{-19}\times10^{5}=1.6\times10^{-14}\ J$

6. (a) Any charge in the universe is given by

$q=ne\Rightarrow e=\frac{q}{n}$ (where n is an integer)

$$q_1:q_2:q_3:q_4:q_5:q_6::n_1:n_2:n_3:n_4:n_5:n_6$$

$$6.563:8.204:11.5:13.13:16.48:18.09::n_1:n_2:n_3:n_4:n_5:n_6$$

Divide by 6.563

$$1:1.25:1.75:2.0:2.5:2.75::n_1:n_2:n_3:n_4:n_5:n_6$$

Multiplied by 4

$$4:5:7:8:10:11::n_1:n_2:n_3:n_4:n_5:n_6$$

$$e=\frac{q_1+q_2+q_3+q_4+q_5+q_6}{n_1+n_2+n_3+n_4+n_5+n_6}=\frac{73.967\times10^{-19}}{45}$$

$$=1.641\times10^{-19}C$$

(**Note :** If you take 45.0743 in place of 45, you will get the exact value)

7. (d) Because magnetic force always points perpendicular to the particle velocity. That is why velocity remains unchanged thereby keeping energy $\left(\frac{1}{2}mv^2\right)$ and momentum (mv) unchanged.

8. (b)

9. (c) Mass is basically a constant term for any physical application at low velocity. But in accordance with Einstein's theory of relativity, at higher speeds the mass of the particle change according to formula

$$m=\frac{m_0}{\sqrt{1-(v^2/c^2)}}$$

10. (b) Refer Q.No. 9. Here the velocity of electron increases, so as per Einstein's equation mass of the electron increases, hence the specific charge $\frac{e}{m}$ decreases.

11. (c) If the voltage given is V, then the energy of electron

$$\frac{1}{2}mv^2=eV\Rightarrow v=\sqrt{\frac{2eV}{m}}$$

$$=\sqrt{\frac{2\times1.6\times10^{-19}\times1000}{9.1\times10^{-31}}}=1.875\times10^{7}\approx1.9\times10^{7}m/s$$

12. (b)

13. (d) Momentum $p=mv$ and $v=\sqrt{\frac{2QV}{m}}$

$$\Rightarrow p=\sqrt{2QmV}\Rightarrow p\propto\sqrt{Qm}\Rightarrow\frac{p_e}{p_\alpha}=\sqrt{\frac{e\times m_e}{2e\times m_\alpha}}=\sqrt{\frac{m_e}{2m_\alpha}}$$

14. (b) In an electric field, a force opposite to the direction of electric field acts on negatively charged particles (*i.e.* from lower potential to higher potential).

15. (d)

16. (c) $QE=mg\Rightarrow Q=\frac{mg}{E}\Rightarrow n=\frac{mgd}{Ve}$

$$\Rightarrow n=\frac{1.8\times10^{-14}\times10\times0.9\times10^{-2}}{2\times10^{3}\times1.6\times10^{-19}}=5$$

17. (c)

18. (b) In Millikan's experiment, the charges present on the oil drops are the integral multiples, so $2e$ and $10e(1.6\times10^{-18}\ C)$ charges are present.

19. (c) $eE=evB\Rightarrow v=\frac{E}{B}=\frac{3\times10^{4}}{2\times10^{-3}}=1.5\times10^{7}\ m/s$

20. (b)

21. (b) Charged particles trace a circular path in a perpendicular magnetic field.

22. (c) $\frac{e}{m}=\frac{1.6\times10^{-19}}{9.1\times10^{-31}}=1.76\times10^{11}C/kg$

23. (c)

24. (d) Light consists of photons and cathode rays consists of electrons. However both effect the photographic plate.

25. (c)

26. (d)

27. (b) For ionisation, high energy electrons are required.

28. (b) $v=\frac{E}{B}=\frac{20}{0.5}=40\ m/\sec$.

29. (c) Higher the voltage, higher is the KE. Higher the work function, smaller is the KE.

30. (a) Time period of revolution of electron $T = \frac{2\pi}{\omega} = \frac{2\pi r}{v}$

Hence corresponding electric current $i = \frac{e}{T} = \frac{ev}{2\pi r}$

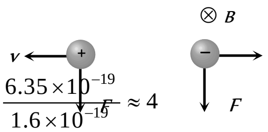
$\Rightarrow i = \frac{1.6\times10^{-19}\times2\times10^{6}}{2\times3.14\times0.5\times10^{-10}} = 1\,mA.$

31. (a) $K = Q.V = 1.6\times10^{-19}\times100 = 1.6\times10^{-17}$ *Joules*

32. (c) $K = Q.V = 1e\times1\,Volt = 1e\,V$

33. (a) Kinetic energy $\propto$ Potential difference

34. (a) In discharge tube cathode rays (a beam of negative particles) and canal rays (positive rays) moves opposite to each other. They will experience a magnetic force in the same direction, if a normal magnetic field is switched on



35. (b) $n = \frac{Q}{e} = \frac{6.35\times10^{-19}}{1.6\times10^{-19}} \approx 4$

36. (b)

37. (a) When cathode rays strike the metal plate, they transfer their energy to plate.

38. (d) Cathode rays are beam of electrons.

39. (b) $K = QV = e\times V = eV$

40. (a) $\frac{1}{2}mv^2 = QV \Rightarrow v = \sqrt{\frac{2QV}{m}} = \sqrt{2\left(\frac{e}{m}\right)V}$

$\Rightarrow v = \sqrt{2\times1.6\times10^{11}\times200} = 8\times10^{6}\,m/s\,.$

41. (c) Speed of the cathode rays is $10^7\ m/\sec - 3\times10^7\,m/s$

42. (d) $QE = mg \Rightarrow mg = \frac{QV}{d}$

43. (d)

44. (c) In the condition of no deflection $\frac{e}{m} = \frac{E^2}{2VB^2} \Rightarrow$ If m is increased by 208 times then B should be increased $\sqrt{208} = 14.4$ times

45. (b) The colour of the positive column in a discharge tube depends on the type of gas e.g. For air, colour is purple red, for H_2, colour is Blue etc.

46. (c)

47. (a) $v = \frac{p}{m} = \frac{h}{m\lambda} = \frac{6.6\times10^{-34}}{9.1\times10^{-31}\times10^{-10}} = 7.25\times10^{6}\ m/s$

48. (d) Cathode rays are stream of negative charged particle, so they deflect in electric field.

49. (c) $\frac{e}{m} = \frac{E^2}{2VB^2} = \frac{(3.6\times10^4)^2}{2\times2.5\times10^3\times(1.2\times10^{-3})^2}$

$= 1.8\times10^{11}\,C/kg\,.$

50. (c) Specific charge $= \frac{q}{m}$; Ratio $= \frac{\left(\frac{q}{m}\right)_\alpha}{\left(\frac{q}{m}\right)_p} = \frac{q_\alpha}{q_p}\times\frac{m_p}{m_\alpha} = \frac{1}{2}$.

51. (c) $v = \frac{E}{B}$; where $E = \frac{V}{d} = \frac{1000}{1\times10^{-2}} = 10^5\ V/m$

$\Rightarrow v = \frac{10^5}{1} = 10^5\,m/s\,.$

52. (b)

53. (b)

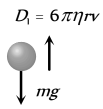
54. (b)

55. (d) In Thomson's mass spectrograph $\vec{E} \parallel \vec{B}$

56. (d)

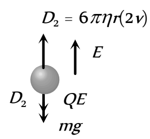
57. (c) In the absence of electric field (*i.e.* $E = 0$)

$mg = 6\pi\eta rv$ ...(i)



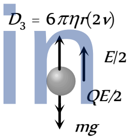
In the presence of Electric field

$mg + QE = 6\pi\eta r(2v)$ ...(ii)



When Electric field to reduced to $E/2$

$mg + Q(E/2) = 6\pi\eta r(v')$ ...(iii)



After solving (i), (ii) and (iii)

We get $v' = \frac{3}{2}v$

58. (a) $v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2\times1.6\times10^{-19}\times45.5}{9.1\times10^{-31}}} = 4\times10^6\ m/s$

59. (b) $i = \frac{Q}{t} = \frac{ne}{t} = 1.8\times10^{14}\times1.6\times10^{-19} = 28.8\times10^{-6}\,A$

$= 29\ \mu A$

60. (a) $\because\ m_e < m_p < m_\alpha \Rightarrow \left(\frac{q}{m}\right)_e > \left(\frac{q}{m}\right)_p > \left(\frac{q}{m}\right)_\alpha$

61. (b) Acceleration $a = \frac{QE}{m} = \frac{(3e)E}{2m}$

62. (b) $\frac{1}{2}mv^2 = eV \Rightarrow \frac{e}{m} = \frac{v^2}{2V} = \frac{(8.4\times10^6)^2}{2\times200} = 1.76\times10^{11}\frac{C}{kg}$.

63. (c) $K = Q.\Delta V = (2e)\times10^6\,V = 2\times10^6\,eV = 2M\,eV$

64. (c) Positive rays consist of positive ions.

65. (b) $2r = \frac{2mv}{qB} \Rightarrow 2r \propto \frac{m}{q} \Rightarrow \frac{m}{q}$ is maximum for C^+

66. (b) $v = \frac{E}{B} = \frac{1.125\times10^{-6}}{3\times10^{-10}} = 3750\,m/s$

67. (a) Positive rays was discovered by J.J. Thomson.

68. (a)

69. (d) If electron oscillate with a frequency of 1 *GHz*, it does not radiate any energy, which corresponds a definite wavelength. It only radiate when it jump from one orbit to another orbit.

70. (b) $eV = \frac{1}{2}mv^2 \Rightarrow v^2 = \frac{2eV}{m} \Rightarrow v = \sqrt{\frac{2eV}{m}}$

71. (a)

72. (c) $eE = mg \Rightarrow e = \frac{mg}{E} = \frac{16 \times 10^{-6} \times 10}{10^6} = 16 \times 10^{-11}\ C.$

Matter Waves

1. (b)

2. (c) According to de-Broglie hypothesis.

3. (a) $\lambda = \frac{h}{p} = \frac{h}{mv}$

4. (a) $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$: $\therefore E = \frac{h^2}{2m\lambda^2}$

λ is same for all, so $E \propto \frac{1}{m}$. Hence energy will be maximum for particle with lesser mass.

5. (a) Particle is photon and it travels with the velocity equal to light in vacuum.

6. (b) $\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mE}}$; $\therefore \lambda \propto \frac{1}{\sqrt{E}}$ (h and m = constant)

7. (a) $\lambda = \frac{h}{m_1 v_1} = \frac{h}{m_2 v_2}$; $\therefore \frac{v_1}{v_2} = \frac{m_2}{m_1} = \frac{4}{1}$

8. (a) $\frac{1}{2}mv^2 = E \Rightarrow mv = \sqrt{2mE}$; $\therefore \lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

9. (d) $\left.\begin{array}{l}\text{Photoelectric effect} \rightarrow \text{Particle nature} \\ \text{Diffraction} \rightarrow \text{Wave nature}\end{array}\right\}$ Dual nature

10. (a) $mvr = \frac{nh}{2\pi}$ According to Bohr's theory

$\Rightarrow 2\pi r = n\left(\frac{h}{mv}\right) = n\lambda$ for $n = 1$, $\lambda = 2\pi r$

11. (b) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}}$ (E = same)

12. (a) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{m}} \Rightarrow \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha}{m_p}} = \frac{2}{1}$

13. (c) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m_\alpha Q_\alpha V}}$

On putting $Q_\alpha = 2 \times 1.6 \times 10^{-19}\ C$

$m_\alpha = 4m_p = 4 \times 1.67 \times 10^{-27}\ kg \Rightarrow \lambda = \frac{0.101}{\sqrt{V}}\ Å$

14. (b)

15. (b) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{E}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{E_2}{E_1}}$

$\Rightarrow \frac{10^{-10}}{0.5 \times 10^{-10}} = \sqrt{\frac{E_2}{E_1}} \Rightarrow E_2 = 4E_1$

Hence added energy $= E_2 - E_1 = 3E_1$

16. (d) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9 \times 10^{-31} \times 80 \times 1.6 \times 10^{-19}}} = 1.4 Å$

17. (c) $\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{m}$

18. (b) If an electron and a photon propagates in the from of waves having the same wavelength, it implies that they have same momentum. This is according to de-Broglie equation, $p \propto \frac{1}{\lambda}$

19. (c) $\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$

20. (d) In photoelectric effect particle nature of electron is shown. While in electron microscope, beam of electron is considered as electron wave.

21. (b) $K_{\text{particle}} = \frac{1}{2}mv^2$ also $\lambda = \frac{h}{mv}$

$\Rightarrow K_{\text{particle}} = \frac{1}{2}\left(\frac{h}{\lambda v}\right).v^2 = \frac{vh}{2\lambda}$ ...(i)

$K_{\text{photon}} = \frac{hc}{\lambda}$ ...(ii)

$\therefore \frac{K_{\text{particle}}}{K_{\text{photon}}} = \frac{v}{2c} = \frac{2.25 \times 10^8}{2 \times 3 \times 10^8} = \frac{3}{8}$

22. (c) $2\pi r n = \lambda \Rightarrow n = \frac{\lambda}{2\pi r} = \frac{10^{-9}}{2 \times 3.14 \times 5.13 \times 10^{-11}} = 3$

23. (a) By using $\lambda_{electron} = \frac{h}{m_e v} \Rightarrow v = \frac{h}{m_e \lambda_e}$

$= \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 10^{-10}} = 7.25 \times 10^6\ m/s.$

24. (a) By using $\lambda = \frac{h}{\sqrt{2mE}}$ $E = 10^{-32}\ J$ = Constant for both particles. Hence $\lambda \propto \frac{1}{\sqrt{m}}$ Since $m_p > m_e$ so $\lambda_p < \lambda_e$.

25. (b) By using $\lambda \propto \frac{1}{\sqrt{V}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}}$

$\Rightarrow \frac{10^{-10}}{\lambda_2} = \sqrt{\frac{600}{150}} = 2 \Rightarrow \lambda_2 = 0.5\ Å.$

26. (b) $\lambda = \frac{h}{mv_{rms}} \Rightarrow \lambda = \frac{6.6 \times 10^{-34}}{2 \times 1.67 \times 10^{-27} \times 3 \times 10^3} = 0.66\ Å$

27. (c) $\lambda \propto \frac{1}{p} \Rightarrow \frac{\Delta p}{p} = -\frac{\Delta\lambda}{\lambda} \Rightarrow \left|\frac{\Delta p}{p}\right| = \left|\frac{\Delta\lambda}{\lambda}\right|$

$\Rightarrow \frac{p_0}{p} = \frac{0.25}{100} = \frac{1}{400} \Rightarrow p = 400\ p_0.$

28. (a) $\lambda_{neutron} \propto \frac{1}{\sqrt{T}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{T_2}{T_1}}$

$\Rightarrow \frac{\lambda}{\lambda_2} = \sqrt{\frac{(273 + 927)}{(273 + 27)}} = \sqrt{\frac{1200}{300}} = 2 \Rightarrow \lambda_2 = \frac{\lambda}{2}.$

29. (d) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow E \propto \frac{1}{\sqrt{m}}$ (λ = constant)

$\because m_e < m_p$ so $E_e > E_p$

30. (b)

31. (a) Wavelength of photon will be greater than that of electron because mass of photon is less than that of electron $\Rightarrow \lambda_{ph} > \lambda_e$

32. (b) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow E = \frac{h^2}{2m\lambda^2}$

$= \frac{(6.6\times10^{-34})^2}{2\times9.1\times10^{-31}\times(0.3\times10^{-9})^2} = 2.65\times10^{-18}\,J$

$= 16.8\,eV$

33. (c) $\lambda = \frac{h}{\sqrt{2mQV}} \Rightarrow \lambda \propto \frac{1}{\sqrt{mQ}} \Rightarrow \frac{\lambda_p}{\lambda_\alpha} = \sqrt{\frac{m_\alpha Q_\alpha}{m_p Q_p}}$

$= \sqrt{\frac{4m_p\times2Q_p}{m_p\times Q_p}} = 2\sqrt{2}$

34. (a) $\lambda = \frac{h}{p} \Rightarrow p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{2\times10^{-6}}$

$= 3.31\times10^{-28}\,kg\text{-}m/\sec$

35. (a) $\lambda = \frac{h}{mv} = \frac{6.6\times10^{-34}}{1\times2000} = 3.3\times10^{-37}\,m = 3.3\times10^{-27}\,Å$

36. (a) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times5\times1.6\times10^{-19}}}$

$= 5.469\times10^{-10}\,m = 5.47\,Å$

37. (c) $\lambda = \frac{h}{\sqrt{2mQV}} = \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times100}}$

$= 1.23\,Å$

38. (c) The De-Broglie wavelength is $\lambda = \frac{h}{|p|} = \frac{h}{|I|} \Rightarrow \lambda \propto \frac{1}{|I|}$

39. (d) Davission and Germer proved the wave nature of electron by performing an experiment.

40. (a) $\lambda = \frac{h}{\sqrt{2mE}} \Rightarrow \lambda \propto \frac{1}{\sqrt{E}}$.

41. (d) $\lambda = \frac{\hbar}{\sqrt{2mE}}; \frac{\lambda'}{\lambda} = \sqrt{\frac{E}{E'}} \Rightarrow \frac{E}{E} = \left(\frac{0.5}{1}\right)^2 \Rightarrow E' = \frac{E}{0.25} = 4E$

The energy should be added to decrease wavelength.

$= E' - E = 3E$

42. (d)

43. (d)

Photon and Photoelectric Effect

1. (d) $p = \frac{h\nu}{c} \Rightarrow \nu = \frac{pc}{h} = \frac{3.3\times10^{-29}\times3\times10^{8}}{6.6\times10^{-34}} = 1.5\times10^{13}\,Hz$

2. (d)

3. (c) $p = \frac{E}{c} \Rightarrow E = p\times c = 2\times10^{-16}\times(3\times10^{10}) = 6\times10^{-6}\,erg.$

4. (a)

5. (a) $p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{(5000\times10^{-10})} = 1.3\times10^{-27}\,kg\text{-}m/s$

6. (b) $p = \frac{E}{c} = \frac{h\nu}{c}$

7. (d) $E = h\nu = mc^2 \Rightarrow m = \frac{h\nu}{c^2}$

8. (b) $p = \frac{E}{c} = \frac{h\nu}{c} \Rightarrow \nu = \frac{pc}{h}$

9. (b) $P = \frac{W}{t} = \frac{nhc}{\lambda t} \Rightarrow \left(\frac{n}{t}\right) = \frac{P\lambda}{hc} = \frac{10\times10^3\times300}{6.6\times10^{-34}\times3\times10^8}$

$= 1.5\times10^{31}$

10. (a) Momentum of photon $p = \frac{E}{c}$

$\Rightarrow$ Velocity of photon $c = \frac{E}{p}$

11. (b) By using $E(eV) = \frac{12375}{\lambda(Å)}$

$\Rightarrow \lambda = \frac{12375}{2.48} = 4989.9\,Å \approx 5000\,Å$

12. (b) $E = \frac{hc}{\lambda} = \frac{3\times10^8\times6.62\times10^{-34}}{0.21\times1.6\times10^{-19}} = 5.9\times10^{-6}\,eV$

13. (b) Momentum of photon

$p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{10^{-10}} = 6.6\times10^{-24}\,kg\text{-}m/sec.$

14. (c) $E \propto \frac{1}{\lambda} \Rightarrow \frac{2.5}{E'} = \frac{1}{5000} \Rightarrow E' = (2.5)\times5000\,eV$

15. (a) $E = h\nu = 6.6\times10^{-34}\times10^{15} = 6.6\times10^{-19}\,J$

16. (a) Since $h\nu = mc^2$, hence $p = mc = \frac{h\nu}{c} = \frac{h}{\lambda}$

17. (b) $E = h\nu \Rightarrow \nu = \frac{E}{h} = \frac{1\times10^6\times1.6\times10^{-19}}{6.6\times10^{-34}} = 2.4\times10^{20}\,Hz$

18. (a) $p = \frac{h\nu}{c} = \frac{6.6\times10^{-34}\times1.5\times10^{13}}{3\times10^8} = 3.3\times10^{-29}\,kg\text{-}m/\sec$

19. (a) $E = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3\times10^8}{450\times10^{-9}} = 4.4\times10^{-19}\,J$

20. (c) $E = h\nu \Rightarrow \nu = \frac{E}{h} = \frac{66\times1.6\times10^{-19}}{6.6\times10^{-34}} = 16\times10^{15}\,Hz$

21. (d) $E \propto \frac{1}{\lambda}$; also $\lambda_{infrared} > \lambda_{visible}$ so $E_{infrared} < E_{visible}$

22. (c) Energy of photon $E = \frac{hc}{\lambda}$ (Joules) $= \frac{hc}{e\lambda}(eV)$

$\Rightarrow E_{(eV)} = \frac{6.6\times10^{-34}\times3\times10^8}{1.6\times10^{-19}\times\lambda(Å)} = \frac{12375}{\lambda(Å)}$

$\Rightarrow E(keV) = \frac{12.37}{\lambda(Å)} \approx \frac{12.4}{\lambda}$

23. (b) $E = h\nu \Rightarrow 100\times1.6\times10^{-19} = 6.6\times10^{-34}\times\nu$

$\Rightarrow \nu = 2.42\times10^{16}\,Hz$.

24. (a) $p = \frac{h}{\lambda} = \frac{6.6\times10^{-34}}{4400\times10^{-10}} = 1.5\times10^{-27}\,kg.m/s$

and mass $m = \frac{p}{c} = \frac{1.5\times10^{-27}}{3\times10^{8}} = 5\times10^{-36} kg$

25. (a)

26. (a)

27. (a) $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E}$

28. (c)

29. (d) $E(eV) = \frac{h\nu}{e} = \frac{6.0\times10^{-34}\times10^{12}\times10^{6}}{1.6\times10^{-19}} = 4.14\times10^{3} eV$.

30. (c) $E = nh\nu \Rightarrow \nu \propto \frac{1}{n} \Rightarrow \frac{n_1}{n_2} = \frac{\gamma_2}{\gamma_1}$.

31. (c) According to Einstein's photoelectric equation.

32. (a) Kinetic energy of photoelectrons depends on the frequency of incident radiations and is independent of the intensity of illumination.

33. (e) In this case, for photoelectric emission the wavelength of incident radiations must be less then $5200 Å$. Wavelength of ultraviolet radiations is less then this value (5200 Å) but wavelength of infrared radiations is higher than this value.

34. (a) Frequency of light of wavelength $(\lambda = 4000 Å)$ is $\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{4000\times10^{-10}} = 0.75\times10^{15}$ which is less than the given threshold frequency. Hence no photoelectric emisssion takes place.

35. (d) Refer to the application of photo-cell.

36. (c) Albert Einstein was awarded Nobel Prize in 1921 for discovering the photoelectric effect.

37. (d)

38. (c) Energy of incident light $E(eV) = \frac{12375}{3320} = 3.72 eV$

$(332 nm = 3320 Å)$

According to the relation $E = W_0 + eV_0$

$\Rightarrow V_0 = \frac{(E-W_0)}{e} = \frac{3.72 eV - 1.07 eV}{e} = 2.65 \ Volt$

39. (d)

40. (b) $K_{max} = (h\nu - W_0)$; ν = frequency of incident light.

41. (a) Refer to threshold frequency.

42. (c) $W_0(eV) = \frac{12375}{\lambda_0} \Rightarrow \lambda_0 = \frac{12375}{4.2} \approx 2955 Å$

43. (d) Intensity $\propto$ (No. of photons) $\propto$ (No. of photoelectrons)

44. (d) $E = W_0 + K_{max}$; $E = \frac{12375}{3000} = 4.125 eV$

$\Rightarrow K_{max} = E - W_0 = 4.125 eV - 1 eV = 3.125 eV$

$\Rightarrow \frac{1}{2}mv^2_{max} = 3.125\times1.6\times10^{-19} \ J$

$\Rightarrow v_{max} = \sqrt{\frac{2\times3.125\times1.6\times10^{-19}}{9.1\times10^{-31}}} = 1\times10^{6} m/s$

45. (d) Retarding potential $V_0 = \frac{h}{e}(\nu - \nu_0)$

46. (c)

47. (c) $K_{max} = \frac{hc}{\lambda} - W_0 = \frac{6.4\times10^{-34}\times3\times10^{8}}{6400\times10^{-10}} - 1.6\times10^{-19}$

$= 1.4\times10^{-19} \ J$

48. (b) $K_{max}(eV) = E(eV) - W_0(eV) = 6.2 - 4.2 = 2 \ eV$

$\therefore \ K_{max}(Joules) = 2\times1.6\times10^{-19} J = 3.2\times10^{-19} J$

49. (c) Since $W_0 = \frac{hc}{\lambda_0}$; $\therefore \frac{(W_0)_T}{(W_0)_{Na}} = \frac{\lambda_{Na}}{\lambda_T}$ or

$\lambda_T = \frac{\lambda_{Na}\times(W_0)_{Na}}{(W_0)_T} = \frac{5460\times2.3}{4.5} = 2791 \ Å$

50. (a) $K_{max} = (E - W_0) = (3.4 - 2) \ eV = 1.4 \ eV$

51. (a) Energy of incident light $E = \frac{12375}{2000} = 6.18 \ eV$

According to relation $E = W_0 + eV_0$

$\Rightarrow V_0 = \frac{(E-W_0)}{e} = \frac{(6.18 \ eV - 5.01 \ eV)}{e} = 1.17 \ V \approx 1.2 \ V$

52. (b) $W_0 = \frac{12375}{6600} = 1.87 \ eV$.

53. (d)

54. (b) $E = h\nu = 6.64\times10^{-34}\times1.0\times10^{14} = 6.62\times10^{-20} \ J$

55. (a) Number of photons emitted per second

$n = \frac{p}{h\nu} = \frac{10\times10^{3}}{6.6\times10^{-34}\times880\times10^{3}} = 1.72\times10^{31}$

56. (d) Number of ejected electrons $\propto$ (Intensity) $\propto \frac{1}{(\text{Distance})^2}$

Therefore an increment of distance two times will reduce the number of ejected electrons to $\frac{1}{4}th$ of the previous one.

57. (d) According to Einstein's photoelectric equation

$E = W_0 + K_{max} \ \Rightarrow V_0 = \frac{hc}{e}\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$

Hence if λ decreases V_0 increases.

58. (b) $W_0 = \frac{12375}{\lambda_0(Å)} = \frac{12375}{5420} = 2.28 \ eV$

59. (b) Number of electrons can be measured which are directly proportional to the intensity of radiation.

60. (a) $K_{max} = h\nu - W_0 = 6.6\times10^{-34}\times8\times10^{14} - 3.2\times10^{-19}$

$= 2.1\times10^{-19} \ J$

61. (c)

62. (b) $K_{max}(eV) = 12375\left[\frac{1}{\lambda(Å)} - \frac{1}{\lambda_0(Å)}\right]$

$= 12375\left[\frac{1}{1000} - \frac{1}{2000}\right] = 6.2 \ eV$

63. (b) Stopping potential does not depend on the relative distance between the source and the cell.

64. (c)

65. (a) Energy of incident light $E(eV) = \frac{12375}{4000} = 3.09\ eV$

Stopping potential is $-2V$ so $K_{max} = 2\ eV$

Hence by using $E = W_0 + K_{max}$; $W = 1.09\ eV \approx 1.1\ eV$

66. (d) $\frac{hc}{\lambda} = W_0 + \frac{1}{2}mv_{max}^2$

Assuming W_0 to be negligible in comparison to $\frac{hc}{\lambda}$

i.e. $v_{max}^2 \propto \frac{1}{\lambda} \Rightarrow v_{max} \propto \frac{1}{\sqrt{\lambda}}$.

(On increasing wavelength λ to 4λ, v_{max} becomes half).

67. (d) $W_0 = h\nu_0 \Rightarrow \nu_0 = \frac{W_0}{h} = \frac{2.51 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}}$

$= 6.08 \times 10^{14}\ Cycle / sec$.

68. (c)

69. (b)

70. (a) By changing distance of source, photoelectric current changes. But there is no change in stopping potential.

71. (d) $\nu_0 = \frac{W_0}{h} = \frac{3.3 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = 8 \times 10^{14}\ Hz$

72. (a) For no emission of photoelectron, energy of incident light < Work function $\Rightarrow h\nu < \phi \Rightarrow \nu < \frac{\phi}{h}$

73. (c) Number of electrons emitted $\propto$ intensity $\propto \frac{1}{(\text{distance})^2}$

$\Rightarrow \frac{n_1}{n_2} = \left(\frac{d_2}{d_1}\right)^2 = \left(\frac{2}{1}\right)^2 = 4 \Rightarrow n_2 = \frac{n_1}{4}$

74. (c) $E = \frac{hc}{\lambda} - W_0$ and $2E = \frac{hc}{\lambda'} - W_0$

$\Rightarrow \frac{\lambda'}{\lambda} = \frac{E + W_0}{2E + W_0} \Rightarrow \lambda' = \lambda\left(\frac{1 + W_0/E}{2 + W_0/E}\right)$

Since $\frac{(1 + W_0/E)}{(2 + W_0/E)} > \frac{1}{2}$ so $\lambda' > \frac{\lambda}{2}$

75. (b) Stopping potential $V_0 = \frac{hc}{e}\left[\frac{1}{\lambda} - \frac{1}{\lambda_0}\right]$. As λ decreases so V_0 increases.

76. (c) $W.(eV) = \frac{12375}{\lambda_0(Å)} \Rightarrow \lambda_0 = \frac{12375}{4.125} = 3000Å$

77. (a) Intensity increases means more photons of same energy will emit more electrons of same energy, hence only photoelectric current increases.

78. (a) $E = W_0 + K_{max}$; $E = \frac{12375}{5000} = 2.475\ eV$

$\therefore K_{max} = E - W_0 = 2.475 - 1.9 = 0.57\ eV$

79. (b)

80. (c) $\lambda_0 = \frac{hc}{W_0} = \frac{12400}{4} = 3100Å = 310\ nm$

81. (b) $K_{max} = (|V_s|)eV \Rightarrow |V_s| = 4V$

82. (d) Threshold wavelength $\lambda_0 = \frac{12375}{2.1} = 5892.8\ Å$

83. (c) $P = \frac{nhc}{\lambda t} \Rightarrow \frac{n}{t} = \frac{P.\lambda}{hc} = \frac{100 \times 5000 \times 10^{-10}}{6.6 \times 10^{-34} \times 3 \times 10^8}$

$= 2.50 \times 10^{20}$

84. (c) $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0 = h\nu - W_0$

$\Rightarrow K_1 = h\nu - W_0$ and $K_2 = 2h\nu - W_0 \Rightarrow K_2 > 2K_1$

85. (b) Work function $= \frac{hc}{\lambda_0}$; where λ_0 is threshold wavelength.

$\therefore \frac{W_{0_1}}{W_{0_2}} = \frac{\lambda_{0_2}}{\lambda_{0_1}} = \frac{2}{1}$

86. (c) $W_0 = \frac{hc}{\lambda_0} = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{5000 \times 10^{-10}} J = 4 \times 10^{-19} J$

87. (a) The work function has no effect on current so long as $h\nu > W_0$. The photoelectric current is proportional to the intensity of light. Since there is no change in the intensity of light, therefore $I_1 = I_2$.

88. (b) Number of photons emitted is proportional to the intensity.

Also $\frac{hc}{\lambda} = W_0 + E$.

89. (c) Photoelectric current $\propto$ Intensity of light

90. (d) $V_0 = \frac{(E - W_0)}{e} = \frac{(2eV - 0.6\ eV)}{e} = 1.4V$

91. (a) $\lambda_r > \lambda_y > \lambda_g$. Here threshold wavelength $< \lambda_y$.

92. (a) For electron emission $\lambda_{incident} < \lambda_0$

93. (a) $K_{max} = (|V_0|)eV = 2eV$.

94. (b) Threshold wavelength for *Na*, $\lambda_{Na} = \frac{12375}{2} = 6187.5Å$

Also $\lambda_{Cu} = \frac{12375}{4} = 3093.75$

Since $\lambda_{Na} > 4000Å$; So *Na* is suitable.

95. (c) By using $E = W_0 + K_{max}$

$E = \frac{12375}{5000} = 2.475\ eV$ and $K_{max} = eV_0 = 1.36\ eV$

So $2.475 = W_0 + 1.36 \Rightarrow W_0 = 1.1\ eV$.

96. (b) For emission of electrons incident energy of each photon must be greater than work function (threshold energy).

97. (d) K_{max} of photoelectrons doesn't depends upon intensity of incident light.

98. (a) By using $E = W_0 + \frac{1}{2}mv_{max}^2$ where $E = \frac{12375}{2000} = 6.18\ eV$

$\Rightarrow 6.18\ eV = 4.2\ eV + \frac{1}{2}mv_{max}^2 \Rightarrow 1.98\ eV = \frac{1}{2}mv_{max}^2$

$\Rightarrow 1.98 \times 1.6 \times 10^{-19} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v_{max}^2$

$\Rightarrow v_{max} = 8.4 \times 10^5\ m/s$

99. (b) By using $E = W_0 + \frac{1}{2}mv_{max}^2$; where $E = \frac{12375}{4558} = 2.71\ eV$

$\Rightarrow 2.71\ eV = 2.5\ eV + \frac{1}{2} \times 9.1 \times 10^{-31} \times v_{max}^2$

$\Rightarrow 0.21 \times 1.6 \times 10^{-19} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v_{max}^2$

$\Rightarrow v_{max} = 2.65 \times 10^5\ m/s$

100. (b) $E = W_0 + K_{max}$ .....(i)

$\Rightarrow hf = W_A + K_A$ .....(ii)

and $2hf = W_B + K_B = 2W_A + K_B$ $\left(\because \frac{W_A}{W_B} = \frac{1}{2}\right)$

Dividing equation (i) by (ii)

$\frac{1}{2} = \frac{W_A + K_A}{2W_A + K_B} \Rightarrow \frac{K_A}{K_B} = \frac{1}{2}$

101. (a)

102. (d) Stopping potential depends upon the energy of photon

103. (a) $\lambda_0 = \frac{12375}{W_0(eV)} = \frac{12375}{3} = 4125Å$

104. (b) With decrease in wavelength of incident photons, energy of photoelectrons increases.

105. (b)

106. (a) By using $\frac{hc}{\lambda} = W_0 + \frac{1}{2}mv^2$

$\Rightarrow \frac{hc}{400 \times 10^{-9}} = W_0 + \frac{1}{2}mv^2$ .....(i)

and $\frac{hc}{250 \times 10^{-9}} = W_0 + \frac{1}{2}m(2v)^2$ .....(ii)

On solving (i) and (ii)

$\frac{1}{2}mv^2 = \frac{hc}{3}\left[\frac{1}{250 \times 10^{-9}} - \frac{1}{400 \times 10^{-9}}\right]$ .....(iii)

From equation (i) and (iii) $W_0 = 2hc \times 10^6\ J$.

107. (a) $E = W_0 + eV_0 \Rightarrow 4eV = 2eV + eV_0 \Rightarrow V_0 = 2\ volt$

108. (b)

109. (a) $W_0 = \frac{12375}{6800} = 1.8eV$

110. (b) With the increase in intensity of light photoelectric current increases, but Kinetic energy of ejected electron, stopping potential and work function remains unchanged.

111. (c) $E = h\nu = 6.6 \times 10^{-34} \times 8 \times 10^{15} = 5.28 \times 10^{-18}\ J = 33eV$ By using $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0$

$= 33 - 6.125 = 27eV$

112. (b) $\lambda = \frac{12375}{W_0} = \frac{12375}{2} = 6187.5Å = 620\ nm$

113. (a) Minimum kinetic energy is always zero.

114. (c) Speed of photon is $3 \times 10^8\ m/s$ in vacuum.

115. (c) Minimum frequency : $W_0 = h\nu_0$

$\Rightarrow \nu_0 = \frac{W_0}{h} = \frac{1.65 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = 4 \times 10^{14}\ Hz$

116. (b) By using $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0$

Hence, $K_1 = 1 - 0.5 = 0.5$

and $K_2 = 2.5 - 0.5 = 2 \Rightarrow \frac{K_1}{K_2} = \frac{1}{4}$.

117. (c) $W_0 \propto \frac{1}{\lambda} \Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{(W_0)_2}{(W_0)_1} = \frac{4.5}{2.3} = \frac{2}{1}$.

118. (d) $K_{max} = eV_0 \Rightarrow eV_0 = 4eV \Rightarrow V_0 = 4V$

119. (a) Number of photo electrons

$(N) \propto$ Intensity $\propto \frac{1}{d^2} \Rightarrow \frac{N_1}{N_2} = \left(\frac{d_2}{d_1}\right)^2$

$\Rightarrow \frac{N_1}{N_2} = \left(\frac{100}{50}\right)^2 = \frac{4}{1} \Rightarrow N_2 = \frac{N_1}{4}$.

120. (c) $P = \frac{W}{t} = \frac{nhc}{\lambda t} \Rightarrow 10^3 = \frac{n \times 6.6 \times 10^{-34} \times 3 \times 10^8}{198.6 \times 1}$

$\Rightarrow n = 10^{30}$.

121. (c) $p = \frac{nhc}{\lambda t} \Rightarrow 100 = \frac{n \times 6 \times 10^{-34} \times 3 \times 10^8}{540 \times 10^{-9} \times 1} \Rightarrow n = 3 \times 10^{20}$

122. (c) $\frac{1}{2}mv_{max}^2 = eV_0 \Rightarrow v_{max} = \sqrt{2\left(\frac{e}{m}\right)V_0}$

$= \sqrt{2 \times 1.8 \times 10^{11} \times 9} = 1.8 \times 10^6\ m/s$.

123. (b) $\frac{hc}{\lambda} = W_0 + K_{max} \Rightarrow \frac{hc}{\lambda_A} = W_0 + K_A$ ...(i)

and $\frac{hc}{\lambda_B} = W_0 + K_B$ ...(ii)

Subtracting (i) from (ii), $hc\left[\frac{1}{\lambda_B} - \frac{1}{\lambda_A}\right] = K_B - K_A$

$\Rightarrow hc\left[\frac{1}{\lambda_B} - \frac{1}{2\lambda_B}\right] = K_B - K_A \Rightarrow \frac{hc}{2\lambda_B} = K_B - K_A$ ...(iii)

From (ii) and (iii), $2K_B - 2K_A = W_0 + K_B$

$\Rightarrow K_B - 2K_A = W_0$

$\Rightarrow K_A = \frac{K_B}{2} - \frac{W_0}{2}$ which gives $K_A < \frac{K_B}{2}$.

124. (a) $\lambda_0 = \frac{12375}{6500} = 1.9\ eV \approx 2eV$.

125. (a) $\lambda_{X-ray} < \lambda_{UV-ray}$

126. (a) $E = h\nu_0 + K_{max} \Rightarrow h(4\nu_0) = h\nu_0 + K_{max} \Rightarrow K_{max} = 3h\nu_0$.

127. (a)

128. (c) $W_0 = \frac{12375}{2.3} = 5380Å$.

129. (d)

130. (b) Using Einstein photoelectric equation $E = W_0 + K_{max}$

$hf_1 = W_0 + \frac{1}{2}mv_1^2$ .....(i)

$hf_2 = W_0 + \frac{1}{2}mv_2^2$ .....(ii)

$\Rightarrow h(f_1 - f_2) = \frac{1}{2}m(v_1^2 - v_2^2) \Rightarrow (v_1^2 - v_2^2) = \frac{2h}{m}(f_1 - f_2)$

131. (d)

132. (b) By using $\frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = V_0$

$\Rightarrow \frac{hc}{e}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = 4.8$ .....(i)

and $\frac{hc}{e}\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right) = 1.6$ .....(ii)

From equation (i) by (ii), $\frac{\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)}{\left(\frac{1}{2\lambda} - \frac{1}{\lambda_0}\right)} = \frac{4.8}{1.6} \Rightarrow \lambda_0 = 4\lambda$.

133. (c)

134. (d) $E = W_0 + K_{max}$. From the given data E is 6.78 eV (for λ= 1824 $Å$) or $10.17\,eV$ (for $\lambda = 1216$ $Å$)

$\therefore\ W_0 = E - K_{max} = 6.78 - 5.3 = 1.48\,eV$

or

$W_0 = 10.17 - 8.7 = 1.47\,eV$.

135. (c) $E = \frac{hc}{\lambda} \Rightarrow \frac{E_1}{E_2} = \frac{\lambda_1}{\lambda_2} \Rightarrow \frac{3.32 \times 10^{-19}}{E_2} = \frac{4000}{6000}$

$\Rightarrow E_2 = 4.98 \times 10^{-19}\,J = 3.1\,eV$.

136. (c) Number of waves $= \frac{10^{-3}}{4000 \times 10^{-10}} = 0.25 \times 10^4$

137. (d) Velocity of photon $c = \nu\lambda$

138. (b) $\lambda_0 = \frac{12375}{6.825} = 1813\,Å \approx 1800Å$

139. (c) Work function $W_0 = h\nu_0 = 6.6 \times 10^{-34} \times 1.6 \times 10^{15}$

$= 1.056 \times 10^{-18}\,J = 6.6\,eV$

From $E = W_0 + K_{max} \Rightarrow K_{max} = E - W_0 = 1.4\,eV$

140. (c) $P = \frac{h}{\lambda}, E = \frac{hc}{\lambda} \Rightarrow E = Pc$.

141. (a) $E = \frac{hc}{\lambda} \Rightarrow \frac{E_1}{E_2} = \frac{300}{150} = \frac{2}{1}$

142. (d)

143. (b) If frequency of incident light increases, kinetic energy of photoelectron also increases.

144. (d) Photoelectric effect can be explained on the basis of spectrum of an atom.

145. (b) $W_0 = \frac{12375}{\lambda_0} = \frac{12375}{5420} = 2.28\,eV$

146. (c)

147. (a) $E = \frac{12375}{\lambda} = \frac{12375}{5000} = 2.47\,eV \approx 2.5\,eV$

148. (a) Momentum $p = \frac{E}{c} \Rightarrow E^2 = p^2c^2$

149. (c) Energy of incident radiations (in eV) $= \frac{12375}{4100} = 3.01\,eV$

Work function of metal A and B are less then $3.01eV$, so A and B will emit photo electrons.

150. (d) From $E = W_0 + \frac{1}{2}mv_{max}^2$

$\Rightarrow 2h\nu_0 = h\nu_0 + \frac{1}{2}mv_1^2 \Rightarrow h\nu_0 = \frac{1}{2}mv_1^2$ .....(i)

and $5h\nu_0 = h\nu_0 + \frac{1}{2}mv_2^2 \Rightarrow 4h\nu_0 = \frac{1}{2}mv_2^2$ .....(ii)

Dividing equation (ii) by (i) $\left(\frac{v_2}{v_1}\right)^2 = \frac{4}{1}$

$\Rightarrow v_2 = 2v_1 = 2 \times 4 \times 10^6 = 8 \times 10^6\,m/s$

151. (d) Number of photoelectrons $\propto \frac{1}{(\text{Distance})^2}$.

152. (b) The value of saturation current depends on intensity. It is independent of stopping potential

153. (a) In tungsten, photoemission take place with a light of wavelength 2300 $Å$. As emission of electron is inversely proportional to wavelength, all the wavelengths smaller then 2300 $Å$ will cause emission of electrons.

154. (c) Stopping potential $= 1.8\,eV - 1.2\,eV = 0.6\,eV$.

155. (a)

156. (a) $K.E. = h\nu - h\nu_0 = 8\ eV - \left(\frac{6 \times 10^{-34} \times 1.6 \times 10^{15}}{1.6 \times 10^{-19}}\,eV\right)$

$= 8\ eV - 6\ eV = 2\ eV$

X-Rays

1. (c) $\lambda_{min} = \frac{12375}{50 \times 10^3}\,Å = 0.247 = 0.25\,Å$.

2. (c) X-rays are electromagnetic waves of wavelength ranging from 0.1 to $100\,Å$.

3. (a) Penetrating power is greater for lower wavelength.

4. (a)

5. (d) From the formula

$V = \frac{12375}{\lambda_{min}} = \frac{12375}{0.3094} = 39.99\ kV \approx 40\,kV$

6. (b) Refer to the application of X-rays.

7. (a)

8. (b)

9. (c)

10. (c) The voltage applied across the X-ray tube is of the range of 10 kV – 80 kV.

11. (c)

12. (b) In X-ray tube, target must be heavy element with high melting point.

13. (c) $\nu \propto (Z - b)^2 \Rightarrow \nu = a(Z - b)^2$

Z = atomic number of element (a, b are constant).

14. (c)

15. (b) *X*-rays and gamma rays are electromagnetic waves.

16. (c) Since $\lambda_{min} = \frac{12375}{V} Å = \frac{12375}{10^5} Å = 0.123 Å$

$E_{max} = \frac{hc}{\lambda_{min}}$;

On putting the values. $E_{max} \cong 10^{-1} MeV$.

17. (b) $\lambda_{min} = \frac{hc}{eV}$. where *h*, *c* and *e* are constants. Hence $\lambda_{min} \propto \frac{1}{V}$

18. (c) Range of *X*-rays is 0.1Å to 100 Å.

19. (d) The production of *X*-rays is an atomic property whereas the production of γ -rays is a nuclear property.

20. (a) $\lambda_{min} = \frac{12375}{40,000} = 0.30 Å$ Hence wavelength less than 0.30 Å is not possible.

21. (a) $\lambda_{min} = \frac{hc}{eV}$

22. (b) $p = \frac{h}{\lambda} = \frac{6.6 \times 10^{-34}}{0.01 \times 10^{-10}} = 6.6 \times 10^{-22} \, kg\text{-}m/sec$.

23. (a) *X*-rays are absorbed by the target; they are not reflected by the target.

24. (c)

25. (d)

26. (a)

27. (d)

28. (c)

29. (b) Continuous spectrum of *X*-rays consists of radiations of all possible wavelength range having a definite short wavelength limit.

30. (b) $\frac{E}{t} = P = \frac{h\nu}{t}$

i.e. Penetrating power $\propto$ energy $\propto$ Frequency

31. (c) In general *X*-rays have larger wavelength than that of gamma rays.

32. (c) According to Mosley's law $\nu = a(Z-b)^2$ and $\nu \propto \frac{1}{\lambda}$

33. (b) $E = h\nu = eV \Rightarrow \nu \propto V$

34. (c) $E = eV = h\nu_{max} \Rightarrow \nu_{max} = \frac{eV}{h}$

35. (c) $E = eV = h\nu_{max} = \frac{hc}{\lambda_{min}} \Rightarrow \lambda_{min} = \frac{hc}{eV}$

36. (d) $\lambda_{min} = \frac{hc}{eV}$ or $\lambda_{min} \propto \frac{1}{V}$ On increasing potential, λ_{min} decreases.

37. (a) $h\nu_o = eV \therefore \nu_o = \frac{eV}{h} = \frac{1.6 \times 10^{-19} \times 42000}{6.63 \times 10^{-34}} = 10^{19} \, Hz$

38. (d) Nucleus of heavy atom captures electron of *k*-orbit. This is a radioactive process, so vacancy of this electron is filled by an outer electron and *x*-rays are produces.

39. (d) Because they are electromagnetic waves.

40. (c) $\nu_{max} \propto \frac{1}{\lambda_{min}}$ Hard *X*-rays have high frequency and low wavelength.

41. (d) X-rays are electromagnetic in nature so they remains unaffected in electric and magnetic field.

42. (b)

43. (c)

44. (b) *X*-rays have high energy. They penetrate into the solid crystal and used to find out the internal structure.

45. (a) By changing the filament current with the help of rheostat, thermionic emission intensity of *X*-rays can be changed.

46. (c) Applied voltage must be greater than binding energy.

47. (a)

48. (d) $\lambda = \frac{12375}{(40 \times 10^3)} = 0.309 Å \approx 0.31 Å$

49. (c)

50. (b) $\lambda_{min} = \frac{hc}{eV} = \frac{12375}{V} Å = 0.495 \; Å \approx 0.5 \, Å$

51. (c) $\lambda_{min} = \frac{hc}{eV} = \frac{12375}{V} Å; \therefore V = \frac{12375}{\lambda \text{ in } Å} = 124 \; kV$

52. (a) Mosley's law is $f = a(Z-b)^2$

53. (b) The potential difference across the filament and target determines the energy and thence the penetrating power of *X*-rays.

54. (d) The energy of *X*-ray photon obtained from a coolidge tube by an electronic transition of target atom such as K_α line is obtained from transition from *L* orbit in *K* orbit.

55. (b) $\lambda_{min} = \frac{12375}{V} = \frac{12375}{30 \times 10^3} = 0.4 Å$

56. (d) $\lambda_{min} = \frac{12375}{100 \times 10^3} Å = 0.124 Å$

57. (d) $\lambda_{min} = \frac{12375}{50000} = 0.025 \; nm$

58. (c)

59. (a) Refer theory

60. (a) With the increase in potential difference between anode and cathode energy of striking electrons increases which in turn increases the energy (penetration power) of X-rays.

61. (a)

62. (b)

63. (b) The wavelength range of *X*-ray is 0.1 Å – 100 Å.

64. (b) Energy $E = h\nu = h\frac{c}{\lambda} \therefore \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{5000}{1}$

65. (b)

66. (a) Interatomic spacing in a crystal acts as a diffraction grating.

67. (b) The wavelength of the γ-rays is shorter. However the main distinguishing feature is the nature of emission.

68. (d) $h\nu_{max} = eV \Rightarrow \frac{hc}{\lambda_{min}} = eV \therefore \lambda_{min} \propto \frac{1}{V}$

69. (d) Hard X-rays are of higher energy and the energy of X-rays depends on the potential difference between the cathode and the target.

70. (d) Penetration is directly proportional to the energy of radiations.

71. (d) Greater the number of electrons striking the anode, larger is the number of X-ray photons emitted.

72. (a) $\lambda_{min} = \frac{12375}{V}\,Å \Rightarrow V = \frac{12375}{1} = 12375\,V$
$= 12.375\,kV \approx 12.42\,kV$

73. (c)

74. (c)

75. (c) $E(eV) = \frac{12375}{1.65} = 7500eV = 7.5\ keV$.

76. (d)

77. (b)

78. (a) $\lambda_{min} = \frac{12375}{40}\,Å = 3.09\times10^{-8}m$

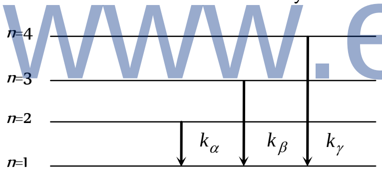
79. (d) Target should be of high atomic number and high melting point

80. (a) Intensity of X-rays depends upon the number of electron striking the target.

81. (b) $E(eV) = \frac{hc}{e\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times1\times10^{-10}} = 12375\,eV$

82. (c) When applied voltage is greater then energy of K-electron, continuous and all characterstic X-rays are emitted.

83. (c)



84. (d) When current through the filament increases, number of emitted electrons also increases. Hence intensity of X-ray increases but no effect on penetration power.

85. (a) $i = \frac{Ne}{t} \Rightarrow \frac{N}{t} = \frac{i}{e} = \frac{3.2\times10^{-3}}{1.6\times10^{-19}} = 2\times10^{16}\,/\,sec$

86. (d)

87. (a) Because X-rays are electromagnetic (Neutral) in nature.

88. (d) $\lambda_{min} = \frac{hc}{eV} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}V} = \frac{12375}{V} \approx \frac{12400}{V}\,Å$

89. (c) Frequency of hard X-rays is greater than that of soft X-rays.

90. (b)

91. (a) $\lambda_{min} = \frac{12375}{V}\,Å \Rightarrow V = \frac{12375}{0.4125} = 30\,kV$

92. (b)

93. (d)

94. (a) $\lambda_{min} = \frac{12375}{40\times10^{3}} = 0.309\,Å \approx 0.31\,Å$

95. (d) $\lambda_{min} = \frac{hc}{eV} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times100\times10^{3}} = 0.123Å$

96. (d) According to Mosley's law $\nu \propto (Z-b)^2$
For k_α line, $b = 1$, and it has maximum frequency so $\nu_{max} \propto (Z-1)^2$

97. (b) The velocity of X-rays is always equal to that of light.

98. (b)

99. (d) $\lambda_{min} = \frac{12375}{V}\,Å \Rightarrow V = \frac{12375}{2.5} = 4950\ V \simeq 5\ kV$.

100. (c) $\lambda_{min} = \frac{hc}{eV(\text{energy})}$; when KE (or eV) increases, λ decreases.

101. (c)

102. (b) When a high energy electron incident on heavy metal, it produces X-rays.

103. (b) $\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{1\times10^{-10}} = 3\times10^{18}\,Hz$

104. (b) $\lambda \propto \frac{1}{Z^2} \Rightarrow \frac{c}{\nu} \propto \frac{1}{Z^2} \Rightarrow \nu \propto Z^2$

105. (d)

106. (a) $eV = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.5\times10^{-10}}$
$\Rightarrow V = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}\times1.5\times10^{-10}} = 8280\ Volt.$

107. (d)

108. (d)

109. (b) Required ionisation energy
$= \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.54\times10^{-10}}\,J = 12.9\times10^{-16}\,J$

110. (c) $\lambda \propto \frac{1}{(Z-1)^2} \Rightarrow \frac{\lambda_2}{\lambda_1} = \left(\frac{Z_1-1}{Z_2-1}\right)^2$
$\Rightarrow \frac{\lambda_2}{\lambda} = \left(\frac{43-1}{29-1}\right)^2 = \left(\frac{42}{28}\right)^2 \Rightarrow \lambda_2 = \frac{9}{4}\lambda$.

111. (a)

Critical Thinking Questions

1. (b) For one second, distance = Velocity $= 3\times10^{4}\,m/\sec$ and $Q = i\times1 = 10^{-6}C$. Charge density $= \frac{\text{Charge}}{\text{Volume}}$
$= \frac{10^{-6}}{3\times10^{4}\times0.5\times10^{-6}} = 6.6\times10^{-5}C/m^3$.

2. (c) By law of conservation of momentum
$0 = m_1\vec{v_1} + m_2\vec{v_2} \Rightarrow m_1\vec{v_1} = -m_2\vec{v_2}$
$-$ *ve* sign indicates that both he particles are moving in opposite direction. Now de-Broglie wavelengths
$\lambda_1 = \frac{h}{m_1v_1}$ and $\lambda_2 = \frac{h}{m_2v_2}$; $\therefore \frac{\lambda_1}{\lambda_2} = \frac{m_2v_2}{m_1v_1} = 1$

3. (b) $\lambda_{photon} = \frac{hc}{E}$ and $\lambda_{proton} = \frac{h}{\sqrt{2mE}}$

$$\Rightarrow \frac{\lambda_{\text{photon}}}{\lambda_{\text{electron}}} = c\sqrt{\frac{2m}{E}} \Rightarrow \frac{\lambda_{\text{photon}}}{\lambda_{\text{electron}}} \propto \frac{1}{\sqrt{E}}$$

4. (a,b,c) $K_{max} = E - W_o$

$\therefore T_A = 4.25 - (W_o)_A$ ...(i)

$T_B = (T_A - 1.5) = 4.70 - (W_o)_B$ ...(ii)

Equation (i) and (ii) gives $(W_o)_B - (W_o)_A = 1.95\ eV$

De Broglie wave length $\lambda = \frac{h}{\sqrt{2mK}} \Rightarrow \lambda \propto \frac{1}{\sqrt{K}}$

$$\Rightarrow \frac{\lambda_B}{\lambda_A} = \sqrt{\frac{K_A}{K_B}} \Rightarrow 2 = \sqrt{\frac{T_A}{T_A - 1.5}} \Rightarrow T_A = 2eV$$

From equation (i) and (iii)

$W_A = 2.25\ eV$ and $W_B = 4.20\ eV$.

5. (d)

6. (b) In the presence of inert gas photoelectrons emitted by cathode ionise the gas by collision and hence the current increases.

7. (b) For electron and positron pair production, minimum energy is 1.02 MeV.

Energy of photon is given $1.7 \times 10^{-13} J = \frac{1.7 \times 10^{-13}}{1.6 \times 10^{-19}}$

$= 1.06\ MeV$.

Since energy of photon is greater than 1.02 MeV,

So electron, positron pair will be created.

8. (c) According to Einstein's photoelectric equation

$$\frac{hc}{\lambda} = \phi + \frac{1}{2}mv^2 \Rightarrow v = \left[\frac{2(hc - \lambda\phi)}{m\lambda}\right]^{1/2}$$

9. (b) Cut off voltage is independent of intensity and hence remains the same. Since distance becomes 3 times, so intensity (I) becomes $\frac{I}{9}$. Hence photo current also decreases by this factor *i.e.* becomes $\frac{18}{9} = 2\,mA$.

10. (d) $h\nu - W_0 = \frac{1}{2}mv_{\max}^2 \Rightarrow \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = \frac{1}{2}mv_{\max}^2$

$$\Rightarrow hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right) = \frac{1}{2}mv_{\max}^2 \Rightarrow v_{\max} = \sqrt{\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)}$$

When wavelength is λ and velocity is v, then

$$v = \sqrt{\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)} \quad \text{.... (i)}$$

When wavelength is $\frac{3\lambda}{4}$ and velocity is v' then

$$v' = \sqrt{\frac{2hc}{m}\left[\frac{\lambda_0 - (3\lambda/4)}{(3\lambda/4) \times \lambda_0}\right]} \quad \text{....(ii)}$$

Divide equation (ii) by (i), we get

$$\frac{v'}{v} = \sqrt{\frac{[\lambda_0 - (3\lambda/4)]}{\frac{3}{4}\lambda\lambda_0} \times \frac{\lambda\lambda_0}{\lambda_0 - \lambda}}$$

$$v' = v\left(\frac{4}{3}\right)^{1/2}\sqrt{\frac{[\lambda_0 - (3\lambda/4)]}{\lambda_0 - \lambda}} \quad \textit{i.e. } v' > v\left(\frac{4}{3}\right)^{1/2}$$

11. (c) Intensity of light

$I = \frac{Watt}{Area} = \frac{nhc}{A\lambda} \Rightarrow$ Number of photon $n = \frac{IA\lambda}{hc}$

$\therefore$ Number of photo electron $= \frac{1}{100} \times \frac{IA\lambda}{hc}$

$$= \frac{1}{100}\frac{1 \times 10^{-4} \times 300 \times 10^{-9}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 1.5 \times 10^{12}$$

12. (b) By using $h\nu - h\nu_0 = K_{\max}$

$\Rightarrow h(\nu_1 - \nu_0) = K_1$ ....(i)

And $h(\nu_2 - \nu_0) = K_2$ ....(ii)

$\Rightarrow \frac{\nu_1 - \nu_0}{\nu_2 - \nu_0} = \frac{K_1}{K_2} = \frac{1}{K}$, Hence $\nu_0 = \frac{K\nu_1 - \nu_2}{K - 1}$.

13. (b) $E = W_0 + eV_0$

For hydrogen atom, $E = +13.6\,eV$

$\therefore +13.6 = 4.2 + eV_0$

$\Rightarrow V_0 = \frac{(13.6 - 4.2)eV}{e} = 9.4\ V$

Potential at anode $= -9.4\ V$

14. (a) From $\lambda_0 = \frac{12375}{W_0}$

The maximum wavelength of light required for the photoelectron emission, $(\lambda_0)_{Li} = \frac{12375}{2.3} = 5380\mathring{A}$.

Similarly $(\lambda_0)_{Cu} = \frac{12375}{4} = 3094$ Å.

Since the wavelength 3094 Å does not in the visible region, but it is in the ultraviolet region. Hence to work with visible light, lithium metal will be used for photoelectric cell.

15. (a) Direction of scattered photon $\cos\phi = 1 - \frac{\Delta\lambda m_e c}{h}$

Here $\Delta\lambda = 0.011\ \mathring{A}$

$$\therefore \cos\phi = 1 - \frac{0.011 \times 10^{-10} \times 9.1 \times 10^{-31} \times 3 \times 10^8}{6.624 \times 10^{-34}}$$

$$= 1 - 0.453 = 0.547$$

$\therefore \phi = \cos^{-1}(0.547)$

16. (d) Bragg's law, $2d\sin\theta = n\lambda$ or $\lambda = \frac{2d\sin\theta}{n}$

For maximum wavelength, $n_{\min} = 1$, $(\sin\theta)_{\max} = 1$

$\therefore \lambda_{\max} = 2d$ or $\lambda_{\max} = 2 \times 10^{-7}\,cm = 20\,\mathring{A}$

17. (a,c,d) $P = VI = 50 \times 10^3 \times 20 \times 10^{-3} = 1000\ W$

Power converted into heat $= 990\ W$

$ms\Delta T = 990 \Rightarrow \Delta T = 2^o\,C/\sec$

Now $\frac{hc}{\lambda_{\min}} = eV \Rightarrow \lambda_{\min} = \frac{hc}{eV} = 0.248 \times 10^{-10}\,m$

18. (c) The wavelength of X-ray lines is given by Rydberg

Formula $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For K_α line, $n_1 = 1$ and $n_2 = 2$

$\therefore \frac{1}{\lambda} = RZ^2\left(\frac{3}{4}\right) \Rightarrow Z = \left(\frac{4}{3R\lambda}\right)^{1/2}$

$= \left[\frac{4}{3\,(1.097\times10^7 m^{-1})(0.76\times10^{-10} m)}\right]^{1/2}$ = 39.99 ≈ 40

19. (b) If intensity of X-ray is decreased by dI, when it passes through a length dx of absorbing material then, the amount of observed intensity is $\mu I\,dx$.

Thus, $-dI = \mu I\,dx$ or $\frac{dI}{dx} + \mu I = 0$

On solving this equation $I = I_0 e^{-\mu x} = I_0 e^{-\mu d}$ $(x = d)$

20. (c) $E_K - E_L = \frac{hc}{\lambda} = \frac{(6.6\times10^{-34})\,(3\times10^8)}{(0.021\times10^{-9})\,(1.6\times10^{-19})} eV = 59\,keV$

21. (d) Minimum wavelength of continuous X-ray spectrum is given by

$\lambda_{\min}(\text{in Å}) = \frac{12375}{E(eV)} = \frac{12375}{80\times10^3} \approx 0.155$

Also the energy of the incident electrons (80 KeV) is more than the ionization energy of the K-shell electrons (*i.e.* 72.5 KeV). Therefore characteristic X-ray spectrum will also be obtained because energy of incident electron is enough to knock out the electron from K or L shells.

22. (a) The wave length of L_α line is given by

$\frac{1}{\lambda} = R\,(z-7.4)^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \lambda \propto \frac{1}{(Z-7.4)^2}$

$\Rightarrow \frac{\lambda_1}{\lambda_2} = \frac{(z_2-7.4)^2}{(z_1-7.4)^2} \Rightarrow \frac{1.30}{\lambda_2} = \frac{(42-7.4)^2}{(78-7.4)^2} \Rightarrow \lambda_2 = 5.41\,Å$

23. (c) de-Broglie wavelength $\lambda = \frac{h}{mv_{rms}}$, rms velocity of a gas particle at the given temperature (T) is given as

$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT \Rightarrow v_{rms} = \sqrt{\frac{3kT}{m}} \Rightarrow mv_{rms} = \sqrt{3mk\,T}$

$\therefore \lambda = \frac{h}{mv_{rms}} = \frac{h}{\sqrt{3mkT}}$

$\Rightarrow \frac{\lambda_H}{\lambda_{He}} = \sqrt{\frac{m_{He}T_{He}}{m_H T_H}} = \sqrt{\frac{4(273+127)}{2(273+27)}} = \sqrt{\frac{8}{3}}$

24. (c) $n = \frac{E\lambda}{hc} = \frac{1\times10^{-7}\times200\times10^{-9}}{6.6\times10^{-34}\times3\times10^8} = 1\times10^{11}$

Number of electrons ejected $= \frac{10^{11}}{10^3} = 10^8$

$\therefore V = \frac{q}{4\pi\varepsilon_0 r} = \frac{(10^8\times1.6\times10^{-19})\times9\times10^9}{4.8\times10^{-2}} = 3\,V$

25. (b) The momentum of the incident radiation is given as $p = \frac{h}{\lambda}$.

When the light is totally reflected normal to the surface the direction of the ray is reversed. That means it reverses the direction of it's momentum without changing it's magnitude

$\therefore \Delta p = 2p = \frac{2h}{\lambda} = \frac{2\times6.6\times10^{-34}}{6630\times10^{-10}} = 2\times10^{-27}$ *kg-m/sec.*

26. (c) When a charged particle (charge q, mass m) enters perpendicularly in a magnetic field (B) than, radius of the path described by it $r = \frac{mv}{qB} \Rightarrow mv = qBr$.

Also de-Broglie wavelength $\lambda = \frac{h}{mv}$

$\Rightarrow \lambda = \frac{h}{qBr} \Rightarrow \frac{\lambda_\alpha}{\lambda_p} = \frac{q_p r_p}{q_\alpha r_\alpha} = \frac{1}{2}$

27. (a) $\sqrt{f_1} = \sqrt{\frac{v}{\lambda_1}} = a(11-1)$ and $\sqrt{f_2} = \sqrt{\frac{v}{\lambda_2}} = a(Z-1)$

By dividing, $\sqrt{\frac{\lambda_2}{\lambda_1}} = \frac{10}{Z-1} \Rightarrow \sqrt{\frac{4}{1}} = \frac{10}{Z-1} \Rightarrow Z = 6$

28. (c) $K.E. = 2E_0 - E_0 = E_0$ (for $0 \le x \le 1$) $\Rightarrow \lambda_1 = \frac{h}{\sqrt{2mE_0}}$

$K.E. = 2E_0$ (for $x > 1$) $\Rightarrow \lambda_2 = \frac{h}{\sqrt{4mE_0}} \Rightarrow \frac{\lambda_1}{\lambda_2} = \sqrt{2}$.

29. (b) Given $m_0c^2 = 0.51\,MeV$ and $v = 0.8\,c$

$K.E.$ of the electron $= mc^2 - m_0c^2$

But $m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}} = \frac{m_0}{\sqrt{1-\left(\frac{0.8\,c}{c}\right)^2}} = \frac{m_0}{\sqrt{0.36}} = \frac{m_0}{0.6}$

Now, $mc^2 = \frac{0.51}{0.6}\,MeV = 0.85\,MeV$

$\therefore$ $K.E. = (0.85 - 0.51)\,MeV = 0.34\,MeV$.

30. (a) The deflection suffered by charged particle in an electric field is

$y = \frac{q\,ELD}{mu^2} = \frac{q\,ELD}{p^2/m}$ $(p = mu)$

$\Rightarrow y \propto \frac{qm}{p^2} \Rightarrow y_p : y_d : y_\alpha = \frac{q_p m_p}{p_p^2} : \frac{q_d m_d}{p_d^2} : \frac{q_\alpha m_\alpha}{p_\alpha^2}$

Since $p_\alpha = p_d = p_p$ (given)

$m_p : m_d : m_\alpha = 1 : 2 : 4$ and $q_p : q_d : q_\alpha = 1 : 1 : 2$

$\Rightarrow y_p : y_d : y_\alpha = 1\times1 : 1\times2 : 2\times4 = 1 : 2 : 8$

31. (c) Using $Z^2 = k\left(\frac{q}{m}\right)y$; where $k = \frac{B^2LD}{E}$. For parabolas to coincide in the two photographs, the $\frac{kq}{m}$ should be same for the two cases. Thus, $\frac{B_1^2\,LDe}{E_1 m_1} = \frac{B_2^2 LD(2e)}{E_2 m_2}$

$\Rightarrow \frac{m_1}{m_2} = \left(\frac{B_1}{B_2}\right)^2 \times \left(\frac{E_2}{E_1}\right) \times \frac{1}{2} = \frac{9}{4} \times \frac{2}{1} \times \frac{1}{2} = \frac{9}{4}$

32. (c) According to the energy diagram of X-ray spectra

$\because \Delta E = \frac{hc}{\lambda} \Rightarrow \lambda \propto \frac{1}{\Delta E}$

(ΔE = Energy radiated when e jumps from, higher energy orbit to lower energy orbit)

$\because (\Delta E)_{k_\beta} > (\Delta E)_{k_\alpha} > (\Delta E)_{L_\alpha} \therefore \lambda'_\alpha > \lambda_\alpha > \lambda_\beta$

Also $(\Delta E)_{k_\beta} = (\Delta E)_{k_\alpha} + (\Delta E)_{L_\alpha}$

$$\Rightarrow \frac{hc}{\lambda_\beta} = \frac{hc}{\lambda_\alpha} + \frac{hc}{\lambda'_\alpha} \Rightarrow \frac{1}{\lambda_\beta} = \frac{1}{\lambda_\alpha} + \frac{1}{\lambda'_\alpha}$$

33. (c) By using $I = \frac{P}{A}$; where P = radiation power

$$\Rightarrow P = I \times A \Rightarrow \frac{nhc}{t\lambda} = IA \Rightarrow \frac{n}{t} = \frac{IA\lambda}{hc}$$

Hence number of photons entering per sec the eye $\left(\frac{n}{t}\right) = \frac{10^{-10} \times 10^{-6} \times 5.6 \times 10^{-7}}{6.6 \times 10^{-34} \times 3 \times 10^{8}}$ = 300.

34. (d) $\Delta\lambda = \lambda_{K_\alpha} - \lambda_{\min}$ When V is halved $\lambda_{\min}$ becomes two times but λ_{K_α} remains the same.

$\therefore \quad \Delta\lambda' = \lambda_{K_\alpha} - 2\lambda_{\min} = 2(\Delta\lambda) - \lambda_{K_\alpha}$

$\therefore \quad \Delta\lambda' < 2(\Delta\lambda)$

35. (b) Energy of photons corresponding to light of wave length λ_1 = 2475 Å is $E_1 = \frac{12375}{2475} = 5\,eV$.

and that corresponding to λ_2 = 6000 Å is

$$E_2 = \frac{12375}{6000} = 2.06\,eV$$

As $E_2 < W_0$ and $E_1 > W_0$

Photoelectric emission is possible with λ_1 only. Maximum kinetic energy of emitted photoelectrons $K = E - W_0 = 5 - 4.8 =$ 0.2 eV.

Photo electrons experiences magnetic force and move along a circular path of radius

$$r = \frac{\sqrt{2\,mk}}{Q\,B} = \frac{\sqrt{2 \times 9 \times 10^{-31} \times 0.2 \times 1.6 \times 10^{-19}}}{1.6 \times 10^{-19} \times 3 \times 10^{-5}}$$

= 0.05 m = 5 cm.

36. (a) Number of photoelectrons emitted up to t = 10 sec are

$$n = \frac{(\text{Number of photons per unit area per unit time}) \times (\text{Area} \times \text{Time})}{10^6}$$

$$= \frac{1}{10^6}[(10)^{16} \times (5 \times 10^{-4}) \times (10)] = 5 \times 10^7$$

At time t = 10 sec

Charge on plate A ; $q_A = +ne = 5 \times 10^7 \times 1.6 \times 10^{-19}$

$= 8 \times 10^{-12}\,C = 8\,pC$

and charge on plate B ; $q_B = 33.7 - 8 = 25.7\,pc$

Electric field between the plates

$$E = \frac{(q_B - q_A)}{2\,\varepsilon_0 A} = \frac{(25.7 - 8) \times 10^{-12}}{2 \times 8.85 \times 10^{-12} \times 5 \times 10^{-4}} = 2 \times 10^3\,\frac{N}{C}.$$

37. (a) As we know in Young's double slit experiment fringe width = separation between two consecutive fringe or dark fringes

$$= \beta = \frac{\lambda D}{d}$$

Here $\beta = 2y \Rightarrow 2y = \frac{\lambda D}{d} \Rightarrow \lambda = \frac{2yd}{D}$

$$\Rightarrow \lambda = \frac{2 \times 1 \times 10^{-3} \times 0.24 \times 10^{-3}}{1.2} = 4 \times 10^{-7}\,m = 4000\,Å$$

Energy of light incident on photo plate

$$E\,(eV) = \frac{12375}{4000} = 3.1\,eV$$

According to Eienstein photoelectric equation

$$E = W_0 + eV_0 \Rightarrow V_0 = \frac{(E - W_0)}{e} = \frac{(3 + 2.2)}{e}eV \approx 0.9\,V$$

38. (a) $E = \frac{12375}{5000} = 2.475\,eV \approx 4 \times 10^{-19}\,J$

So the minimum intensity to which the eye can respond

I_{Eye} = (Photon flux) × (Energy of a photon)

$$\Rightarrow I_{Eye} = (5 \times 10^4) \times (4 \times 10^{-19}) \simeq 2 \times 10^{-14}\,(W/m^2)$$

Now as lesser the intensity required by a detector for detection, more sensitive it will be

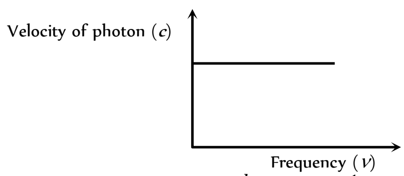
$\frac{S_{Eye}}{S_{Ear}} = \frac{I_{Ear}}{I_{Eye}} = \frac{10^{-13}}{2 \times 10^{-14}} = 5$ *i.e.* as intensity (power) detector, the eye is five times more sensitive than ear.

39. (c) Due to 10.2 eV photon one photon of energy 10.2 eV will be detected.

Due to 15 eV photon the electron will come out of the atom with energy (15 – 13.6) = 1.4 eV.

Graphical Questions

1. (a) Velocity of photon (*i.e.* light) does not depend upon frequency. Hence the graph between velocity of photon and frequency will be as follows



2. (d) De-Broglie wavelength $\lambda = \frac{h}{p} \Rightarrow \lambda \propto \frac{1}{p}$

i.e. graph will be a rectangular hyperbola.

3. (a) The stopping potential for curves a and b is same.

$\therefore \quad f_a = f_b$

Also saturation current is proportional to intensity

$\therefore \quad I_a < I_b$

4. (d) According to Einstein equation

$h\nu = h\nu_0 + K_{\max} \Rightarrow K_{\max} = h\nu - h\nu_0$ on comparing it with $y = mx + c$, it is clear to say that,

This is the equation of straight line having positive slope (h) and negative intercept ($h\nu_0$) on KE axis.

5. (c) Comparing Einstein's equation

$K_{\max} = h\nu - h\nu_0$, with $y = mx + c$, we get slope, $m = h$

6. (b) $K_{max} = h\nu - h\nu_0 \Rightarrow eV_0 = h\nu - h\nu_0 \Rightarrow V_0 = \frac{h}{e}\nu - \frac{h\nu_0}{e}$

Comparing this equation with $y = mx + c$, we get slope $m = \frac{h}{e} \Rightarrow h = m \times e$.

7. (a) Using Einstein's equation, $V_0 = \left(\frac{h}{e}\right)\nu - \frac{W_0}{e}$

Comparing this equation with $y = mx + c$

We get intercept on $-V$ axis $= \frac{W_0}{e}$

$\Rightarrow OB = \frac{W_0}{e} \Rightarrow W_0 = OB \times e$

8. (b) From the given graph it is clear that if we extend the given graph for *A* and *B*, intercept of the line *A* on *V* axis will be smaller as compared to line *B* means work function of *A* is smaller than that of *B*.

9. (a) Wavelength λ_k is independent of the accelerating voltage (V), while the minimum wavelength λ_c is inversely proportional to V. Therefore as V increases, λ_k remains unchanged whereas λ_c decreases or $\lambda_k - \lambda_c$ will increase.

10. (c) In *X*-ray spectra, depending on the accelerating voltage and the target element, we may find sharp peaks super imposed on continuous spectrum. These are at different wavelengths for different elements. They form characteristic *X*-ray spectrum.

11. (b) Photo current (i) directly proportional to light intensity (I) falling on a photosensitive plate. $\Rightarrow i \propto I$

12. (d) According to Einstein's equation

$h\nu = W_0 + K_{max} \Rightarrow V_0 = \left(\frac{h}{e}\right)\nu - \frac{W_0}{e}$

This is the equation of straight line having positive slope (h/e) and intercept on $-V_0$ axis, equals to $\frac{W_0}{e}$

13. (d) In photocell, at a particular negative potential (stopping potential V) of anode, photoelectric current is zero,

At the potential difference between cathode and anode increases current through the circuit increases but after some time constant current (saturation current) flows through the circuit even if potential difference still increasing.

14. (b) Stopping potential does not depend upon intensity of incident light (I).

15. (a) Stopping potential is that negative potential for which photo electric current is zero.

16. (d) $\because V_0 = \left(\frac{h}{e}\right)\nu - \left(\frac{W_0}{e}\right)$. From the graph $V_2 > V_1$

$\Rightarrow \frac{h\nu_2}{e} - \frac{W_0}{e} > \frac{h\nu_1}{e} - \frac{W_0}{e} \Rightarrow \nu_2 > \nu_1$

$\Rightarrow \lambda_1 > \lambda_2$ (as $\lambda \propto \frac{1}{\nu}$)

17. (d) $I \propto \frac{1}{d^2}$ and photo current $i \propto I \Rightarrow i \propto \frac{1}{d^2}$

18. (a) $h\nu = h\nu_0 + KE_{max} \Rightarrow KE_{max} = h\nu - h\nu_0$

On comparing this equation with $y = mx + c$ we get

$m = h =$ Universal constant

19. (b) $\lambda_0 = \frac{c}{\nu_0} = \frac{3 \times 10^8}{5 \times 10^{14}} = 6 \times 10^{-7} m = 6000\,Å$

20. (c) Work function is the intercept on *K.E.* axis *i.e.* $2eV$.

21. (b) From the graph stopping potential $|V| = -V$

Also $k_{max} = |V|eV = 4eV$.

22. (c) By Moseley's law, $\sqrt{\nu} = a(Z - b)$ or, $\nu = a^2(Z - b)^2$

Comparing with the equation of a parabola, $y^2 = 4ax$ it conforms to graph *c*.

23. (a) $\lambda_{min} = \frac{hc}{eV} \Rightarrow \lambda \propto \frac{1}{V}$

$\because \lambda_2 > \lambda_1$ (see graph) $\Rightarrow V_1 > V_2$

$\sqrt{\nu} = a(Z - b)$ Moseley's law

$\nu \propto (Z-1)^2 \Rightarrow \lambda \propto \frac{1}{(Z-1)^2}$ $\left(\because \nu \propto \frac{1}{\lambda}\right)$

$\lambda_1 > \lambda_2$ (see graph for characteristic lines) $\Rightarrow Z_2 > Z_1$.

24. (a) $K_{max} = h\nu - h\nu_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$ *i.e.* graph between K_{max} and $\frac{1}{\lambda}$ will be straight line having slope (hc) and intercept $\frac{hc}{\lambda_0}$ on $-KE$ axis.

25. (a) ν varies from 0 to ν_{max}.

26. (a) $\lambda_{min} = \frac{hc}{eV} \Rightarrow \log.\lambda_{min} = \log\frac{hc}{e} - \log V$

$\Rightarrow \log \lambda_{min} = -\log V + \log\frac{hc}{e}$

This is the equation of straight line having slope (–1) and intercept $\log\frac{hc}{e}$ on $+\log_e \lambda_{min}$ axis.

27. (c) For K_α line $\nu \propto (Z-1)^2 \Rightarrow \lambda \propto \frac{1}{(Z-1)^2}$

i.e. the graph between λ and *z* will be (*c*).

28. (b) Slope of $V_0 - \nu$ curve $= \frac{h}{e}$

$\Rightarrow h = \text{Slope} \times e = 1.6 \times 10^{-19} \times 4.12 \times 10^{-15}$

$= 6.6 \times 10^{-34}$ *J-sec*.

29. (b) $I_1 > I_2$ (given) $\Rightarrow i_1 > i_2$ $(\because i \propto I)$

and stopping potential does not depend upon intensity. So its value will be same (V_0).

30. (c) Slope of $V - \nu$ curve for all metals be same $\left(\frac{h}{e}\right)$ *i.e.* curves should be parallel.

31. (c) $\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2m}} \cdot \frac{1}{\sqrt{E}}$. Taking log of both sides

$\log \lambda = \log\frac{h}{\sqrt{2m}} + \log\frac{1}{\sqrt{E}} \Rightarrow \log\lambda = \log\frac{h}{\sqrt{2m}} - \frac{1}{2}\log E$

$\Rightarrow \log\lambda = -\frac{1}{2}\log E + \log\frac{h}{\sqrt{2m}}$

This is the equation of straight line having slope (–1/2) and positive intercept on log λ axis.

32. (b) $\sqrt{\nu} \propto (Z - b)$

33. (b) Peak of K_α is greater than peak of K_β line.

34. (a) $|-4V| > |-2V|$

35. (a) $\because x \propto \frac{1}{v^2}$. The ion whose deflection is less, its velocity will be more. From the curve $x_1 < x_2 < x_3 < x_4$, therefore $v_1 > v_2 > v_3 > v_4$.

36. (a) All the positive ions of same specific charge moving with different velocity lie on the same parabola.

37. (b) The equation of curve between V and ν is $\frac{h\nu}{e} - \frac{h\nu_0}{e} = V_0$.

This is equation of a straight line with slope $= \frac{h}{e}$.

38. (b) Stopping potential equals to maximum kinetic energy. Since stopping potential is varying linearly with the frequency. There fore max. *KE* for both the metals also vary linearly with frequency.

Assertion and Reason

1. (a) Momentum of a photon is given by $p = \frac{h}{\lambda}$

Also the photon is a form of energy packets behaves as a particle having energy $E = \frac{hc}{\lambda}$. So $p = \frac{E}{c}$

2. (d) Photoelectric effect demonstrates the particle nature of light. Number of emitted photoelectrons depends upon the intensity of light.

3. (b) Charge does not change with speed but mass varies with the speed as per relation $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$. Hence specific charge *e/m* decreases with increase in speed.

4. (a) X-rays lies in electromagnetic spectrum.

5. (b) Mass of moving photon $m = \frac{h\nu}{c^2} = \frac{h}{c\lambda}$ and $E = mc^2$.

6. (d) According Einstein equation $KE = h\nu - h\nu_0$; *i.e.,* *KE* depends upon the frequency. Photoelectron emitted only if incident frequency more than threshold frequency.

7. (e) The atomic number (number of electrons or protons) remains same in isotope. Isotope of an element can be separated on account of their different atomic weight by using mass spectrograph.

8. (b) The specific charge (e/m) of the positive rays is not universal constant because these rays may consists of ions of different element.

9. (b) Less work function means less energy is required for ejecting out the electrons.

10. (a) de-Broglie wavelength associated with gas molecules varies as $\lambda \propto \frac{1}{\sqrt{T}}$

11. (e) If electron is moving parallel to the magnetic field, then the electron is not deflected *i.e.,* if electron is not deflected we cannot be sure that there is no magnetic field in that region.

12. (d) At normal pressure positive ions and electrons liberated by ionisation of gas atoms, due to cosmic rays are very small in number and they collide constantly with the gas atoms which are present in large numbers, and hence are unable to move a long distance under the electric field and soon get recombined *i.e.,* flow of ions in the gas does not take place.

13. (d) Light is produced in gases in the process of electric discharge at low pressure. When accelerated electrons collide with atoms of the gas, atoms get excited. The excited atoms return to their normal state and in this process light radiations are emitted.

14. (d) The discharge depends on both pressure of discharge tube and ionisation potential of gas. Since the ionisation potential of different gases are different, hence the discharge in different gases takes place at different potential.

15. (d) If electric field is used for detecting the electron beam, then very high voltage will have to be applied or very long tube will have to be taken.

16. (b) Specific charge of a positive ion corresponding to one gas is fixed but it is different for different gases.

17. (e) In Millikan's experiment oil drops should be of microscopic sizes. If much bigger oil drops are used, then a very high electric field will be required to balance it which is not possible to achieve practically.

Further, the apparent weight of the liquid $\frac{4}{3}\pi a^3 g (\rho_{\text{liquid}} - \sigma_{\text{air}}) = 6\pi a \eta v$.

If a is large, v will be large and the experimental errors will be high.

18. (e) Only the photoelectrons emitted from the surface of the metal have maximum kinetic energy. Those emitted from inside the metal loses part of their energy in collision with the other atoms inside the metal.

19. (d) On increasing the intensity of incident light, the current in photoelectric cell will increase. The energy of the photons $(h\nu)$ will, however not increase with increase in intensity, and hence the kinetic energy of the emitted electrons will not increase.

20. (a) When a light of single frequency falls on the electron of inner layer of metal, then this electron comes out of the metal surface after a large number of collisions with atoms of its upper layer.

21. (b) There is no emission of photoelectrons till the frequency of incident light is less than a minimum frequency, however intense light it may be. In photoelectric effect, it is a single particle collision. Intensity is $h\nu \times N$, where $h\nu$ is the individual energy of the photon and N is the total number of photon. In the wave theory, the intensity is proportional, not only to ν^2 but also to the amplitude squared. For the same frequency, increase in intensity only increase the number of photons (in the quantum theory of Einstein).

22. (a) The photoemissive cell may be evacuated contain an inert gas at low pressure. An inert gas in the cell gives greater current but causes a time lag in the response of the cell to very rapid changes of radiation which may make it unsuitable for some purpose.

23. (c) Wavelength of *X*-rays is very small $(\approx \mathring{A})$. Hence they are not diffracted by means of ordinary grating. *X*-rays follows the Bragg's law.

24. (b) The penetrating power of *X*-rays depends upon the voltage applied across the tube producing *X*-rays. *X*-rays can pass through matter of lighter elements such as flesh (which is composed of oxygen, hydrogen and carbon) but cannot pass through substances made of heavier elements like bones (which are made of phosphorus and calcium).

25. (c) Intensity of *X*-rays (I) is proportional to the filament current and also to the square of the voltage. It is well known that intensity of *X*-rays depends on the number of photons emitted per second from target.

26. (b) When fast moving electrons strike the atoms of the target, then most of their kinetic energy is used in increasing the thermal agitation of the atoms of the target and only a small part is radiated in the form of *X*-rays. So the temperature of the target rises.

27. (e) Higher is the wavelength of *X*-ray, lesser is the frequency and penetration power.

28. (a) The distance between the atoms of crystals is of the order of wavelength of *X*-rays. When they fall on a crystal, they are diffracted. The diffraction pattern is helpful in the study of crystal structure.

29. (b) In photoelectric effect, the photon falling on some matter is absorbed by the matter and its energy is transferred to an electron of the matter. In *X*-ray production, photons are produced which get energy from energetic electrons ionising the inner shells of the target which in turn cause a cascade of emission lines.

30. (e) Soft and hard *X*-rays differ only in frequency. But both types of *X*-ray travel with speed of light.

Electron, Photon, Photoelectric Effect and X-rays

SET Self Evaluation Test - 25

1. Which of the following will have the least value of $\frac{q}{m}$

(a) Electron (b) Proton

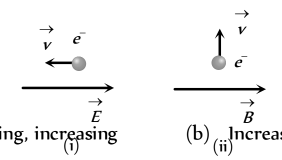
(c) α-particle (d) β-particle

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

(a) Orange (b) Red

(c) Indigo (d) None of the above

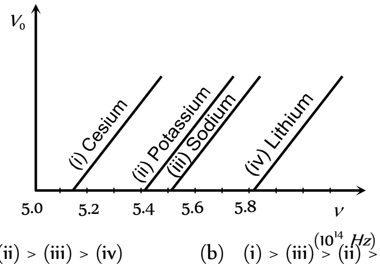
3. An electron is moving through a field. It is moving (i) opposite an electric field (ii) perpendicular to a magnetic field as shown. For each situation the de-Broglie wave length of electron



(a) Increasing, increasing (b) Increasing, decreasing

(c) Decreasing, same (d) Same, Same

4. The figure shows different graphs between stopping potential (V_0) and frequency (ν) for photosensitive surface of cesium, potassium, sodium and lithium. The plots are parallel. Correct ranking of the targets according to their work function greatest first will be



(a) (i) > (ii) > (iii) > (iv) (b) (i) > (iii) > (ii) > (iv)

(c) (iv) > (iii) > (ii) < (i) (d) (i) = (iii) > (ii) = (iv)

5. The K_α X-rays arising from a cobalt (z = 27) target have a wavelength of 179 *pm*. The K_α X-rays arising from a nickel target (z = 28) is

(a) > 179 *pm* (b) < 179 *pm*

(c) = 179 *pm* (d) None of these

6. If a voltage applied to an X-ray tube is increased to 1.5 times the minimum wavelength (λ_{min}) of an X-ray continuous spectrum shifts by $\Delta\lambda = 26\ pm$. The initial voltage applied to the tube is

(a) ≈ 10 *kV* (b) ≈ 16 *kV*

(c) ≈ 50 *kV* (d) ≈ 75 *kV*

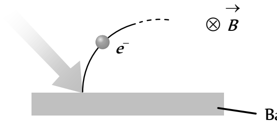
7. Light of wavelength 2475 Å is incident on barium. Photoelectrons emitted describe a circle of radius 100 *cm* by a magnetic field of flux density $\frac{1}{\sqrt{17}} \times 10^{-5}$ *Tesla*. Work function of the barium is (Given $\frac{e}{m} = 1.7 \times 10^{11}$)

(a) 1.8 *eV*

(b) 2.1 *eV*

(c) 4.5 *eV*

(d) 3.3 *eV*



8. Five elements *A*, *B*, *C*, *D* and *E* have work functions 1.2 *eV*, 2.4 *eV*, 3.6 *eV*, 4.8 *eV* and 6 *eV* respectively. If light of wavelength 4000 Å is allowed to fall on these elements, then photoelectrons are emitted by

(a) *A*, *B* and *C* (b) *A*, *B*, *C*, *D* and *E*

(c) *A* and *B* (d) Only *E*

9. If light of wavelength λ_1 is allowed to fall on a metal, then kinetic energy of photoelectrons emitted is E_1. If wavelength of light changes to λ_2 then kinetic energy of electrons changes to E_2. Then work function of the metal is

(a) $\frac{E_1E_2(\lambda_1 - \lambda_2)}{\lambda_1\lambda_2}$ (b) $\frac{E_1\lambda_1 - E_2\lambda_2}{(\lambda_1 - \lambda_2)}$

(c) $\frac{E_1\lambda_1 - E_2\lambda_2}{(\lambda_2 - \lambda_1)}$ (d) $\frac{\lambda_1\lambda_2 E_1E_2}{(\lambda_2 - \lambda_1)}$

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

(a) 30 *volt* (b) 45 *volt*

(c) 59 *volt* (d) Information is insufficient

11. Three particles having their charges in the ratio of 1 : 3 : 5 produce the same spot on the screen in Thomson's experiment. Their masses are in the ratio of

(a) 5 : 3 : 1 (b) 3 : 1 : 5

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

12. If the momentum of an electron is changed by Δp, then the de-Broglie wavelength associated with it changes by 0.50%. The initial momentum of the electron will be

(a) $\frac{\Delta p}{200}$ (b) $\frac{\Delta p}{199}$

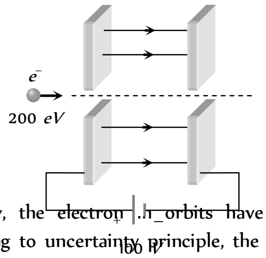
(c) $199\ \Delta p$ (d) $400\ \Delta p$

13. If 10000 *V* is applied across an X-ray tube, what will be the ratio of de-Broglie wavelength of the incident electrons to the shortest wavelength of X-ray produced ($\frac{e}{m}$ for electron is $1.8 \times 10^{11}\ c\,kg^{-1}$)

(a) 1 (b) 0.1

(c) 0.2 (d) 0.3

14. Two large parallel plates are connected with the terminal of 100 *V* power supply. These plates have a fine hole at the centre. An electron having energy 200 *eV* is so directed that it passes through the holes. When it comes out it's de-Broglie wavelength is



(a) 1.22 Å

(b) 1.75 Å

(c) 2 Å

(d) None of these

15. According to Bohr's theory, the electron orbits have definite energy values, then according to uncertainty principle, the life time of an excited state will be

(a) Zero (b) Finite

(c) 10^{-8} *sec* (d) Infinite

16. Monochromatic light of wavelength 3000 Å is incident on a surface area $4 cm^2$. If intensity of light is 150 mW/m^2, then rate at which photons strike the target is

(a) $3 \times 10^{10}/sec$ (b) $9 \times 10^{13}/sec$

(c) $7 \times 10^{15}/sec$ (d) $6 \times 10^{19}/sec$

17. For characteristic *X*-ray of some material

(a) $E(K_\gamma) < E(K_\beta) < E(K_\alpha)$ (b) $E(K_\alpha) < E(L_\alpha) < E(M_\alpha)$

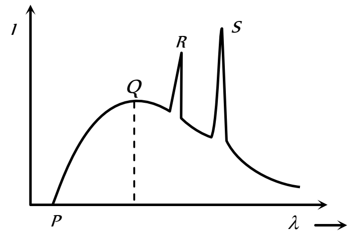
(c) $\lambda(K_\gamma) < \lambda(K_\beta) < \lambda(K_\alpha)$ (d) $\lambda(M_\alpha) < \lambda(L_\alpha) < \lambda(K_\alpha)$

18. The maximum velocity of electrons emitted from a metal surface is *V*. When frequency of light falling on it is *f*. The maximum velocity when frequency becomes 4*f* is

(a) 2 *V* (b) > 2 *V*

(c) < 2 *V* (d) Between 2 *V* and 4 *V*

19. If the potential difference between the anode and cathode of the *X*-ray tube is increases



(a) The peaks at *R* and *S* would move to shorter wavelength

(b) The peaks at *R* and *S* would remain at the same wavelength

(c) The cut off wavelength at *P* would decrease

(d) (b) and (c) both are correct

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

(a) The photo current will increase

(b) The kinetic energy of the electrons will increase

(c) The stopping potential will decrease

(d) The threshold wavelength will increase

Answers and Solutions

(SET -25)

1. (c) Mass of α-particle is maximum so $\left(\frac{q}{m}\right)_\alpha$ is least.

2. (c) Wave length of green light is threshold wave length.
Hence for emission of electron, wave length of incident light < wavelength of green light.

3. (c) $\lambda = \frac{h}{mv}$. Since v is increasing in case (i), but it is not changing in case (ii). Hence, in the first case de-Broglie wavelength will change, but it second case, it remain the same

4. (c) The graph between V_0 and ν cut the ν-axis at ν_0.
For the given graphs $(\nu_0)_{(iv)} > (\nu_0)_{(iii)} > (\nu_0)_{(ii)} > (\nu_0)_{(i)}$

$\therefore (W_0)_{(iv)} > (W_0)_{(iii)} > (W_0)_{(ii)} > (W_0)_{(i)}$.

5. (b) $\lambda_{k\alpha} \propto \frac{1}{(Z-1)^2} \Rightarrow \frac{\lambda_{Ni}}{\lambda_{Co}} = \left(\frac{Z_{Co}-1}{Z_{Ni}-1}\right)^2 = \left(\frac{27-1}{28-1}\right)^2$

$\Rightarrow \lambda_{Ni} = \left(\frac{26}{27}\right)^2 \times \lambda_{Co} = \left(\frac{26}{27}\right)^2 \times 179 = 165.9\, pm < 179\, pm$.

6. (b) $\lambda_{min} = \frac{hc}{eV} \Rightarrow \lambda_1 = \frac{hc}{eV_1}$ and $\lambda_2 = \frac{hc}{eV_2}$

$\therefore \Delta\lambda = \lambda_2 - \lambda_1 = \frac{hc}{e}\left[\frac{1}{V_2} - \frac{1}{V_1}\right]$. Given $V_2 = 1.5\, V_1$

on solving we get $V_1 = 16000\ volt = 16\ kV$.

7. (c) Radius of circular path described by a charged particle in a magnetic field is given by $r = \frac{\sqrt{2mK}}{qB}$; where K = Kinetic energy of electron $\Rightarrow K = \frac{q^2B^2r^2}{2m} = \left(\frac{e}{m}\right)\frac{eB^2r^2}{2}$

$= \frac{1}{2} \times 1.7 \times 10^{11} \times 1.6 \times 10^{-19} \times \left(\frac{1}{\sqrt{17}} \times 10^{-5}\right)^2 \times (1)^2$

$= 8 \times 10^{-20}\, J = 0.5\, eV$

By using $E = W_0 + K_{max}$

$\Rightarrow W_0 = E - K_{max} = \left(\frac{12375}{2475}\right) eV - 0.5\, eV = 4.5\, eV$

8. (c) $E = \frac{12375}{4000} = 3.09\, eV$ Photoelectrons emits if energy of incident light > work function.

9. (c) $E = W_0 + K_{max} \Rightarrow \frac{hc}{\lambda_1} = W_0 + E_1$ and $\frac{hc}{\lambda_2} = W_0 + E_2$

$\Rightarrow hc = W_0\lambda_1 + E_1\lambda_1$ and $hc = W_0\lambda_2 + E_2\lambda_2$

$\Rightarrow W_0\lambda_1 + E_1\lambda_1 = W_0\lambda_2 + E_2\lambda_2 \Rightarrow W_0 = \frac{E_1\lambda_1 - E_2\lambda_2}{(\lambda_2 - \lambda_1)}$.

10. (b) $v_{max} = 4 \times 10^8\ cm/sec = 4 \times 10^6\ m/sec$.

$\therefore K_{max} = \frac{1}{2}mv_{max}^2 = \frac{1}{2} \times 9 \times 10^{-31} \times (4 \times 10^6)^2$

$= 7.2 \times 10^{-18} J = 45\ eV$.

Hence, stopping potential $|V_0| = \frac{K_{max}}{e} = \frac{45\, eV}{e} = 45\, volt$.

11. (c) Since spot is same, hence $\frac{e}{m}$ should be same *i.e.,*

As $q_1 : q_2 : q_3 = 1 : 3 : 5$. Hence $m_1 : m_2 : m_3 = 1 : 3 : 5$

12. (c) $\lambda = \frac{h}{p} \Rightarrow \lambda - \frac{0.5}{100}\lambda = \frac{h}{p + \Delta p} \Rightarrow \frac{199\lambda}{200} = \frac{h}{p + \Delta p} = \frac{199}{200}\frac{h}{p}$

$\Rightarrow p + \Delta p = \frac{200}{199}p \Rightarrow p = 199\ \Delta p$

13. (b) For the incident electron $\frac{1}{2}mv^2 = eV$ or $p^2 = 2meV$

$\therefore$ de-Broglie wavelength $\lambda_1 = \frac{h}{p} = \frac{h}{\sqrt{2meV}}$

Shortest X-ray wavelength $\lambda_2 = \frac{hc}{eV}$

$\therefore \frac{\lambda_1}{\lambda_2} = \frac{1}{c}\sqrt{\left(\frac{V}{2}\right)\left(\frac{e}{m}\right)} = \frac{\sqrt{\frac{10^4}{2} \times 1.8 \times 10^{11}}}{3 \times 10^8} = 0.1$

14. (a) Energy of the electron, when it comes out from the second plate = 200 eV – 100 eV = 100 eV

Hence accelerating potential difference = 100 V

$\lambda_{Electron} = \frac{12.27}{\sqrt{V}} = \frac{12.27}{\sqrt{100}} = 1.23 Å$

15. (d) According to Bohr's theory $\Delta E = 0$, since $\Delta E \cdot \Delta t \geq h$

$\Rightarrow \Delta t \to \infty$

16. (b) $\frac{n}{t} = \frac{IA\lambda}{hc} = \frac{150 \times 10^{-3} \times 4 \times 10^{-4} \times 3 \times 10^{-7}}{6.6 \times 10^{-34} \times 3 \times 10^8} = 9 \times 10^{13}\ \frac{1}{sec}$

17. (c) $\because E(K_\gamma) > E(K_\beta) > E(K_\alpha) \Rightarrow \lambda(K_\gamma) < \lambda(K_\beta) < \lambda(K_\alpha)$

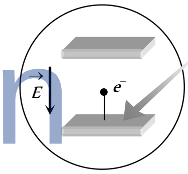
18. (b) $\because E = W_0 + \frac{1}{2}mv_{max}^2 \Rightarrow v_{max} = \sqrt{\frac{2(hf - W_0)}{m}}$

If frequency becomes $4f$ then

$V' = \sqrt{\frac{2(h \times 4f - W_0)}{m}} = 2\sqrt{\frac{2\left(hf - \frac{W_0}{4}\right)}{m}} \Rightarrow V' > 2V$

19. (d) Peaks on the graph represent characteristic X-ray spectrum. Every peak has a certain wavelength, which depends upon the transition of electron inside the atom of the target. While λ_{min} depends upon the accelerating voltage (As. $\lambda_{min} \propto 1/V$).

20. (b) In electric field photoelectron will experience force and accelerate opposite to the field so it's *K.E.* increases (*i.e.* stopping potential will increase), no change in photoelectric current, and threshold wavelength.



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