MODERN PHYSICS PROBLEMS

Q.1. The half life of ^{215}At is 100 μs. Find the time taken for the radioactive of a sample of ^{215}At to decay to $1/16^{th}$ of its initial value.

Q.2. The half life of ^{215}At is 100μs. If a sample initially contains 6 mg of the element, what is its activity initially ?

Q.3. The K-absorption edge of an unknown element is 0.171 A^0
(a) Identify the element.
(b) Find the average wavelengths of the K-series lines.
(c) If a 100 eV electron struck the target of this element, what is the cut off wavelength ?

Q.4. What is the fractional change in wavelength of light when it passes through water from glass. (n_w = 4/3 and n_g = 3/2)

Q.5. If the momentum of a photon is same as that of an electron moving with velocity 2×10^5 m/s, then find the wavelength of the photon.

Q.6. At a given time there are 25 % undecay nuclei in a sample. After 10 sec number of undecayed nuclei reduces to 12.5 %. Then find the mean life of the nuclei.

Q.7. In Moseley's equation $\sqrt{\nu}$ = a (z - b), where a and b are constant. Find the values of a and b with the help of the following data.

Element	Z	Wavelength of k_α X-rays
Mo	42	0.71 A^0
Co	27	1.785 A^0

Q.8. 24.6 eV of energy is required to remove one of the electrons from a neutral helium atom. Calculate energy (in eV) required to remove both the electrons from a neutral helium atom ?

Q.9. A spectral line results from the transition n =2 to n =1, in the atoms/species given below which one of these will produce the shortest wavelength emission H, He^+, Li^{++}.

Q.10. If the wavelength of Kα line for silicon (X = 47) is 0.57 A°, then find the value of wavelength for uranium (Z = 92).

Q.11. For sodium light, the two yellow lines occur at λ_1 and λ_2 wavelengths. If the arithmetic mean of these two is 6000 A^0, and $|\lambda_2 - \lambda_1|$ = 6A^0, then find the energy difference between the two levels corresponding to λ_1 and λ_2.

Q.12. The wavelength of K_α, L_α and K_β of a radiation of a material are λ_1, λ_2 and λ_3 respectively. Find the relationship among λ_1, λ_2 and λ_3.

Q.13. A radioactive nuclide A of decay constant λ is being produced at the constant rate of 'n' per second. Find N (number of active nuclei of A) at time t seconds. Initially the number of active nuclei of A was N_0. (λ is decay constant)

Q.14. Cathode of a photocell having cathode with work direction W_1 and current I_1 is changed with some other material with work function W_2 and current I_2. When ($W_2 > W_1$), then find the relation between I_1 & I_2.

Q.15. Nucleus of a radioactive element A are being produced at a constant rate α. At time t = 0, there are N_0 nucleus of the element. Calculate the number N of nucleus of A at time t

Q.16. The surface of a metal is irradiated, one after another, by waves of wavelength $\lambda_1 = 3.4 \times 10^{-7}$ m and $\lambda_2 = 5.4 \times 10^{-7}$ m respectively. The ratio of stopping potential in two cases is 2 : 1, What is the work function of metal.

Q.17. If the wavelength of $K\alpha$ line for silicon (X = 47) is 0.57 A°, then find the value of wavelength of k_α line for uranium (Z = 92).

Q.18. The surface of a metal is irradiated, one after another, by waves of wavelength $\lambda = 3.4 \times 10^{-7}$ m and $\lambda = 5.4 \times 10^{-7}$ m respectively. The ratio of stopping potential in two cases is 2: 1, what is the work function of metal.

Q.19. In the decay process $_{94}X \rightarrow {}^{235}_{92}Y + \alpha$

If X is initially at rest and the speed of the emerging α-particle is found to be 1.59×10^7 m/s then find the Q value of the reaction and the mass of X in amu. Given m (Y) = 235.04 amu, $\left({}^4_2He\right)$ = 4.003 amu.

Q.20. The kinetic energy of neutrons in a neutron beam is 0.0237 eV. If half life of neutrons is 700 sec, find the fraction of neutrons decaying before traveling a distance 10 m.

Q.21. An x-rays tube with a copper target is found to be emitting lines other than those due to copper. The k_α line of copper is known to have a wavelength 1.5405 A^0 and the other two k_α lines observed have wavelengths 0.7092 A^0 and 1.6578^{0}A. Identify the impurities.

Q.22. The intensity of sun light on the surface of earth is 1400 w/m^2. Assuming the mean wavelength of sunlight to be 6000 A^0. Calculate the photon flux arriving at 1 m^2 area on earth perpendicular to light radiation.

Q.23. A nucleus of ^{60}Ni in an excited state decays to its ground state by emitting 1.33MeV photon. What is the recoil energy and recoil speed of the ^{60}Ni nucleus?

Q.24. A perfectly absorbing surface intercepts a parallel beam of monochromatic light of λ = 500 nm, incident on it normally. If the power through any cross-section of beam is 10 w, find -

(i) the number of photons absorbed per second by the surface,
(ii) the force exerted by light beam on the surface.

Q.25. If the wavelength of the incident radiation is increased from 4000 A^0 to 4002 A^0 in photoelectric effect. Find the corresponding change in the stopping potential.

Q.26. The K-absorption edge of an unknown element is 0.171 A^0 Identify the element. i.e. find its atomic number.

Q.27. Cathode of a photocell having cathode with work function W_1 and saturation current I_1 is changed with some other material with work function W_2 and saturation current I_2.
[Given : $W_2 > W_1$]. Find the ratio of I_1 & I_2.

Q.28. The kinetic energy of neutrons in a neutron beam is 0.0237 eV. If half life of neutrons is 700 sec, find the fraction of neutrons decaying before traveling a distance 10 m.

Q.29. A ^{7}Li target is bombarded with a proton beam current of 10^{-4} A for 1 hour to produce ^{7}Be of activity 1.8×10^8 disintegration's per second. Assuming that one ^{7}Be radioactive nucleus is produced by bombarding 1000 protons, determine its half-life.

Q.30. The line at 121 nm in Balmer series of He^+ ion corresponds to a transition of an electron from nth of second Bohr orbit of He^+ ion. Then find the number of revolutions made by electron in nth orbit per second of He^+ ion.

Q.31. How the electron in the ground state of hydrogen atom is excited by means of monochromatic radiation of wavelength 970.6 A^0. How many different lines are possible in the resulting emission spectrum ?

Q.32. A ^{118}Cd radionuclide goes though the transformation chain.

$$^{118}\text{Cd} \xrightarrow[30\ \text{min}]{} {}^{118}\text{In} \xrightarrow[45\ \text{min}]{} {}^{118}\text{Sn} \quad \text{(stable)}$$

The half lives are written below the respactive arrows. At time t = 0 only Cd was present find the fraction of nuclei transformed into stable over 60 minutes.

Q.33. A monochromatic light of wavelength 400 nm falls on a metal plate of a photoelectric arrangement. The work function of the metal is 2.5 eV. Find the maximum magnitude of the linear momentum of emitted photoelectron.

Q.34. 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. (Ionization 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?

Q.35. It is proposed to use the nuclear fusion reaction ${}_1H^2 + {}_1H^2 \to {}_2He^4$
in a nuclear reactor of 200 MW rating. If the energy from the above reaction is used with a 25% efficiency in the reactor, how many grams of the deuterium fuel will be needed per day. The masses of ${}_1H^2$ and ${}_2He^4$ are 2.0141 amu and 4.0026 amu respectively?

Q.36. A radionuclide with half life 1620 second is produced in a reactor at a constant rate 1000 nuclei per second. During each decay energy 200 Mev is released. If production of radionuclide is started at t = 0, calculate
(a) rate of release of energy at t = 3240 sec.
(b) total energy released upto t = 405 sec.

Q.37. Nucleus of a radioactive element A are being produced at a constant rate α. At time t = 0, there are N_0 nucleus of the element. Calculate the number N of nucleus of A at time t

Q.38. A monochromatic of wavelength 400 nm falls on the metal plate of a photoelectric arrangement. The work function of the metal is 2.5 eV
(a) find the maximum magnitude of the linear momentum of emitted photoelectron
(b) also calculate the stopping potential for this arrangement.

Q.39. A radioactive element A are being produced at a constant rate α. At t = 0 there was no nuclei present. Show that after $t >> t_{1/2}$, the number of active nuclei will become constant. find the value of this constant. [$t_{1/2}$ = half life]

Q.40. A hydrogen like atom of atomic number Z is in an excited state of quantum number 2n. 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 the value of n and Z. 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.

Q.41. A fusion reaction taking place in a reactor to produce the power is given by

$${}_1^2D + {}_1^2D \to {}_1^3T + {}_1^1P + \Delta E$$

Calculate the number of deuterium atom required per hour for a power out put of 100 MW. Take efficiency of process be 60 %.

Mass of ${}_1^2D$ = 2.01458 amu

${}_1^3D = 3.01605$ amu

${}_1^1P = 1.00728$ amu

& 1 amu = 930 MeV

Q.42. A nucleus X - initially at rest, undergoes alpha - decay, according to the equation

$${}_{92}X^A \to {}_Z Y^{228} + \alpha .$$

(i) Find the value of A and Z in the above process.
(ii) The α - particle in the above process is found to move in a circular track of radius 0.11 m in a uniform magnetic field of 3T. Find the energy (in MeV) released during the process and binding energy of the parent nucleus X.
Given:
m_y = 228.03 amu ; m_α = 4.003 amu
m $({}_0n^1)$ = 1.009 amu ; $m({}_1H^1)$ = 1.008 amu

Q.43. Neon-23 beta decays in the following way :

$${}_{10}^{23}Ne \to {}_{11}^{23}Na + {}_{-1}^{0}\beta + \bar{\nu}$$

Find the minimum and maximum kinetic energies that the β-particle can have. Atomic masses of ${}^{23}Ne$ and ${}^{23}Na$ are 22.9945 u and 22.9898 u respectively.

Q.44. Find out the wavelength of the first line of the He^+ ion in a spectral series whose frequency width is $\Delta v = 3.3 \times 10^{15}\ s^{-1}$.

Q.45. A ^7Li target is bombarded with a proton beam current of 10^{-4} A for 1 hour to produce ^7Be of activity 1.8×10^8 disintegrations per second. Assuming that one ^7Be radioactive nucleus is produced by bombarding 1000 protons, determine its half-life.

Q.46. In the fission reaction ${}_1^2H + {}_1^2H \rightarrow {}_2^3He + {}_0^1n$;

Deuteron, helium and the neutron have masses 2.015 amu,3.017 amu and 1.009 amu respectively. Estimate total energy released if 1 kg of deuterium undergoes complete fission?

Q.47. (i) A perfectly absorbing surface intercepts a parallel beam of monochromatic light of λ = 500 nm, incident on it normally. If the power through any cross-section of beam is 10 Watts, find the number of photons absorbed per second by the surface,

(ii) A nucleus X - initially at rest, undergoes alpha - decay, according to the equation

$${}_{92}X^A \rightarrow {}_Z Y^{228} + \alpha .$$

Find the value of A and Z in the above process.

Q.48. A μ-meson particle moves in a circular orbit around a very heavy nucleus (of infinite mass) of charge + 3e. Assuming Bohr's model is applicable to this system,

(a) Derive an expression for the radius of nth Bohr orbit.

(b) Find n, for which radius of orbit is approximately same as that of Ist Bohr orbit for a hydrogen atom.

(c) Find wavelength of radiation emitted when μ - meson jumps from 3rd orbit to Ist orbit

[μ - meson is a particle, whose charge is equal to that of an electron and mass = 208 times that of an electron].

Q.49. It is proposed to use the nuclear fusion reaction ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4$

In a nuclear reactor of 200 MW rating. If the energy from the above reaction is used with 25% efficiency in the reactor, how many grams of the deuterium fuel will be needed per day? The masses of ${}_1H^2$ and ${}_2He^4$ are 2.0141 amu and 4.0026 amu respectively.

Q.50. In a photocell the plates P and Q have a separation of 10cm, which are connected through an ammeter without any cell. Light of wavelength range between 4000A° and 6000A° are incident on plate Q whose work function is 2.39 eV. If a uniform magnetic field B exists parallel to the plates, find the minimum value of B for which the ammeter shows zero deflection.

Q.51. If an X-ray tube operates at the voltage of 10kV, find the ratio of the de-Broglie wavelength of the incident electrons to the shortest wavelength of X-rays produced. The specific charge of electron is1.8×10^{11} C/kg.

Q.52. A monochromatic light source of frequency f 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 $\frac{5}{6}f$, the photoelectrons so emitted are able to excite the hydrogen atom beam which then emits a radiation of wavelength 1215Å.

(a) Find the work function of the metal.
(b) What is the frequency of radiation?

Q.53. Light from a discharge tube containing hydrogen atoms falls on the surface of a piece of sodium. The kinetic energy of the fastest photo-electrons emitted from sodium is 0.73 eV. The work function for sodium is 1.82 eV. Find the
(a) The energy of the photons causing the photo-electric emission.
(b) The quantum number of the two levels involved in the emission of these photons.
(c) The change in the angular momentum of the electron in the hydrogen atom in the above transition.
(d) The recoil speed of the emitting atom assuming it to be at rest before the transition (Take mass of hydrogen = 1.6×10^{-27} kg)

Q.54. Two metallic plates *A* and *B*, each of area 5×10^{-4} m^2, are placed parallel to each other at a separation of 1 cm. Plate *B* carries a positive charge of 33.7 x 10^{-12}C. A monochromatic beam of light, with photons of energy 5 eV each, starts falling on plate *A* at *t* = 0 so that 10^{16} photons fall on it per square meter per second. Assume that one photoelectron is emitted for every 10^6 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 2eV. Determine
(a) The number of photoelectrons emitted up to *t* = 10 s,
(b) The magnitude of the electric field between the plates *A* and *B* at *t* = 10 s, and
(c) The kinetic energy of the most energetic photoelectron emitted at *t* = 10 s when it reaches plate *B*.
Neglect the time taken by the photoelectron to reach plate *B*.
Take $\varepsilon_o = 8.85 \times 10^{-12}$ C^2/N-m^2

Q.55. For a certain hypothetical one – electron atom, the wavelength (in A^0) for the spectral lines for transitions originating at n = P and terminating at n = 1 are given by

$\lambda = \dfrac{1500P^2}{P^2 - 1}$ where P = 2, 3, 4………..

(a) Find the wavelength of the least energetic and most energetic photons in this series.
(b) Constant an energy level diagram for this element showing the energies of the lowest three levels.
(c) What is the ionization potential of this element?

Q.56. A μ-meson particle moves in a circular orbit around a very heavy nucleus (of infinite mass) of charge + 3e. Assuming Bohr's model is applicable to this system,
(a) Derive an expression for the radius of nth Bohr orbit.
(b) Find n, for which radius of orbit is approximately same as that of Ist Bohr orbit for a hydrogen atom.
(c) Find wavelength of radiation emitted when μ - meson jumps from 3rd orbit to Ist orbit
[μ - meson is a particle, whose charge = that of an electron, mass = 208 times that of an electron].

Q.57. In Moseley's equation $\sqrt{\nu}$ = a (z - b), a and b are constant. Find their values with the help of the following data.

Element	Z	Wavelength of k_α X-rays

Mo	42	0.71 A^0
Co	27	1.785 A^0

Q.58. A proton is bombarded on a stationary lithium nucleus. As a result of the collision two α-particles are produced. If the direction of motion of one of the α-particles with the initial direction of motion makes an angle $\cos^{-1}$ (1/4). Find the kinetic energy of the striking proton. Given binding energies per nucleon of Li and He^4 are 5.60 and 7.06 MeV respectively.
(Assume mass of proton $\approx$ mass of neutron).

Q.59. Photons emitted by a gas consisting of excited hydrogen like atoms (A) during a transition from a higher quantum state (quantum no. n) to a lower quantum state (quantum no : m) are incident on a metallic surface (B) causing the emission of photoelectrons. The fastest photoelectrons pass undeviated through a region consisting of electric field, E_0 = 3.7 V/cm and magnetic field, $B_0 = 10^{-3}$ T, oriented in perpendicular directions and the photoelectrons enter the region perpendicular to both electric and magnetic field
The threshold wavelength for the metal B equals 830 nm. The spectrum of light emitted by the excited hydrogen –like atoms (A) consists of 15 different wavelengths.
Find the quantum numbers of the states n, m and atomic number (Z) of the elements (A).
(Take 1.89 /13.6 $\approx$ 1/7)

Q.60. The radiation emitted when an electron jumps from n = 3 to n = 2 orbit in hydrogen atom falls on a metal to produce photoelectrons. The electrons from metal surface with maximum kinetic energy are made to move perpendicular to a magnetic field of (1/320) T in a radius of 10^{-3} m.
Find (a) the kinetic energy of electrons
(b) Work function of metal and
(c) Wavelength of radiation.

Q.61. The radiation emitted when an electron jumps from n = 4 to n = 3 in a Lithium atom, falls on a metal surface to produce photoelectron. When the photoelectrons with maximum KE are made to move perpendicular to a magnetic field of 4×10^{-4}T, they trace out a circular path of radius 1.68cm. Find the
(a) wavelength of radiation falling on the metal surface.
(b) Kinetic energy of photo-electrons.
(c) Work function of the metal.

Q.62. The energy levels of a hypothetical one electron atom are given by

$$E_n = -\frac{18.0}{n^2}\ \text{eV}$$

Where n=1, 2, 3……….
(a) Compute the four lowest energy levels and construct the energy level diagram.
(b) What is the excitation potential from ground state to the stage n = 2?
(c) What wavelengths ($\mathring{A}$) can be emitted when these atoms in the ground state are bombarded by electrons that have been accelerated through a potential difference of 16.2 V ?
(d) If these atoms are in the ground state, can they absorb radiation having a wavelength of 2000 $\mathring{A}$?
(e) What is the photoelectric threshold wavelength (for the ground state) of this atom?

Q.63. A neutron with kinetic energy T = 10 MeV activate a nuclear reaction C^{12} (n, α) Be^9 whose threshold is T_{th} = 6.17 MeV. Find the kinetic energy of the α particles outgoing at right angles to the incoming neutrons' direction.

Q.64. Light from a discharge tube containing hydrogen atoms falls on the surface of a piece of sodium. The kinetic energy of the fastest photo-electrons emitted from sodium is 0.73 eV. The work function for sodium is 1.82 eV. Find the
(a) The energy of the photons causing the photo-electric emission.
(b) The quantum number of the two levels involved in the emission of these photons.
(c) The change in the angular momentum of the electron in the hydrogen atom in the above transition.
(d) The recoil speed of the emitting atom assuming it to be at rest before the transition (Take mass of hydrogen = 1.6×10^{-27} kg)

Q.65. Electromagnetic Radiation consisting of a mixture of three wavelengths 4500 A^0 6000 A^0 & 12000 A^0 is incident on a metallic sample. It is observed that the emerging photoelectrons having maximum energy could just cause the excitation of H-atoms from n = 2 to n = 4 level.
Find
(a) the de-Broglie wavelengths of the photoelectrons, of maximum energy, emitted by each kind of photons.
(b) The photocurrent from the material, assuming that the efficiency of conversion is 20 % and that the total intensity of 1.44×10^2 W/m^2 is distributed evenly among all wavelengths. (Area of the sample is 1 cm^2).
(c) If the work-function of the material was 40 % lower, what will be the photocurrent and the stopping potential of the photoelectrons?

Q.66. A nucleus X, initially at rest, undergoes α – decay according to the equation

$${}_{92}X^{A} \rightarrow {}_{Z}Y^{228} + \alpha$$

(a) Find the value of A and Z in the above process.
(b) The α – particle in the above process is found to move in a circular track of radius 0.11 m in a uniform magnetic field of 3T. Find the energy (in MeV) released during the process and the binding energy of the parent nucleus X.
Given that,
M_y = 228.03 amu, m_α = 4.003 amu
$m({}_0n^1)$ = 1.009 amu, $m({}_1H^1)$ = 1.008 amu
(Neglect relativistic effects)

Q.67. A doubly ionized 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. (Ionization 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?

Q.68. A hydrogen-like atom (described by the Bohr model) is observed to emit six wavelengths, originating from all possible transitions 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.

(b) Calculate the smallest wavelength emitted in these transitions.
(Take *hc*= 1240 eV-nm, ground state energy of hydrogen atom = –13.6eV)

Q.69. Find out the wavelength of the first line of the He^+ ion in a spectral series whose frequency width is $\Delta v = 3.3 \times 10^{15}\ s^{-1}$.

Q.70. The K-absorption edge of an unknown element is 0.171 A^0
(a) Identify the element.
(b) Find the average wavelengths of the K-series lines.
(c) If a 100 eV electron struck the target of this element, what is the cut off wavelength ?