EXERCISE-1

SECTION (A) : PHOTON EMISSION FROM A SOURCE AND RADIATION

A 1. A parallel beam of monochromatic light of wavelength 663 nm is incident on a totally reflecting plane mirror. The angle of incidence is 60° and the number of photons striking the mirror per second is 1.0×10^{19}. Calculate the force exerted by the light beam on the mirror.

A 2. A beam of white light is incident normally on a plane surface absorbing 70% of the light and reflecting the rest. If the incident beam carries 10 W of power, find the force exerted by it on the surface.

A 3. It is desired to move a small space vehicle of mass 50 kg at rest, by a lamp (fitted on the vehicle) of 100 Watt emitting blue light of wavelength 4700 Å. If the vehicle if in free space, find its acceleration.

SECTION (B) : PHOTOELECTRIC EFFECT

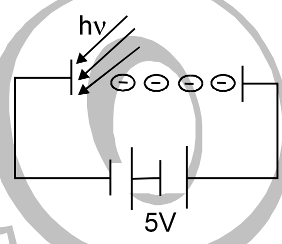
B 1. Find the maximum magnitude of the linear momentum of a photoelectron emitted when light of wavelength 400 nm falls on a metal having work function 2.5 V

B 2. The electric field associated with a monochromatic beam becomes zero 1.2×10^{15} times per second Find the maximum kinetic energy of the photoelectrons when this light falls on a metal surface whose work functions is 2.0 eV

B 3. Calculate the number of photons emitted per second by a 10 W sodium vapour lamp. Assume that 60% of the consumed energy is converted into light. Wavelength of sodium light = 590 nm.

B 4. One milliwatt of light of wavelength 4560 Å is incident on a cesium surface. Calculate the electron current liberated. Assume a quantum efficiency of 0.5 %. [ϕ for cesium = 1.89 ev]

B 5. Photons of energy 5 eV are incident on cathode. Electrons reaching the anode have kinetic energies varying from 6eV to 8eV. Find the work function of the metal & state whether the current in the circuit is less than or equal to saturation current.



B 6. Suppose the wavelength of the incident light is increased from 3000 Aº to 3040 Aº. Find the corresponding change in the stopping potential. [Take the product hc = 12.4×10^{-7} ev m]

B 7. The electric field at a point associated with a light wave is E = (100 V/m) sin [3.0×10^{15} S^{-1})t] sin [(6.0×10^{15} s^{-1})t] If this light falls on a metal surface having a work function of 2.0 eV , what will be the maximum kinetic energy of the photoelectrons ?

B 8. In a photoelectric experiment, it was found that the stopping potential decreases from 1.85 eV to 0.82 eV as the wavelength of the incident light is varies from 3000Å to 4300Å. Calculate the value of the Planck's constant from these data.

B 9. Lithium has a work function of 2.3 eV. It is exposed to light of wavelength 4800 Å. Find the maximum kinetic energy with which electron leaves the surface. What is the longest wavelength which can produce the photoelectrons?

B 10. A monochromatic light source of intensity 5 mW emits. 8×10^{15} photons per second. This light ejects photoelectrons from a metal surface. The stopping potential for this setup is 2.0eV, calculate the work function of the metal.

B 11. A monochromatic light source of frequency ν illuminates a metallic surface and ejects photoelectrons. The photoelectrons having maximum energy are just able to ionize the hydrogen atoms in ground state. When the whole experiment is repeated with an incident radiation of frequency $\frac{5}{6}\nu$, the photoelectrons so emitted are able to excite the hydrogen atom beam which then emits a radiation of wavelength of 1215 Å. Find the work function of the metal and the frequency ν.

B 12. A stationary He^+ ion emitted a photon corresponding to the first line of the Lyman series. That photon liberated a photoelectron from a stationary hydrogen atom in the ground state. Find the velocity of photoelectron.

B 13. A small metal plate (work function = ϕ) is kept at a distance *d* from a singly and positively ionized, fixed ion. A monochromatic light beam is incident on the metal plate and photoelectrons are emitted. Find the maximum wavelength of the light beam so that some of the photoelectrons may go round the ion along a circle.

SECTION (C) : DE-BROGLIE WAVES

C 1. Photo electrons are liberated by ultraviolet light of wave length 3000 Aº from a metallic surface for which the photoelectric threshold wavelength is a 4000 Aº. Calculate the de Broglie wave length of electrons emitted with maximum kinetic energy.

C 2. What amount of energy should be added to an electron to decrease its de Broglie wavelength from 100 pm to 50 pm ?

SECTION (D) : BOHR'S THEORY FOR HYDROGEN, HYDROGEN LIKE ATOMS (PROPERTIES)

D 1. Employing Thomson's model, calculate the radius of a hydrogen atom if the ionization energy of the atom is known to be equal to E = 13.6 eV.

D 2. Find the numerical value of DeBroglie wavelength of an electron in the 1st orbit of hydrogen atom assuming Bohr's atomic model. You can use standard values of the constants. Leave your answer in terms of π.

D 3. Find the radius and energy of a He^+ ion in the states (a) n = 1, (b) n = 4 and (c) n = 10.

D 4. (a) Find the first excitation potential of He^+ ion (b) Find the ionization potential of Li^{++} ion.

D 5. A positive ion having just one electron ejects it if a photon of wavelength 228Å or less is absorbed by it. Identifying the ion.

D 6. The average kinetic energy of molecules in a gas at temperature T is 1.5KT. Find the temperature at which the average Kinetic energy of the molecules of hydrogen equals the binding energy of its atoms. Will hydrogen remain in molecular form at this temperature?

D 7. Suppose the potential energy between electron and proton at a distance *r* is given by $U = -ke \ln(r)$, where *k* is a positive constant. Use Bohr's theory to obtain the energy of *n*th energy level for such an atom.

D 8. A small particle of mass m moves in such a way that the potential energy $U = -\frac{1}{2} mb^2r^2$, where *b* is a constant and *r* is the distance of the particle from the origin (Nucleus). Assuming Bohr model of quantization of angular momentum and circular orbits, show that radius of the *n*th allowed orbit is proportional to $\sqrt{n}$.

D 9. Suppose the potential energy between electron & proton at a distance *r* is given by $\frac{-ke^2}{3r^3}$. Use Bohr's theory to obtain energy levels of such a hypothetical hydrogen atom.

SECTION (E) : ELECTRONIC TRANSITION IN THE H/H-LIKE ATOM/SPECIES & EFFECT OF MOTION OF NUCLEUS

E 1. A stationary hydrogen atom emits a photon corresponding to first line of the Lyman series. What velocity does the atom acquire ?

E 2. From the condition of the foregoing problem, find how much (in %) the energy of the emitted photon differs from the energy of the corresponding transition in a hydrogen atom.

E 3. Find the wavelength of the radiation emitted by hydrogen in the transitions
(a) n = 3 to n = 2, (b) n = 5 to n = 4 and (c) n = 10 to n = 9.

E 4. A hydrogen atom emits ultraviolet radiation of wavelength 102.5 nm. What are the quantum numbers of the states involved in the transition ?

E 5. A hydrogen atom in a state having a binding energy of 0.85 eV makes transition to a state with excitation energy 10.2 eV
(a) identify the quantum numbers n of the upper and the lower energy states involved in the transition.
(b) Find the wavelength of the emitted radiation .

E 6. Calculate the smallest wavelength of radiation that may be emitted by
(a) hydrogen, (b) He^+ and (c) Li^{++}

E 7. Calculate the angular frequency of an electron occupying the second Bohr orbit of He^+ ion.

E 8. Find the quantum number n corresponding to the excited state of He^+ ion if on transition to the ground state that ion emits two photons in succession with wave lengths 108.5 and 30.4 nm.

E 9. What hydrogen like ion has the wavelength difference between the first lines of the Balmer and Lyman series equal to 59.3 nm ?

E 10. In a transition to a state of excitation energy 10.19 eV a hydrogen atom emits a 4890 Aº photon. Determine the binding energy of the initial state. Also find the nature of transition?

E 11. A positive ion hydrogen just one electron ejects it if a photon of wavelength 228 Å or less is absorbed by it. Identify the ion.

E 12. A gas of hydrogen like ions is prepared in a particular excited state A it emits photons having wavelength equal to the wavelength of the first line of the lyman series together with photons of five other wavelength. Identify the gas and find the principal quantum number of the state A.

E 13. Suppose in certain conditions only those transitions are allowed to hydrogen atoms in which the principal quantum number n change by 2 (a) Find the smallest wavelength emitted by hydrogen (b) List the wavelengths emitted by hydrogen in the visible range (380 nm to 780)

E 14. Find the velocity of photoelectrons liberated by electromagnetic radiation of wavelength λ = 18.0 nm from stationary He^+ ions in the ground state.

E 15. To what minimum distance will an alpha particle with kinetic energy T = 0.40 Mev approach in the case of a head on collision to:
(a) A fixed Pb nucleus
(b) Initially stationary but free Li nucleus.

E 16. A hydrogen atom in n = 6 makes two successive transitions & reaches the ground state. In the first transition a photon of 1.13 eV is emitted. Find the energy of the photon emitted in the second transition & value of n for the intermediate state.

E 17. Find the quantum number n corresponding to the excited state of He^+ ion if on transition to the ground state that ion emits two photons in succession with wave lengths 108.5 and 30.4 nm.

E 18. (a) Find the maximum wavelength λ of light which can ionize a H-atom in ground state.
(b) Light of wavelength λ is incident on a H-atom which is in its first excited state. Find the kinetic energy of the electron coming out.

E 19. A doubly ionised Lithium atom is hydrogen - like with atomic number 3 ;
(a) Find the wavelength of radiation required to excite the electron in Li^{++} from the first to the third Bohr orbit. (Ionisation energy of the hydrogen atom equals 13.6 eV).
(b) How many spectral lines are observed in the emission spectrum of the above excited system ?

E 20. A particular hydrogen-like ion emits radiation of frequency 2.467×10^{15} Hz when it makes transition from $n = 2$ to $n = 1$. What will be the frequency of the radiation emitted a transition from $n = 3$ to $n = 1$?

E 21. Monochromatic radiation of wavelength λ is incident on hydrogen sample in ground state. H-atom absorbs a fraction of light & subsequently emit radiation of six different wavelengths. Find the value of λ.

E 22. A filter transmits only the radiation of wavelength greater than 4400Å. Radiation from a hydrogen discharge tube goes through such a filter and is incident on a metal of work function 2.0eV. Find the stopping potential which can stop the photoelectrons.

E 23. Light from Balmer series of hydrogen is able to eject photoelectron from a metal. What can be the maximum work function of the metal?

SECTION (F) : ATOMIC COLLISIONS

F 1. At what minimum kinetic energy must a hydrogen atom move for its inelastic head–on collision with another, stationary, hydrogen atom to make one of them capable of emitting photon? Both atoms are supposed to be in the ground state prior to the collision.

SECTION (G) : X-RAYS

G 1. Iron emits K_α x-ray of energy 6.4 keV and calcium emits k_α X-ray of energy 3.69 keV Calculate the times taken by an iron K_α photon and a calcium K_α photon to cross through a distance of 3 km

G 2. Find the cutoff wavelength for the continuous X-rays coming from an X-ray tube operating at 30 kV.

G 3. If the operating potential in an X -ray tube is increased by 1% by what percentage does the cutoff wavelength decrease?

G 4. The short wavelength limit shifts by 26 pm when the operating voltage is an X-ray tube in increased to 1.5 times the original value .What was the original value of the operating voltage ?

G 5. An X-ray tube operates at 40KV. Suppose the electrons converts 70% of its energy into a photon at each collision. Find the lowest three wavelengths emitted from the tube. Neglect the energy imparted to the atom with which the electron collides.

G 6. The wavelengths of K_α and L_α X-rays of material are 21.3pm and 141 pm respectively Find the wavelength of K_β X-ray of the material.

G 7. Find the wave length of the K_α line in copper (Z = 29), if the wave length of the K_α line in iron (Z = 26) is known to be equal to 193 pm. (Take b = 1)

G 8. The k_p x-ray of argon has a wavelength of 0.36 nm . The minimum energy needed to ionize an argon atom is 16 eV Find the energy needed to knock out an electrons from the K shall of an argon

G 9. Proceeding from Moseley 's law find:
(a) The wave length of the K_α line in aluminium and cobalt.
(b) The difference in binding energies of K and L electrons in vanadium. (z = 23)
(Take b = 1 for k_α x-ray)

EXERCISE-2

(* Mark Questions are MCQ)

SECTION (A) : PHOTON EMISSION FROM A SOURCE AND RADIATION PRESSURE

A 1. Let n_r and n_b be respectively the number of photons emitted by a red bulb and a blue bulb of equal power in a given time.
(A) $n_r = n_b$ (B) $n_r < n_b$ (C) $n_r > n_b$
(D) the information is insufficient to get a relation between n_r and n_b

A 2. The wavelength of a photon is 2.2×10^{-11} m. Given that Planck's constant h = 6.6 x 10-34 J.s, the momentum of the photon will be
(A) 3×10^{-23} kg m/s (B) 2.2×10^{-26} kg m/s (C) 4×10^{-23} kg m/s (D) 6.6×10^{-31} kg m/s

A 3. A photon of light enters a block of glass after travelling through a vacuum. The energy of the photon on entering the glass block
(A) Increases because its associated wavelength decreases
(B) Decreases because the speed of the radiation decreases
(C) Stays the same because the speed of the radiation and the associated wavelength do not change
(D) Stays the same because the frequency of the radiation does not change

A 4. The equation E = pc is valid
(A) for an electron as well as for a photon (B) for an electron but not for a photon
(C) for a photon but not for an electron (D) neither for an electron nor for a photon.

SECTION (B) : PHOTOELECTRIC EFFECTS

B 1. Ligth of wavelength λ falls on a metal having work function hc/λ_0. Photoelectric effect will take place only if
(A) $\lambda \geq \lambda_0$ (B) $\lambda \geq 2\lambda_0$ (C) $\lambda \leq \lambda_0$ (D) $\lambda < \lambda_0/2$.

B 2. A monochromatic light beam of frequency ν falls on a metal surface of work funcation $\phi > h\nu$, then
(A) photoelectrons of equal energies are emitted
(B) photoelectrons of different energies are emitted
(C) photoelectrons are emitted only perpendicular to the metal surface

(D) no photoelectrons are emitted

B 3. When stopping potential is applied in an experiment on photoelectric effect, no photocurrent is observed. This means that
(A) the emission of photoelectrons is stopped
(B) the photoelectrons are emitted but are reabsorbed by the emitter metal
(C) the photoelectrons are accumulated near the collector plate
(D) the photoelectrons are dispersed from the sides of the apparatus.

***B 4.** Photoelectric effect supports quantum nature of light because
(A) there is a minimum frequency below which no photoelectrons are emitted
(B) the maximum kinetic energy of photoelectrons depends only on the frequency of light and not on its intensity
(C) even when the metal surface is faintly illuminated the photoelectrons leave the surface imme diately
(D) electric charge of the photoelectrons is quantized

B 5. If the frequency of light in a photoelectric experiment is double, the stopping potential will
(A) be doubled (B) be halved
(C) become more than double (D) become less than double

B 6. Two separate monochromatic light beams A and B of the same intensity are falling normally on a unit area of a metallic surface. Their wavelength are λ_A and λ_B respectively. Assuming that all the incident light is used in ejecting the photoelectrons, the ratio of the number of photoelectrons from beam A to that from B is

(A) $\left(\frac{\lambda_A}{\lambda_B}\right)$ (B) $\left(\frac{\lambda_B}{\lambda_A}\right)$ (C) $\left(\frac{\lambda_A}{\lambda_B}\right)^2$ (D) $\left(\frac{\lambda_B}{\lambda_A}\right)^2$

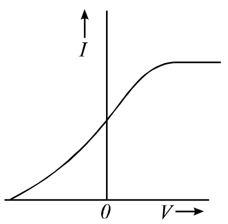
B 7. The photoelectric emission from the surface of a metal starts only when the light incident on the surface has a certain :
(A) minimum frequency (B) minimum wavelength (C) minimum intensity (D) minimum speed

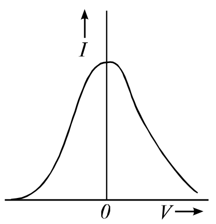
B 8. At frequencies of the incident radiation above the threshold frequency, the photoelectric current in a photoelectric cell increases with increase in :
(A) intensity of incident radiation (B) wavelength of incident radiation
(C) frequency of incident radiation (D) speed of incident radiation

B 9. 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 is :
(A) 2V (B) 4V (C) 6V (D) 10V

B 10. The photoelectrons emitted from a metal surface :
(A) Are all at rest (B) Have the same kinetic energy
(C) Have the same momentum
(D) Have speeds varying from zero up to a certain maximum value

B 11. Which one of the following graphs in figure shows the variation of photoelectric current (I) with voltage (V) between the electrodes in a photoelectric cell ?

(A)


(B)


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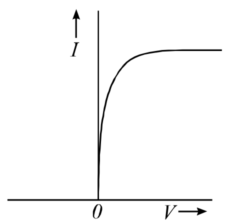

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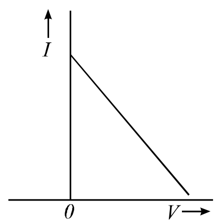


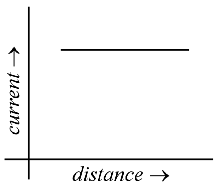
B 12. The work function for aluminium surface is 4.2 eV and that for sodium surface is 2.0 ev. The two metals were illuminated with appropriate radiations so as to cause photo emission. Then :
(A) Both aluminium and sodium will have the same threshold frequency
(B) The threshold frequency of aluminium will be more than that of sodium

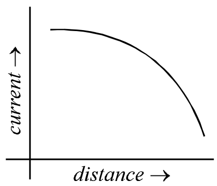
(C) The threshold frequency of aluminium will be less than that of sodium
(D) The threshold wavelength of aluminium will be more than that of sodium

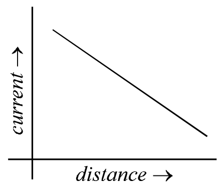
B 13. In a photo-emissive cell, with exciting wavelength λ, the fastest electron has a speed v. If the exciting wavelength is changed to $3\lambda/4$, the speed of the fastest emitted electron will be :
(A) $v\sqrt{\frac{3}{4}}$ (B) $v\sqrt{\frac{4}{3}}$ (C) less than $v\sqrt{\frac{4}{3}}$ (D) more than $v\sqrt{\frac{4}{3}}$

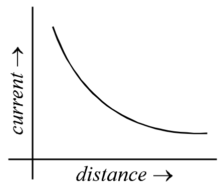
B 14. A point source of light is used in a photoelectric effect. If the source is removed farther from the emitting metal, the stopping potential
(A) will increase (B) will decrease
(C) will remain constant (D) will either increase or decrease

B 15. A point source causes photoelectric effect from a small metal plate. Which of the following curves may represent the saturation photocurrent as a function of the distance between the source and the metal?

(A) 

(B) 

(C) 

(D) 

B 16. A nonmonochromatic light is used in an experiment on photoelectric effect. The stopping potential
(A) is related to the mean wavelength (B) is related to the longest wavelength
(C) is related to the shortest wavelength (D) is not related to the wavelength.

B 17. When a centimetre thick surface is illuminated with light of wavelength λ, the stopping potential is V. When the same surface is illuminated by light of wavelength 2λ, the stopping potential is $V/3$. The threshold wavelength for the surface is :
(A) $\frac{4\lambda}{3}$ (B) 4λ (C) 6λ (D) $\frac{8\lambda}{3}$

B 18. The collector plate in an experiment on photoelectric effect is kept vertically above the emitter plate. Light source is put on and a saturation photocurrent is recorded. An electric field is switched on which has vertically downward direction
(A) The photocurrent will increase (B) The kinetic energy of the electrons will increase
(C) The stopping potential will decrease (D) The threshold wavelength will increase

SECTION (C) : DE-BROGLIE WAVES

C 1. The energy that should be added to an electron, to reduce its debroglie wavelength from 2×10^{-9} m to 0.5×10^{-9} m will be:
(A) 1.1 MeV (B) 0.56 MeV (C) 0.56 KeV (D) 5.67 eV

C 2. An enclosure filled with helium is heated to a temperature of 400 K. A beam of helium atom emerges out of the enclosure. The mean debroglie wavelength of this beam is
(A) 0.44 Å (B) 0.63 Å (C) 0.77 Å (D) none of these

C 3. The energy of a photon of frequency ν is $E = h\nu$ and the momentum of a photon of wavelength λ is $p = h/\lambda$. From this statement one may conclude that the wave velocity of light is equal to :
(A) 3×10^{8} ms^{-1} (B) $\frac{E}{p}$ (C) Ep (D) $\left(\frac{E}{p}\right)^2$

C 4. The wavelength λ of de Broglie waves associated with an electron (mass m, charge e) accelerated through a potential difference of V is given by (h is Planck's constant) :
(A) $\lambda = h/mV$ (B) $\lambda = h/2\,meV$ (C) $\lambda = h/\sqrt{meV}$ (D) $\lambda = h/\sqrt{2meV}$

C 5. If a hydrogen atom at rest, emits a photon of wavelength λ, the recoil speed of the atom of mass m is given by:
(A) $\frac{h}{m\lambda}$ (B) $\frac{mh}{\lambda}$ (C) $mh\lambda$ (D) none of these

C 6. The de Broglie wavelength of an electron moving with a velocity 1.5×10^8 ms^{-1} is equal to that of a photon. The ratio of the kinetic energy of the electron to that of the energy of photon is :
(A) 2 (B) 4 (C) $\frac{1}{2}$ (D) $\frac{1}{4}$

C 7. 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 :
(A) $\frac{m_1}{m_2}$ (B) $\frac{m_2}{m_1}$ (C) 1.0 (D) $\sqrt{\frac{m_2}{m_1}}$

C 8. A proton and an electron move with the same velocity. The associated wavelength for proton is :
(A) shorter than that of the electron (B) longer than that of the electron
(C) the same as that of the electron (D) zero

C 9. Two particles of masses m and $2m$ have equal kinetic energies. Their de Broglie wavelengths are in the ratio of:
(A) 1 : 1 (B) 1 : 2 (C) 1 : $\sqrt{2}$ (D) $\sqrt{2}$: 1

C 10. Let p and E denote the linear momentum and energy of a photon. If the wavelength is decreased,
(A) both p and E increase (B) p increases and E decreases
(C) p decreases and E increases (D) both p and E decreases

C 11. The wavelength of de Broglie wave associated with a thermal neutron of mass m at absolute temperature T is given by (here k is the Boltzmann constant) :
(A) $\frac{h}{\sqrt{mkT}}$ (B) $\frac{h}{\sqrt{2mkT}}$ (C) $\frac{h}{\sqrt{3mkT}}$ (D) $\frac{h}{2\sqrt{mkT}}$

C 12. The de Broglie wavelength of a neutron at 927ºC is λ. What will be its wavelength at 27ºC ?
(A) $\frac{\lambda}{2}$ (B) λ (C) 2λ (D) 4λ

C 13. The de Broglie wavelength of a neutron when its kinetic energy is K is λ. What will be its wavelength when its kinetic energy is 4 K ?
(A) $\frac{\lambda}{4}$ (B) $\frac{\lambda}{2}$ (C) 2λ (D) 4λ

C 14. Moving with the same velocity, which of the following has the longest de Broglie wavelength ?
(A) β-particle (B) α-particle (C) proton (D) neutron

C 15. A proton and an electron are accelerated by the same potential difference. Let λ_0 and λ_p denote the de Broglie wavelengths of the electron and the proton respectively.
(A) $\lambda_e = \lambda_p$ (B) $\lambda_e < \lambda_p$ (C) $\lambda_e > \lambda_p$
(D) The relation between λ_e and λ_p depends on the accelerating potential difference.

SECTION (D) : BOHR'S ATOMIC MODEL OF H-ATOM & H-LIKE SPECIES (PROPERTIES)

D 1. The energy of an atom (or ion) in its ground state is - 54.4eV. It may be
(A) hydrogen (B) deuterium (C) He (D) Li

D 2. If a_0 is the Bohr radius, the radius of the n = 2 electronic orbit in triply ionized beryllium is
(A) $4a_0$ (B) a_0 (C) $a_0/4$ (D) $a_0/16$

D 3. The binding energy of He^+ is
(A) 6.8 eV (B) 13.6 eV (C) 27.2 eV (D) 54.4 eV

D 4. The redius of first orbit of hydrogen atom is 0.053 nm. The radius of its third orbit will be
(A) 0.106 nm (B) 0.159 nm (C) 0.212 nm (D) 0.477 nm

D 5. Binding energy of hydrogen atom is 13.6 eV. The B.E. of a singly ionised helium atom is
(A) 13.6 eV (B) 27.2 eV (C) 54.4 eV (D) 3.4 eV

***D 6.** When Z is doubled in an atom, which of the following statements are consistent with Bohr's theory?

(A) Energy of a state is double
(B) Radius of an orbit is doubled.
(C) Velocity of electrons in an orbit is doubled.
(D) Radius of an orbit is halved.

***D 7.** Let A_n be the area enclosed by the nth orbit in a hydrogen atom. The graph of ln (A_n / A_1) against ln(n)
(A) will pass through the origin
(B) will be a straight line with slope 4
(C) will be a monotonically increasing nonlinear curve
(D) will be a circle

D 8. Ionization energy of a hydrogen-like ion A is greater than that of another hydrogen-like ion B. Let r, u, E and L represent the radius of the orbit, speed of the electron, energy of the atom and orbital angular momentum of the electron respectively. In ground state
(A) $r_A > r_B$ (B) $u_A > u_B$ (C) $E_A > E_B$ (D) $L_A > L_B$

D 9. According to Bohr's theory of the hydrogen atom, the total energy of the hydrogen atom with its electron revolving in the *n*th stationary orbit is :
(A) proportional to n
(B) proportional to n^2
(C) inversely proportional to n
(D) inversely proportional to n^2

D 10. The innermost orbit of the hydrogen atom has a diameter of 1.06 Å. What is the diameter of the tenth orbit ?
(A) 5.3 Å (B) 10.6 Å (C) 53 Å (D) 106 Å

D 11. According to Bohr's theory of the hydrogen atom, the radii r_n of stationary electron orbits are related to the principal quantum number n as :
(A) $r_n \propto 1/n^2$ (B) $r_n \propto 1/n$ (C) $r_n \propto n$ (D) $r_n \propto n^2$

D 12. According to Bohr's theory of the hydrogen atom, the speed v_n of the electron in a stationary orbit is related to the principal quantum number n as (C is a constant) :
(A) $v_n = C/n^2$ (B) $v_n = C/n$ (C) $v_n = C \times n$ (D) $v_n = C \times n^2$

D 13. The orbital speed of the electron in the ground state of hydrogen is v. What will be its orbital speed when it is excited to the energy state – 3.4 eV ?
(A) $2v$ (B) $\frac{v}{2}$ (C) $\frac{v}{4}$ (D) $\frac{v}{8}$

D 14. Which energy state of doubly ionized lithium (Li^{++}) has the same energy as that of the ground state of hydrogen ? Given Z for lithium = 3 :
(A) $n = 1$ (B) $n = 2$ (C) $n = 3$ (D) $n = 4$

D 15. In Q. 14, what is the ratio of the electron orbital radius of Li^{++} to that of hydrogen ?
(A) 1 (B) 2 (C) 3 (D) 4

D 16. In the Bohr model of the hydrogen atom, the ratio of the kinetic energy to the total energy of the electron in a quantum state n is :
(A) – 1 (B) + 1 (C) $\frac{1}{n}$ (D) $\frac{1}{n^2}$

D 17. The total energy of the electron in the first excited state of hydrogen is – 3.4 eV. What is the kinetic energy of the electron in this state ?
(A) + 1.7 eV (B) + 3.4 eV (C) + 6.8 eV (D) – 13.4 eV

D 18. In Q. 17, the potential energy of the electron is :
(A) – 1.7 eV (B) – 3.4 eV (C) – 6.8 eV (D) – 13.4 eV

D 19. According to Bohr's theory, the energy of an electron in the *n*th orbit of an atom of atomic number Z is proportional to :
(A) $\frac{Z^2}{n^2}$ (B) $\frac{Z^2}{n}$ (C) $\frac{Z}{n}$ (D) $Z^2 n^2$

D 20. According to Bohr's theory, the radius of the *n*th orbit of an atom of atomic number Z is proportional to :
(A) $\frac{n^2}{Z^2}$ (B) $\frac{n^2}{Z}$ (C) $\frac{n}{Z}$ (D) $n^2 Z^2$

D 21. In Bohr's model of hydrogen atom, the centripetal force is provided by the Coulomb attraction between the proton and the electron. If α_0 is the radius of the ground state orbit, *m* is the mass and *e* the charge of an electron and ε_0 is the vacuum permittivity, the speed of the electron is :

(A) zero (B) $\frac{e}{\sqrt{\varepsilon_0 a_0 m}}$ (C) $\frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$ (D) $\frac{\sqrt{4\pi\varepsilon_0 a_0 m}}{e}$

D 22. If an orbital electron of the hydrogen atom jumps from the ground state to a higher energy state, its orbital speed reduces to half its initial value. If the radius of the electron orbit in the ground state is *r*, then the radius of the new orbit would be :

(A) 2*r* (B) 4*r* (C) 8*r* (D) 16*r*

D 23. The energy difference between the first two levels of hydrogen atom is 10.2 eV. What is the corresponding energy difference for a singly ionized helium atom ?

(A) 10.2 eV (B) 20.4 eV (C) 40.8 eV (D) 81.6 eV

SECTION (E) : ELECTRONIC TRANSITION IN THE H/H-LIKE ATOM/SPECIES OF EFFECT OF MOTION OF NUCLEUS

E 1. In which of the following systems will the wavelength corresponding to n=2 to n=1 be minimum ?

(A) hydrogen atom (B) deuterium atom
(C) singly ionized helium (D) doubly ionized lithium

E 2. The highest energy state, that unexcited hydrogen atoms can reach when they are bombareded with 12.2 eV electron, is

(A) n = 1 (B) n = 2 (C) n = 3 (D) n = 4

E 3. Three photons coming from excited atomic-hydrogen sample are picked up. Their energies are 12.1eV, 10.2eV and 1.9eV. These photons must come from

(A) a single atom (B) two atoms
(C) three atom (D) either two atoms or three atoms

E 4. Suppose, the electron in a hydrogen atom makes transition from n = 3 to n = 2 in 10^{-8} s. The order of the torque acting on the electron in this period, using the relation between troque and angular momentum as discussed in the chapter on rotational mechanics is

(A) 10^{-34} N-m (B) 10^{-24} N-m (C) 10^{-42} N-m (D) 10^{-8} N-m

E 5. In a hypothetical atom, if transition from n = 4 to n = 3 produces visible light then the possible transition to obtain infrared radiation is:

(A) n = 5 to n = 3 (B) n = 4 to n = 2 (C) n = 3 to n = 1 (D) none of these

E 6. Which of the following series in the spectrum of the hydrogen atom lies in the visible region of the electromagnetic spectrum ?

(A) Paschen series (B) Balmar series (C) Lyman series (D) Brackett series

E 7. The different lines in the Lyman series have their wavelengths laying between :

(A) zero to infinite (B) 900 Å to 1200 Å (C) 1000 Å to 1500 Å (D) 500 Å to 1000 Å

E 8. The ratio of the wavelengths of the longest wavelength lines in the Lyman and Balmer series of hydrogen spectrum is :

(A) $\frac{3}{23}$ (B) $\frac{5}{27}$ (C) $\frac{7}{29}$ (D) $\frac{9}{31}$

E 9. The ionization energy of hydrogen atom is 13.6 eV. Hydrogen atoms in the ground state are excited by electromagnetic radiation of energy 12.1 eV. How many spectral lines will be emitted by the hydrogen atom?

(A) one (B) two (C) three (D) four

E 10. Energy levels *A*, *B* and *C* of a certain atom correspond to increasing values of energy, i.e. $E_A < E_B < E_C$. If λ_1, λ_2 and λ_3 are the wavelengths of radiations corresponding to transitions *C* to *B*, *B* to *A* and *C* to *A* respectively, which of the following relations is correct ?

(A) $\lambda_3 = \lambda_1 + \lambda_2$ (B) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$ (C) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (D) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

E 11. The wavelength of the first line in balmer series in the hydrogen spectrum is λ. What is the wavelength of the second line :

(A) $\frac{20\lambda}{27}$ (B) $\frac{3\lambda}{16}$ (C) $\frac{5\lambda}{36}$ (D) $\frac{3\lambda}{4}$

E 12. The frequency of the first line in Lyman series in the hydrogen spectrum is ν. What is the frequency of the corresponding line in the spectrum of doubly ionized Lithium ?
(A) ν (B) 3ν (C) 9ν (D) 27ν

SECTION (F) : ATOMIC COLLISIONS

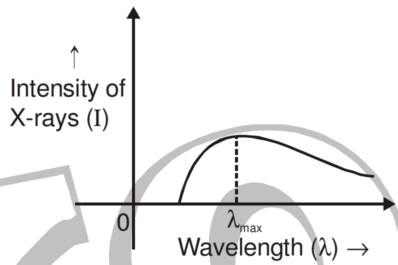
F 1. An electron with kinetic energy 5 eV is incident on a hydrogen atom in its ground state. The collision
(A) must be elastic (B) may be partially elastic
(C) must be completely inelastic (D) may be completely inelastic

F 2. An α particle with a kinetic energy of 2.1 eV makes a head on collision with a hydrogen atom moving towards it with a kinetic energy of 8.4 eV. The collision.
(A) must be perfectly elastic (B) may be perfectly inelastic
(C) may be inelastic (D) must be perfectly inelastic

SECTION (G) : X-RAYS

G 1. Consider a photon of continuous X-ray coming from a Coolidge tube. Its energy comes from
(A) the kinetic energy of the strilking electron
(B) the kinetic energy of the free electrons of the target
(C) the kinetic energy of the ions of the target
(D) an atomic transition in the target

G 2. If λ_{max} is the wavelength at which intensity of X-ray radiation is maximum as shown in figure. As the operating tube voltage is increased, λ_{max} :
(A) Increases
(B) Decreases
(C) Remains unchanged
(D) can't be predicated



G 3. The energy of a photon of characteristic X-ray from a Coolidge tube comes from
(A) the kinetic energy of the strilking electron
(B) the kinetic energy of the free electron of the target
(C) the kinetic energy of the ions of the target
(D) an atomic transition in the target

G 4. If the potential difference applied to the tube is doubled and the separation between the filament and the target is also doubled, the cutoff wavelength
(A) will remain unchanged (B) will be doubled
(C) will be halved (D) will become four times the original

G 5. If the current in the circuit for heating the filament is increased, the cutoff wavelength
(A) will increase (B) will decrease (C) will remain unchanged (D) will change

G 6. 50% of the X-rays coming from a Coolidge tube is able to pass through a 0.1 mm thick aluminum foil. The potential difference between the target and the filament is increased. The thickness of aluminimum foil, which will allow 50% of the X-ray to pass through, will be
(A) zero (B) < 0.1 mm (C) 0.1 mm (D) 0.1 mm

***G 7.** For a given material, the energy and wavelength of characteristic X-ray satisfy
(A) $E(K_\alpha) > E(K_\beta) > E(K_\gamma)$ (B) $E(M_\alpha) > E(L_\alpha) > E(K_\alpha)$
(C) $\lambda(K_\alpha) > \lambda(K_\beta) > \lambda(K_\gamma)$ (D) $\lambda(M_\alpha) > \lambda(L_\alpha) > \lambda(K_\alpha)$

***G 8.** The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation,
(A) the intensity increases (B) the minimum wavelength increases
(C) the intensity remains unchanged (D) the minimum wavelength decreases

***G 9.** X-ray incident on a material
(A) exerts a force on it (B) transfers energy to it
(C) transfers momentum to it (D) transfers impulse to it

G 10. The characteristic X-ray spectrum is emitted due to excitation of
(A) valence electrons of the atom
(B) inner electrons of the atom
(C) nucleus of the atom
(D) both, the inner electrons and the nucleus of the atom

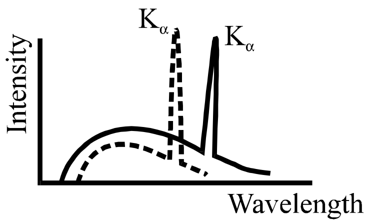
G 11. Moseley's law of characteristic X-rays is $\sqrt{\nu} = a(Z-b)$. in this,
(A) both a and b are independent of the material
(B) a is independent but b depends on the material
(C) b is independent but a depends on the material
(D) both a and b depend on the material

G 12. When ultraviolet light is incident on a photocell, its stopping potential is V_0 and the maximum kinetic energy of the photoelectrons is K_{max}. When X-rays are incident on the same cell, then :
(A) V_0 and K_{max} both increase
(B) V_0 and K_{max} both decrease
(C) V_0 increases but K_{max} remains the same
(D) K_{max} increases but V_0 remains the same

EXERCISE-3

(* Mark Questions are MCQ)

1. Figure shows the intensity-wavelength relations of X-rays coming from two different Coolidge tubes. The solid curve represents the relation for the tube A in which the potential difference between the target and the filament is V_A and the atomic number of the target material is Z_A. These quantities are V_B and Z_B for the other tube. Then,



(A) $V_A > V_B$, $Z_A > Z_B$
(B) $V_A > V_B$, $Z_A < Z_B$
(C) $V_A < V_B$, $Z_A > Z_B$
(D) $V_A < V_B$, $Z_A < Z_B$

2. The relation between λ_1: wavelength of series limit of Lyman series, λ_2: the wavelength of the series limit of Balmer series & λ_3: the wavelength of first line of Lyman series is :
(A) $\lambda_1 = \lambda_2 + \lambda_3$
(B) $\lambda_3 = \lambda_1 + \lambda_2$
(C) $\lambda_2 = \lambda_3 - \lambda_1$
(D) none of these

3. If λ_{min} is minimum wavelength produced in X-ray tube and $\lambda_{k\alpha}$ is the wavelength of k_α line. As the operating tube voltage is increased.
(A) $(\lambda_k - \lambda_{min})$ increases
(B) $(\lambda_k - \lambda_{min})$ decreases
(C) $\lambda_{k\alpha}$ increases
(D) λ_{ka} decreases

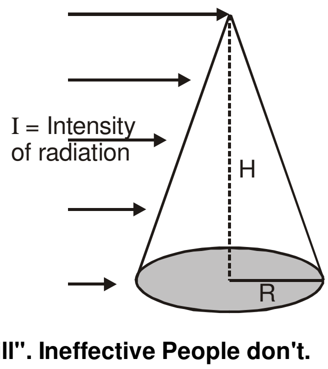
4. If the frquency of K_α X-ray emitted from the element with atomic number 31 is f, then the frequency of K_α X-ray emitted from the element with atomic number 51 would be
(A) $\frac{5f}{3}$
(B) $\frac{51f}{31}$
(C) $\frac{9f}{25}$
(D) $\frac{25f}{9}$

5. According to Moseley's law the ratio of the slopes of graph between $\sqrt{\nu}$ and Z for K_β and K_α is :
(A) $\sqrt{\frac{32}{27}}$
(B) $\sqrt{\frac{27}{32}}$
(C) $\sqrt{\frac{33}{22}}$
(D) $\sqrt{\frac{22}{33}}$

6. If the frequency of K_α X-ray emitted from element with atomic number 31 is f, then the frequency of K_α X-ray emitted from the element with atomic number 51 would be (assume that screening constant for K_α is 1) :
(A) $\frac{5}{3}$ f
(B) $\frac{51}{31}$ f
(C) $\frac{9}{25}$ f
(D) $\frac{25}{9}$ f

***7.** When a hydrogen atom is excited from ground state to first excited state then
(A) its kinetic energy increases by 10.2 eV.
(B) its kinetic energy decreases by 10 .2 eV.
(C) its potential energy increases by 20.4 eV.
(D) its angular momentum increases by 1.05×10^{-34} J-s.

8. The radiation force experinced by body exposed to radiation of intensity I, assuming surface of body to be perfectly absorbing is :



(A) $\frac{\pi R^2 I}{c}$
(B) $\frac{\pi RHI}{c}$
(C) $\frac{IRH}{2c}$
(D) $\frac{IRH}{c}$

9. In a photoelectric experiment, with light of wavelength λ, the fastest electron has speed v. If the exciting wavelength is changed to $\frac{3\lambda}{4}$, the speed of the fastest emitted electron will become

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

10. In a discharge tube when 200 volt potential difference is applied 6.25×10^{18} electrons move from cathode to anode and 3.125×10^{18} singly charged positive ions move from anode to cathode in one second. Then the power of tube is:

(A) 100 watt (B) 200 watt (C) 300 watt (D) 400 watt

11. Radiation pressure on any surface :

(A) is dependent on wavelength of the light used
(B) is dependent on nature of surface and intensity of light used
(C) is dependent on frequency and nature of surface
(D) depends on the nature of source from which light is coming and on nature of surface on which it is falling.

***12.** Two electrons starting from rest are accelerated by equal potential difference.

(A) they will have same kinetic energy
(B) they will have same linear momentum
(C) they will have same de Broglie wave length
(D) they will produce x-rays of same minimum wave length when theystrike different targets.

***13.** In an x–ray tube the voltage applied is 20KV. The energy required to remove an electron from L shell is 19.9 KeV. In the x–rays emitted by the tube

(A) minimum wavelength will be 62.1 pm
(B) energy of the characterstic x–rays will be equal to or less than 19.9 KeV
(C) L_α x–ray may be emitted
(D) L_α x–ray will have energy 19.9 KeV

14. The wavelengths of K_α x-rays of two metals 'A' and 'B' are $\frac{4}{1875\,R}$ and $\frac{1}{675\,R}$ respectively, where 'R' is rydberg constant. The number of elements lying between 'A' and 'B' according to their atomic numbers is

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

15. An atom consists of three energy levels given by a ground state with energy $E_0 = 0$, the first excited state with energy $E_1 = K$ and the second excited state with energy $E_2 = 2K$ where $K > 0$. The atom is initially in the ground state. Light from a laser which emits photons with energy 1.5K is shined on the atom. Which of the following is/are correct ?

(A) The photons are absorbed, putting one atom in a state E_1 and one atom in a state E_2.
(B) A photon will always be absorbed, but half the time the atom will go into the state with energy K and the other half into the state with energy 2K. In this way, energy will be conserved on the average.
(C) The atom absorbs a phton, goes into the first excited state with energy K and emits a photon with energy 0.5 K to conserve energy.
(D) The atom does not absorb any photon and stays in the ground state.

16. The work function of a certain metal is $\frac{hC}{\lambda_0}$. When a monochromatic light of wavelength $\lambda < \lambda_0$ is incident such that the plate gains a total power P. If the efficiency of photoelectric emission is η% and all the emitted photoelectrons are captured by a hollow conducting sphere of radius R already charged to potential V, then neglecting any interaction between plate and the sphere, expression of potential of the sphere at time t is :

(A) $V + \frac{100\eta\lambda Pet}{4\pi\varepsilon_0 RhC}$ (B) $V + \frac{\eta\lambda Pet}{4\pi\varepsilon_0 RhC}$ (C) V (D) $\frac{\lambda Pet}{4\pi\varepsilon_0 RhC}$

17. According to wave theory of radiation, energy is continuously emitted and energy is propagated in the form of waves. Which of the following is not correct according to wave theory ?

(A) Every radiation irrespective of wavelength will cause photoelectric effect
(B) Maximum kinetic energy of photoelectrons depends on the intensity of radiation

(C) Wave theory predicts appreciable time lag with less intense radiation
(D) Maximum kinetic energy of photo electrons depends on wavelength or frequency of radiation

18. An image of the sun is formed by a lens of focal length 30 cm on the metal surface of a photo-electric cell and it produces a current I. The lens forming the image is then replaced by another lens of the same diameter but of focal length 15 cm. The photoelectric current in this case will be :
(A) I/2 (B) 2 I (C) I (D) 4 I

19. The frequency and the intensity of a beam of light falling on the surface of photoelectric material are increased by a factor of two. This will
(A) increase the maximum kinetic energy of the photoelectrons, as well as photoelectric current by a factor of two
(B) increase the maximum kinetic energy of the photo electrons and would increase the photo electric current by a factor of two
(C) increase the maximum kinetic energy of the photo electrons by a factor of two and will have no effect on the magnitude of the photo electrons by a factor of two and will have no effect on the magnitude of the photoelectric current produced
(D) not produce any effect on the kinetic energy of the emitted electrons but will increase the photo electric current by a factor of two.

20. When a monochromatic source of light is at a distance of 0.2 m from a photoelectric cell, the cut-off voltage and the saturation current are respectively 0.6 V and 18 mA. If the same source is placed 0.6 m away from the cell, then :
(A) the stopping potential will be 0.2 V (B) the stopping potential will be 1.8 V
(C) the saturation current will be 6.0 mA (D) the saturation current will be 2.0 mA

21. The electron in a hydrogen atom makes a transition from an excited state to the ground state. Which of the following statements is true ?
(A) Its kinetic energy increases and its potential and total energies decreases
(B) Its kinetic energy decreases, potential energy increases and its total energy remains the same
(C) Its kinetic and total energies decrease and its potential energy increases
(D) Its kinetic, potential and total energies decrease

22. Which one of the following statements is NOT true for de Broglie waves ?
(A) All atomic particles in motion have waves of a definite wavelength associated with them
(B) The higher the momentum, the longer is the wavelength
(C) The faster the particle, the shorter is the wavelength
(D) For the same velocity, a heavier particle has a shorter wavelength

23. Electrons with energy 80 keV are incident on the tungsten target of an X-ray tube. *K* shell electrons of tungsten have – 71.5 keV energy. X-rays emitted by the tube contain :
(A) A continuous x-ray spectrum (Bremsstrahlung) with a minimum wavelength of about 0.155 Å
(B) A continuous X-ray spectrum (Bremsstrahlung) with all wavelengths
(C) The characteristic X-ray spectrum of tungsten
(D) A continuous X-ray spectrum (Bremsstrahlung) with a minimum wavelength of about 0.155 Å and the characteristics X-ray spectrum of tungsten

24. X-rays from a given X-ray tube operating under specified conditions have a sharply defined minimum wavelength. The value of this minimum wavelength could be reduced by
(A) increasing the temperature of the filament.
(B) increasing the p.d. between the cathode and the target.
(C) reducing the pressure in the tube.
(D) using a target material of higher relative atomic mass.

25. Two photons having
(A) equal wavelengths have equal linear momenta (B) equal energies have equal linear momenta
(C) equal frequencies have equal linear momenta (D) equal linear momenta have equal wavelengths.

26. A proton, when accelerated through a potential difference of V volts, has a wavelength λ associated with it. If an alpha particle is to have the same wavelength λ, it must be accelerated through a potential difference of :
(A) $V/8$ volts (B) $V/4$ volts (C) $4V$ volts (D) $8V$ volts

27. Which one of the following statements is NOT true about photoelectric emission ?
(A) For a given emitter illuminated by light of a given frequency, the number of photo-electrons emitted per second is proportional to the intensity of incident light.
(B) For every emitter there is a definite threshold frequency below which no photoelectrons are emitted, no matter what the intensity of light is
(C) Above the threshold frequency, the maximum kinetic energy of photoelectrons is proportional to the frequency of incident light
(D) The saturation value of the photoelectric current is independent of the intensity of incident light

28. When monochromatic light falls on a photosensitive material, the number of photoelectrons emitted per second is n and their maximum kinetic energy is K_{max}. If the intensity of the incident light is doubled keeping the frequency same, then :
(A) both n and K_{max} are doubled (B) both n and K_{max} are halved
(C) n is doubled but K_{max} remains the same (D) K_{max} is doubled but n remains the same

29. An X-ray photon of wavelength λ and frequency ν collides with an initialy stationary electron (but free to move) and bounces off. If λ' and ν' are respectively the wavelength and frequency of the scattered photon, then :
(A) $\lambda' = \lambda; \nu' = \nu$ (B) $\lambda' < \lambda; \nu' > \nu$ (C) $\lambda' > \lambda; \nu' > \nu$ (D) $\lambda' > \lambda; \nu' < \nu$

30. The frequency and intensity of a light source are both doubled. Consider the following statements.
(i) The saturation photocurrent remains almost the same.
(ii) The maximum kinetic energy of the photoelectrons is doubled.
(A) Both (i) and (ii) are true (B) (i) is true but (ii) is false
(C) (i) is false but (ii) is true (D) both (i) and (ii) are false

31. In Millikan's oil drop experiment, a charged oil drop of mass 3.2×10^{-14} kg is held stationary between two parallel plates 6 mm apart by applying a potential difference of 1200 V between them. How many excess electrons does the oil drop carry ? Take $g = 10$ ms^{-2} :
(A) 7 (B) 8 (C) 9 (D) 10

32. In Millikan's oil drop experiment, an oil drop carrying a charge q falls with a terminal velocity v_0 when there is no electric field between the plates. An electric field E is applied to keep it stationary. What additional charge should the oil drop acquire so that it begins to move upwards with a velocity $2v_0$ in the same electric field ?
(A) q (B) $2\,q$ (C) $3\,q$ (D) $4\,q$

33. A caesium photo cell, with a steady potential difference of 60 volt across it, is illuminated by a small bright light placed 50 cm away. When the same light is placed one meter away the electrons crossing the photo cell :
(A) each carry one quarter of their previous energy (B) each carry one quarter of their previous momentum
(C) are half as numerous (D) are one quarter as numerous

34. For the structural analysis of crystals, X-rays are used because :
(A) X-rays have wavelength of the order of the inter-atomic 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

35. The photocurrent is an experiment on photoelectric effect increases if
(A) the intensity of the source is increased (B) the exposure time is increased
(C) the intensity of the source is decreased (D) the exposure time is decreased.

36. An X-ray tube is operated at 66 kV. Then, in the continuous spectrum of the emitted X-rays :
(A) wavelengths 0.01 nm and 0.02 nm will both be present
(B) wavelengths 0.01 nm and 0.02 nm will both be absent
(C) wavelengths 0.01 nm will be present but wavelength 0.02 nm will be absent
(D) wavelength 0.01 nm will be absent but wavelength 0.02 nm will be present

37. A photon of energy 10.2 eV corresponds to light of wavelength λ_0. Due to an electron transition from n = 2 to n = 1 in a hydrogen atom, light of wavelength λ is emitted. If we take into account the recoil of the atom when the photon is emitted,
(A) $\lambda = \lambda_0$ (B) $\lambda < \lambda_0$

(C) $\lambda > \lambda_0$ (D) the data is not sufficient to reach a conclusion

38. Let ν_1 be the frequency of the series limited of the Lyman series, ν_2 be the frequency of the first line of the Lyman series, and ν_3 be the frequency of the series limited of the Balmer series.

(A) $\nu_1 - \nu_2 = \nu_3$ (B) $\nu_2 - \nu_1 = \nu_3$ (C) $\nu_3 = \frac{1}{2}(\nu_1 + \nu_3)$ (D) $\nu_1 + \nu_2 = \nu_3$

EXERCISE-4

1. Write down the matter corresponding to each blank:
When the number of electrons striking the anode of an X- ray tube is increased the _______ of the emitted X- rays increases, while when the speeds of the electrons striking the anode are increased the cut off wavelength of the emitted X - rays ______. **[JEE '86, 2]**

2. The wavelength of the characteristic X - ray K_α line emitted by a hydrogen like element is 0.32 A°. The wavelength of the K_β line emitted by the element will be ________. **[JEE'90,2]**

3. In an x-ray tube, electrons accelerated through a potential difference of 15000 V strike a copper target. The speed of the emitted x-rays inside the tube is ______ m/s. **[JEE '92, 1]**

4. In the Bohr model of the hydrogen atom, the ratio of the kinetic energy to the total energy of the electron in a quantum state n is _________. **[JEE '92, 1]**

5. Select the correct alternative(s): **[JEE'92, 2 + 2]**
When a monochromatic point source of light is at a distance of 0.2 m from a photo electric cell, the cut off voltage & the saturation current are respectively 0.6 volt and 18.0 mA. If the same source is placed 0.6 m away from the photo electric cell, then

(A) the stopping potential will be 0.2 volt (B) the stopping potential will be 0.6 volt
(C) the saturation current will be 6.0 mA (D) the saturation current will be 2.0 mA

6. The radius of the Bohr 's first orbit is a_o. The electron in the n^{th} Bohr orbit has a radius ______ & angular momentum ______. **[REE'93,1]**

7. State TRUE or FALSE: **[REE'94,1]**
If the frequency of light incident on a metallic plate be doubled, the kinetic energy of the emitted electrons is also doubled.

8. Select the correct alternative(s):
When photons of energy 4.25 eV strike the surface of a metal A, the ejected photo electrons have maximum kinetic energy T_A eV and de Broglie wave length λ_A. The maximum kinetic energy of photo electrons liberated from another metalB by photons of energy 4.70 eV is $T_B = (T_A - 1.50)$ eV. If the de-Brogleie wave length of these photo electrons is $\lambda_B = 2\lambda_A$, then:

(A) the work function of A is 2.225 eV (B) the work function of B is 4.20 eV
(C) $T_A = 2.00$ eV (D) $T_B = 2.75$ eV **[JEE '94, 2]**

9. A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energies 10.20 eV & 17.00 eV respectively. Alternatively, the atom from the same excited state can make a transition to the second excited state by sucessively emitting two photons of energies 4.25 eV & 5.95 eV respectively. Determine the values of n & Z. (Ionization energy of hydrogen atom = 13.6 eV) **[JEE'94, 6]**

10. The wavelength of the first line of Lyman series for hydrogen is identical to that of the second line of Balmer series for some hydrogen like ion X. Calculate energies of the first four levels of X. Also find its ionization potential. [Given: Ground state binding energy of hydrogen atom is 13.6 eV]. **[REE'94, 4]**

11. In a photo electric effect set – up, a point source of light of power 3.2×10^{-3} W emits mono energetic photons of energy 5.0 eV. The source is located at a distance of 0.8 m from the centre of a stationary metallic sphere of work function 3.0 eV & of radius 8.0×10^{-3}m. The efficiency of photo electrons emission is one for every 10^6 incident photons. Assume that the sphere is isolated and initially neutral, and that photo electrons are instantly swept away after emission.

(a) Calculate the number of photo electrons emitted per second.

(b) Find the ratio of the wavelength of incident light to the De – Broglie wave length of the fastest photo electrons emitted.

(c) It is observed that the photo electron emission stops at a certain time t after the light source is switched on. Why?

(d) Evaluate the time t. **[JEE'95,10]**

12. Which of the following statements concerning the depletion zone of an unbiased p – n junction is (are) true ? **[JEE'95,1]**

(A) The width of the zone is independent of the densities of the dopants (impurities).

(B) The width of the zone is dependent on the densities of the dopants.

(C) The electric field in the zone is provided by the electrons in the conduction band and the holes in the valence band.

(D) The electric field in the zone is produced by the ionized dopants atoms.

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

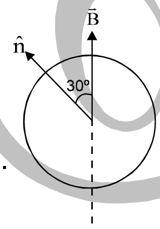
(A) 38.2 (B) 49.2 (C) 51.8 (D) 79.0 **[JEE'95,1]**

14. An electron, in a hydrogen like atom, is in an excited state. It has a total energy of – 3.4 eV. Calculate:

(i) The kinetic energy &

(ii) The De – Broglie wave length of the electron. **[JEE 96, 3]**

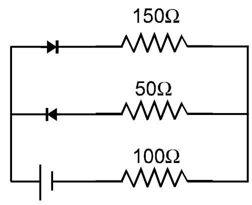
15. An electron in the ground state of hydrogen atoms is revolving in anti clock wise direction in a circular orbit of radius R.



(i) Obtain an expression for the orbital magnetic dipole moment of the electron.

(ii) The atom is placed in a uniform magnetic induction, such that the plane normal to the electron orbit make an angle of 30º with the magnetic induction. Find the torque experienced by the orbiting electron. **[JEE 96, 5]**

16. The circuit shown in the figure contains two diodes each with a forward resistance of 50 Ohms and with infinite backward resistance. If the battery voltage is 6V, the current through the 100 ohm resistance (in Amperes) is: **[Not for JEE]**



(A) Zero (B) 0.02

(C) 0.03 (D) 0.036 **[JEE '97, 1]**

17. Assume that the de Broglie wave associated with an electron can form a standing wave between the atoms arranged in a one dimensional array with nodes at each of the atomic sites. It is found that one such standing wave is formed if the distance 'd' between the atoms of the array is 2 Å. A similar standing wave is again formed if 'd' is increased to 2.5 Å but not for any intermediate value of d. Find the energy of the electrons in electron volts and the least value of d for which the standing wave of the type described above can form. **[JEE '97, 5]**

18. A gas of hydrogen–like ions is prepared in such a way that the ions are only in the ground state & the first excited state. A monochromatic light of wavelength 1216 Å is absorbed by the ions. The ions are lifted to higher excited state and emit radiation of six wavelengths, some higher & some lower than the incident wavelength. Find the principle quantum number of all the excited states. Identify the nuclear charge on the ions. Calculate the values of the maximum and minimum wavelengths. **[REE '97, 5]**

19. A 40 W ultraviolet light source of wavelength 2480 Å illuminates a magnesium (Mg) surface placed 2 m away. Determine the number of photons emitted from the source per second & the number incident on unit area of the Mg surface per second. The photoelectric work function for Mg is 3.68 eV. Calculate the kinetic energy of the fastest electrons ejected from the surface. Determine the maximum wavelength for which the photoelectric effect can be observed with a Mg surface. **[REE '98, 5]**

20. A transistor is used in the common emitter mode as an amplifier. Then: **[JEE '98, 2 (Not for JEE)]**
(A) the base–emitter junction is forward–biased
(B) the base–emitter junction is reverse–biased
(C) the input signal is connected in series with the voltage applied to bias the base emitter junction
(D) the input signal is connected in series with the voltage applied to bias–collector junction.

21. In a p – n junction diode not connected to any circuit, **[JEE '98, 2] (Not for JEE)**
(A) the potential is the same everywhere
(B) the p – type side is at a higher potential than the n – type side
(C) there is an electric field in the junction directed from the n – type side to the p – type side
(D there is an electric field at the junction directed from the p – type side to the n – type side.

22. Photoelectrons are emitted when 400 nm radiation is incident on a surface of work function 1.9eV. These photoelectrons pass through a region containing α–particles. A maximum energy electron combines with an α–particle to form a He^+ ion, emitting a single photon in this process. He^+ ions thus formed are in their fourth excited state. Find the energies in eV of the photons, lying in the 2 to 4eV range, that are likely to be emitted during and after the combination. [Take, $h = 4.14 \times 10^{-15}$ eV–s] **[JEE '99, 5]**

23. **[JEE '2000, Screening 1 + 1]**
(a) Electrons with energy 80keV are incident on the tungsten target of an X–ray tube. K shell electrons of tungsten have –72.5keV energy. 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–ray 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.

(b) Imagine an atom made up of a proton and a hypothetical particle of double the mass of the electron but having the same charge as the electron. Apply the Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength λ (given in terms of the Rydberg constant R for the hydrogen atom) equal to
(A) 9/(5R) (B) 36/(5R) (C) 18/(5R) (D) 4/R

24. A hydrogen – like atom of atomic number Z is in an excited state of quantum number 2 n. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted. Find, n, Z and the ground state energy (in eV) for this atom. Also, calculate the minimum energy (in eV) that can be emitted by this atom during de–excitation. Ground state energy of hydrogen atom is – 13.6 eV. **[JEE '2000, Mains 6]**

25. Find out the wavelength of the first line of the He+ ion in a spectral series whose frequency width is $\Delta \nu = 3.3 \times 10^{15}\ s^{-1}$. **[REE '2000, Mains 6]**

26. A hydrogen – like atom (described by the Bohr model) is observed to emit six wavelength, originating from all possible transitions between a group of levels. These levels have energies between a group of levels. These levels have energies between – 0.85 eV and – 0.544 eV (including both these values):
(a) Find the atomic number of the atom. **[JEE '2002, Mains, 4 + 1]**
(b) Calculate the smallest wavelength emitted in these transitions.
[Take hc = 1240 eV – nm, ground state energy of hydrogen atom = – 13.6 eV]

27. The nucleus of element X (A = 220) undergoes α – decay. If Q value of the reaction is 5.5 MeV, then kinetic energy of α – particle is: **[JEE '2003, Scr. 3]**

(A) 5.5 MeV (B) 5.4 MeV (C) 4.5 MeV (D) 6.1 MeV

28. The attractive potential between electron and nucleus is given by $v = v_0 \ln \frac{r}{r_0}$, v_0 and r_0 are constants and ' r ' is the radius. The radius ' r ' of the nth Bohr's orbit depends upon principal quantum number ' n ' as: **[JEE '2003, Scr. 3]**

(A) $r \propto n^2$ (B) $r \propto n$ (C) $r \propto \frac{1}{n}$ (D) $r \propto \frac{1}{n^2}$

29. If Bohr's theory is applicable to $_{100}Fm^{257}$, then radius of this atom in Bohr's unit is: **[JEE '2003, Scr. 3]**

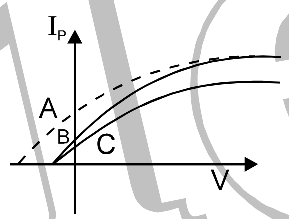
(A) 4 (B) 1/4 (C) 100 (D) 200

30. In a photoelectric effect experiment, photons of energy 5 eV are incident on the photocathode of work function 3 eV. For photon intensity $I_A = 10^{15}\ m^{-2}\ s^{-1}$, saturation current of 4.0 μ A is obtained. Sketch the variation of photocurrent i_p against the anode voltage V_a in the figure below for photon intensity I_A (curve A) and $I_B = 2 \times 10^{15}\ m^{-2}\ s^{-1}$ (curve B) (in JEE graph was to be drawn in the answer sheet itself.) **[JEE '2003, Mains 4]**

31. Characteristic X-rays of frequency 4.2×10^{18} Hz are emitted from a metal due to transition from L- to K-shell. Find the atomic number of the metal using Moseley's law. Take Rydberg constant $R = 1.1 \times 10^7\ m^{-1}$. **[JEE '2003, Mains 2]**

32. The graph is showing the photocurrent with the applied voltage of a photoelectric effect experiment. Then

(A) A & B will have same intensity and B & C have same frequency



(B) B & C have same intensity and A & B have same frequency

(C) A & B will have same frequency and B & C have same intensity

(D) A & C will have same intensity and B & C have same frequency **[JEE '2004, Scr.]**

33. A proton and photon both have same energy of E = 100 K eV. The debroglie wavelength of proton and photon be λ_1 and λ_2 then λ_1/λ_2 is proportional to **[JEE '2004, Scr.]**

(A) $E^{-1/2}$ (B) $E^{1/2}$ (C) E^{-1} (D) E

34. A light ray of wavelength in the range of 450 – 700 nm emits discrete wavelengths of hydrogen spectrum of Balmer seies fall on a metal of work function 2eV. Find the maximum kinetic energy of one photo electron. **[JEE '2004, Mains, 4]**

35. The wavelength of K_α X-ray of an element having atomic number z = 11 is λ. The wavelength of K_α X-ray of another element of atomic number z′ is 4λ. Then z′ is

(A) 11 (B) 44 (C) 6 (D) 4

36. A photon of 10.2 eV energy collides with a hydrogen atom in ground state inelastically. After few microseconds one more photon of energy 15 eV collides with the same hydrogen atom. Then what can be detected by a suitable detector.

(A) one photon of 10.2 eV and an electron of energy 1.4 eV

(B) 2 photons of energy 10.2 eV (C) 2 photons of energy 3.4 eV

(D) 1 photon of 3.4 eV and one electron of 1.4 eV **[JEE (Scr.) 2005, 3/84]**

37. The potential energy of a mass 'm' is given by the following relation

$$U = E_0 \text{ for } 0 \le x \le 1$$
$$= 0 \text{ for } x > 1$$

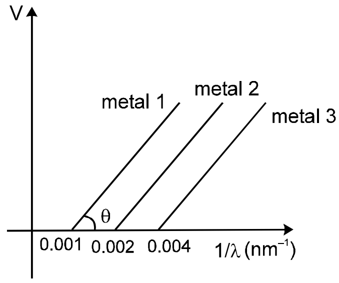
If λ_1 and λ_2 are the de-broglie wavelengths of the mass in the region $0 \le x \le 1$ and for $x > 1$ respectively and the total energy be $2E_0$, then find the value of $\frac{\lambda_1}{\lambda_2}$? **[JEE (Mains) 2005, 2/60]**

38. A metal target consist of large number of atoms (with each atom having number of neutrons is 30). The radius ratio of the target nucleus to ${}^4_2He$ is $(14)^{1/3}$. **[JEE (Mains) 2005, 4/60]**

(a) Find the atomic number of metal

(b) Find the frequency of K_α x-ray for that metal
(Given: Rydberg constant = 1.1×10^7 m^{-1}; speed of light = 3×10^8 m/s.)

39. The graph between $1/\lambda$ and stopping potential (V) of three metals having work functions ϕ_1, ϕ_2 and ϕ_3 in an experiment of photo–electric effect is plotted as shown in the figure. Which of the following statement(s) is/are correct? [Here λ is the wavelength of the incident ray]. **[JEE 2006, 5/184]**



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

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

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

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

40. If the wavelength of the n^{th} line of Lyman series is equal to the de-broglie wavelength of electron in initial orbit of a hydrogen like element (z = 11). Find the value of n. **[JEE 2006, 5/184]**

ANSWER

EXERCISE - 1

SECTION (A) :

A 1. 1.0×10^{-8} N **A 2.** 4.3×10^{-8} N
A 3. 6.66×10^{-9} m/s^2

SECTION (B) :

B 1. 4.2×10^{-25} kg.m/s **B 2.** 0.48 eV
B 3. 1.77×10^{19} **B 4.** 1.84×10^{-6} amp
B 5. ϕ = 2eV and current is less than saturation current
B 6. $dV_s = -5.5 \times 10^{-2}$ volt **B 7.** 3.93 eV
B 8. 3.467×10^{-15} eV–s **B 9.** 0.288 eV, 5400 Å
B 10. 1.9 eV
B 11. w = 6.8 eV, $\nu = 5 \times 10^{15}$ Hz
B 12. $\nu = 3.1 \times 10^{6}$ m/s **B 13.** $\frac{8\pi\varepsilon_0 dhc}{e^2 + 8\pi\varepsilon_0 \phi d}$

SECTION (C) :

C 1. 12.08 Aº **C 2.** 0.45 KeV

SECTION (D) :

D 1. $r = \frac{3Ke^2}{2E} = 0.16\,\text{nm}$

D 2. $\lambda = 2\pi r = 2\pi \times 0.529$ Å $= 1.058\,\pi$ Å
D 3. (a) 0.265 A, – 54.4 eV (b) 4.24 A , – 3.4 eV
D 4. (a) 40.8 V (b) 122.4 V **D 5.** He^{+1}
D 6. 1.05×10^{5} K, how

D 7. $\frac{1}{2}ke\left(1-2\ln\left(\frac{nh}{2\pi\sqrt{kem}}\right)\right)$ **D 9.** $E = \left(\frac{nh}{2\pi}\right)^6 \frac{1}{6\,(Ke^2)^2 m^3}$

SECTION (E) :

E 1. 3.25 m/s **E 2.** $\frac{(E-E')}{E} = 0.55 \times 10^{-6}$ %
E 3. (a) 654 nm (b) 4050 nm (c) 38860
E 4. 1 and 3 **E 5.** (a) 4, 2 (b) 487 nm
E 6. (a) 91 nm (b) 23 nm (c) 10 nm
E 7. 2.07×10^{16} s^{-1} **E 8.** n = 5
E 9. 3, Li^{++} **E 10.** 0.85 eV (n = 4 to n = 2)
E 11. He^{+} **E 12.** He^{+} 4,
E 13. (a) 103 nm (b) 487 nm **E 14.** 2.2×10^{6} m/s
E 15. (a) 0.59 pm (b) $(2\,Z\,ke^2/T)\left(1+\frac{m_\alpha}{m_{Li}}\right) = 0.03$ pm
E 16. 12.1 eV, 3 **E 17.** n = 5
E 18. (a) 913Å, (b) 10.2 eV
E 19. (a) 113.7 Å (b) 3 **E 20.** 2.92×10^{15} Hz
E 21. 975 Å **E 22.** 0.55 volts
E 23. 3.4 eV

SECTION (F) :

F 1. $T_{min} = 20.4$ eV

SECTION (G) : X-RAYS

G 1. 10μs by both **G 2.** 41.4 pm
G 3. approximately 1% **G 4.** 15.9 kV
G 5. 44.3 pm , 493 pm **G 6.** 18.5 pm
G 7. λ = 154 pm **G 8.** 3.47 keV
G 9. (a) 843 pm for Al, 180 pm for Co,
(b) $\cong$ 4936.8 eV

EXERCISE - 2

SECTION (A) :

A 1. C **A 2.** A **A 3.** D **A 4.** C

SECTION (B) :

B 1. C **B 2.** D **B 3.** B **B 4.** ABC
B 5. C **B 6.** A **B 7.** A **B 8.** A
B 9. B **B 10.** D **B 11.** A **B 12.** B
B 13. D **B 14.** C **B 15.** D **B 16.** C
B 17. B **B 18.** B

SECTION (C) :

C 1. D **C 2.** B **C 3.** B **C 4.** D
C 5. A **C 6.** D **C 7.** C **C 8.** A
C 9. D **C 10.** A **C 11.** C **C 12.** C
C 13. B **C 14.** A **C 15.** C

SECTION (D) :

D 1. C **D 2.** B **D 3.** D **D 4.** D
D 5. C **D 6.** CD **D 7.** AB **D 8.** B
D 9. D **D 10.** D **D 11.** D **D 12.** D
D 13. B **D 14.** B **D 15.** C **D 16.** A
D 17. B **D 18.** C **D 19.** A **D 20.** B
D 21. D **D 22.** B **D 23.** C

SECTION (E) :

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

SECTION (F) :

F 1. A **F 2.** C

SECTION (G) :

G 1. A **G 2.** B **G 3.** D **G 4.** C
G 5. C **G 6.** D **G 7.** CD **G 8.** CD
G 9. ABCD **G 10.** B **G 11.** A **G 12.** A

EXERCISE - 3

1.	B	**2.**	D	**3.**	A	**4.**	D
5.	A	**6.**	D	**7.**	BCD	**8.**	D
9.	D	**10.**	C	**11.**	B	**12.**	ACD
13.	ABC	**14.**	D	**15.**	D	**16.**	B
17.	D	**18.**	C	**19.**	B	**20.**	D
21.	A	**22.**	B	**23.**	D	**24.**	B
25.	D	**26.**	A	**27.**	D	**28.**	C
29.	D	**30.**	B	**31.**	D	**32.**	B
33.	D	**34.**	A	**35.**	A	**36.**	D
37.	C	**38.**	A				

EXERCISE - 4

1. Intensity, decreased **2.** 0.27 Å

3. 3×10^8 **4.** -1 **5.** BD

6. $r = a_0 n^2$, $L = \dfrac{nh}{2\pi}$ **7.** False

8. ABC **9.** n = 6, Z = 3

10. - 54.4 eV, - 13.6 eV, - 6.04 eV, - 3.4 eV, 54.4 V

11. (a) $10^5\ s^{-1}$ (b) 286.18 (d) $\dfrac{1000}{9}$ sec = 111s

12. BD **13.** D

14. (i) KE = 3.4 eV (ii) l = 6.66 Aº

15. **(i)** $\dfrac{he}{4\pi m}$ **(ii)** $\dfrac{heB}{8\pi m}$

16. B **17.** KE $\cong$ 151 eV, $d_{least} = 0.5\ A^0$

18. (b) 2, 3, 4, q = +2e, $\lambda_{max} \cong 4750\ A^0, \lambda_{min} \cong 245$ Aº

19. 5×10^{19}, $\dfrac{25\times10^{18}}{8\pi} \cong 1\times10^{18}$, 1.32 eV, 3370Å

20. AC **21.** C

22. during combination = 3.365 eV;
after combination = 3.88 eV ($5 \to 3$) &
2.644 eV ($4 \to 3$)

23. C

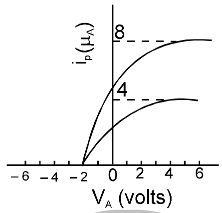
24. n = 2; z = 4; G. S. E. - 217.6 eV ;
Min. energy = $13.6 \times 7/9$ eV

25. Transitions to n = 1, l = 304Å

26. (a) n = 12, z = 3
(b) 620/153 μm = 4.05 μm

27. B **28.** B

29. B **30.**



31. 42 **32.** A

33. B **34.** $K_{max} = h\nu - \phi = 0.55$ eV

35. C **36.** A

37. $\sqrt{2}$

38. (a) Z = 26 (b) 154875×10^{12} Hz

39. AC **40.** n = 24.

Teko Classes, Maths : Suhag R. Kariya (S. R. K. Sir), Bhopal Phone : 0 903 903 7779, 0 98930 58881.