9. Assignment (Subjective Problems)

LEVEL - I

1. Frequency of a photon emitted due to transition of electron of a certain element from L to K shell is found to be 4.2×10^{18} Hz. Using Moseley's law, find the atomic number of the element, given that the Rydberg's constant $R=1.1\times10^{7}\ m^{-1}$.

2. A radioactive sample emits n β-particles in 2 sec. In next 2 sec it emits 0.75 n β-particle, what is the mean life of the sample?

3. The energy of a K-electron in tungsten is -20 KeV and of an L $-$electron is -2 KeV. Find the wavelength of X-rays emitted when there is electron jump from L to K shell.

4. One milliwatt of light of wavelength 4560 Å is incident on a cesium surface. Calculate the photoelectric current produced, if the efficiency of the surface for photoelectric emission is only 0.5%.

5. If the wavelength of the light falling on a surface is increased from 3000 Å to 3040 Å, then what will be the corresponding change in the stopping potential? (Given that hc = 12.4×10^{3} eV Å)

6. In an experiment on photoelectric emission, following observations were made: (i) Wavelength of the incident light = 1.98×10^{-7} m, (ii) stopping potential = 2.5 volt. Find threshold frequency, work-function and energy of photoelectrons with maximum speed. (Given e = 1.6×10^{-19} C, h = 6.6×10^{-34} J-s., c = 3×10^{8} m/s)

7. Light of wavelength 180 nm ejects photo-electrons from a plate of metal whose work-function is 2 eV. If a uniform magnetic field of 5×10^{-5} Tesla be applied parallel to the plate, what would be the radius of the path followed by electrons ejected normally from the plates with maximum energy (h = 6.62×10^{-34} J-s, m = 9.1×10^{-31} kg and e = 1.6×10^{-19} coulomb).

8. Photoelectric threshold wavelength of metallic silver is λ = 3800 Å. Ultra-violet light of λ = 2600Å is incident on silver surface. Calculate
   (a) the value of work function in joule and eV,
   (b) maximum Kinetic energy of the emitted photo electrons,
   (c) the maximum velocity of the photo electrons.
   (Mass of the electron=9.11×10^{-31} kg).

9. Consider the fusion reaction ${}_1H^2 + {}_1H^3 \rightarrow 2He^4$. If 20 MeV of energy is released per fusion reaction, mass of ${}_1H^2$ consumed per day is 0.1 gm, what is the Power of the reactor?

10. The radiation emitted due to de-excitation of electron from n=2 to n=1 in H_2 atom falls on a metal to produce photo electrons. The electrons from the metal surface with maximum kinetic energy are made to move perpendicular to a magnetic field of $\frac{1}{160}$ T in a radius 10^{-3}m. Find the threshold wavelength for the metal.

LEVEL – II

1. A hydrogen atom moving with a velocity 6.24×10^4 m/s makes a perfectly inelastic head on collision with another stationary hydrogen atom. Both atoms are in ground state before collision. Up to what state either one atom may be excited.

2. An X-ray tube with a copper target is found to emit 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 A^0. Identify the impurities (find the value of Z, atomic number). What is the minimum voltage at which the X-ray tube should be operated?

3. Radiation falls on a target kept within a solenoid with 20 turns per cm, carrying a current 2.5 A. Electrons emitted move in a circle with a maximum radius of 1 cm. Find the wavelength of radiation, given that the work function of the target is 0.5 volts, $e = 1.6 \times 10^{-19}$ coulomb, $h = 6.625 \times 10^{-34}$ J–s, $m = 9.1 \times 10^{-31}$ Kg.

4. Electrons in a hydrogen like atom (Z = 3) make transitions from 5th to 4th orbit and from the 4th to the 3rd orbit. The resulting radiation is incident normally on a metal plate and the photo- electrons are ejected. The stopping potential for the photoelectrons ejected by light of shorter wavelength is 3.95V. Calculate the work function of the metal and the stopping potential the photo electrons for the longer wavelength.

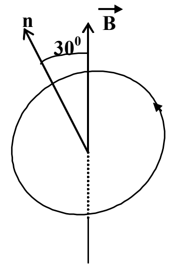
5. When the voltage applied to an X-ray tube increased from V_1 = 10 KV to V_2=20 KV, the wavelength interval between the K_α-line and the short wavelength cut-off of the continuous X-ray spectrum increases by a factor of 3. Find the atomic number of the element of the target.

6. The maximum kinetic energy of photoelectrons emitted from a metallic surface is 30 eV when monochromatic radiation of wavelength λ falls on it. When the same surface is illuminated with light of wavelength 2λ, the maximum kinetic energy photo electrons is observed to be 10 eV. Calculate the wavelength λ and determine the maximum wavelength of incident radiation for which photoelectrons can be emitted by this surface.
($h = 6.62 \times 10^{-34}$ J-S $= 4.14 \times 10^{-15}$ eV-s, $c = 3 \times 10^8$ m/s)

7. A monochromatic beam of light (λ = 4900 Å) incident normally upon a surface produces a pressure of 5×10^{-7} N/m^2 on it. Assuming that 25% of the light incident is reflected and the rest absorbed, find the number of photons falling per second on a unit area of thin surface.

8. A nuclear explosion is designed to deliver 1 MW of heat. How many fission events must be required in a second to attain this power level? Assume that this explosion is designed with nuclear fuel consisting of uranium -235. Calculate the amount of fuel needed to run a reactor at this power level for one year. You can assume that the amount of energy released per fission event is 200 MeV.

9. An electron in the ground state of the hydrogen atom is revolving in the anti-clockwise direction in a circular orbit of radius R.
(a) Obtain an expression for the orbital magnetic dipole moment of the electron.
(b) The atom is placed in a uniform magnetic induction B such that the plane normal to the electron orbit makes an angle 30° with the magnetic induction. Find the torque experienced by the orbiting electron.



10. A radionuclide A_1 with decay constant λ_1 transforms into a radionuclide A_2 with decay constant λ_2. Assuming that at the initial moment the preparation contained only the radionuclide A_1, find:
(a) the equation describing accumulation of the radionuclide A_2.
(b) the time interval after which the activity of radionuclide A_2 reaches the maximum value. Assume concentration of A_1 at t = 0 to be N_o.

10. Assignment (Objective Problems)

LEVEL – I

1. The total energy of the electron in the hydrogen atom in the ground state is −13.6 eV. Which of the following is its kinetic energy in the first excited state?
(A) 13.6 eV
(B) 6.8 eV
(C) 3.4 eV
(D) 1.825 eV

2. A freshly prepared radioactive source of half life 2 hrs emits radiation of intensity which is 32 times the permissible safe value of intensity. Which of the following is the minimum time after which it would be possible to work safely with this source?
(A) 16 hrs
(B) 5 hrs
(C) 10 hrs
(D) 32 hrs

3. The ionisation potential of a hydrogen atom is 13.6 volt. The energy required to remove an electron from the second orbit of hydrogen is:
(A) 3.4 eV
(B) 6.8 eV
(C) 13.6 eV
(D) 27.2 eV

4. The radius of the first Bohr orbit is a_0. The n^{th} orbit has a radius:
(A) na_0
(B) a_0/n
(C) n^2a_0
(D) a_0/n^2

5. The ionisation energy of the ionised sodium atom Na^{+10} is :
(A) 13.6 eV
(B) 13.6 × 11 eV
(C) (13.6/11) eV
(D) 13.6 × (11^2) eV

6. Radius of the second Bohr orbit of a singly ionised helium atom is
(A) 0.53 A^0
(B) 1.06 A^0
(C) 0.265 A^0
(D) 0.132 A^0

7. The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation:
(A) the maximum wavelength increases
(B) the minimum wave length increases
(C) the minimum wavelength remains unchanged
(D) the minimum wave length decreases

8. A beam of electrons accelerated by a large potential difference V is made to strike a metal target to produce X-rays. For which of the following values of V, the resulting X-rays have the lowest minimum wave length:
(A) 10 KV (B) 20 KV
(C) 30 KV (D) 40 KV

9. The X-ray beam emerging from an X-ray tube
(A) is monochromatic
(B) contains all wavelengths smaller than a certain maximum wavelength
(C) contains all wave lengths larger than a certain minimum wavelength
(D) contains all wave lengths lying between a minimum and a maximum wavelength.

10. The relation between half-life T of a radioactive sample and its mean life τ is:
(A) $T = 0.693 \tau$ (B) $\tau = 0.693 T$
(C) $\tau = T$ (D) $\tau = 2.718 T$

11. The stopping potential for the photo electrons emitted from a metal surface of work function 1.7 eV is 10.4 V. Identify the energy levels corresponding to the transitions in hydrogen atom which will result in emission of wavelength equal to that of incident radiation for the above photoelectric effect
(A) n = 3 to 1 (B) n = 3 to 2
(C) n = 2 to 1 (D) n = 4 to 1

12. An electron collides with a fixed hydrogen atom in its ground state. Hydrogen atom gets excited and the colliding electron loses all its kinetic energy. Consequently the hydrogen atom may emit a photon corresponding to the largest wavelength of the Balmer series. The K.E. of colliding electron will be
(A) 10.2 eV (B) 1.9 eV
(C) 12.1 eV (D) 13.6 eV

13. When a radioactive isotope $_{88}Ra^{228}$ decays in series by the emission of three α-particles and a β particle the isotope finally formed is :
(A) $_{84}X^{220}$ (B) $_{86}X^{222}$
(C) $_{83}X^{216}$ (D) $_{83}X^{215}$

14. Photo electric effect supports the quantum nature of light because:
(A) there is a minimum frequency of light below which no photo electrons are emitted.
(B) the maximum K.E. of photoelectrons depends only on the frequency of light and not on its intensity.
(C) even when the metal surface is faintly illuminated by light of the approximate wavelength, the photo electrons leave the surface immediately.
(D) electric charge of photoelectrons is quantized.

15. If the electron in the hydrogen atoms is excited to n = 5 state, the number of frequencies present in the radiation emitted is :
(A) 4 (B) 5
(C) 8 (D) 10

16. The ratio of magnetic dipole moment of an electron of charge e and mass m in the Bohr orbit in hydrogen to the angular momentum of the electron in the orbit is:
(A) e/m (B) e/2m
(C) m/e (D) 2m/e

17. The wave length λ of K_α-ray line of an anticathode element of atomic number Z is nearly proportional to:
(A) Z^2 (B) $(Z - 1)^2$
(C) $\frac{1}{(Z-1)}$ (D) $\frac{1}{(Z-1)^2}$

18. If λ_1 and λ_2 are the wavelengths of characteristic X-ray and gamma rays respectively, then the relation between them is :
(A) $\lambda_1 \leq \lambda_2$ (B) $\lambda_1 = \lambda_2$
(C) $\lambda_1 > \lambda_2$ (D) $\lambda_1 < \lambda_2$

19. In the nuclear reaction given by ${}_2He^4 + {}_7N^{14} \rightarrow {}_1H^1 + X$ then the nucleus X is :
(A) Nitrogen of mass 16 (B) Nitrogen of mass 17
(C) Oxygen of mass 16 (D) Oxygen of mass 17

20. If 10% of a radioactive material decays in 5 days, then the amount of the original material left after 20 days is approximately:
(A) 60% (B) 65%
(C) 70% (D) 75%

LEVEL – II

1. Suppose the potential energy between electron and proton at a distance r is given by $-\frac{Ke^2}{3r^3}$.
Application of Bohr's theory of hydrogen atom in this case shows that :
(A) energy in the nth orbit is proportional to n^6
(B) energy is proportional to m^{-3} (m : mass of electron)
(C) energy in the nth orbit is proportional to n^{-2}
(D) energy is proportional to m^3 (m = mass of electron)

2. X ray from a tube with a target A of atomic number Z shows strong K lines for target A and weak K lines for impurities. The wavelength of K_α lines is λ_z for target A and λ_1 and λ_2 for two impurities.
$\frac{\lambda_z}{\lambda_1} = 4$ and $\frac{\lambda_z}{\lambda_2} = \frac{1}{4}$. Screening constant of K_α lines to be unity. Select the correct statement(s)
(A) The atomic number of first impurity is 2z – 1.
(B) The atomic number of first impurity is 2z + 1.
(C) The atomic number of second impurity is $\frac{(z+1)}{2}$.
(D) The atomic number of second impurity is $\frac{z}{2} + 1$.

3. Energy liberated in the de–excitation of hydrogen atom from 3rd level to 1st level falls on a photo–cathode. Later when the same photo–cathode is exposed to a spectrum of some unknown hydrogen like gas, excited to 2nd energy level, it is found that the de–Broglie wavelength of the fastest photoelectrons, now ejected has decreased by a factor of 3. For this new gas, difference of energies of 2nd Lyman line and 1st Balmer line is found to be 3 times the ionization potential of the hydrogen atom. Select the correct statement(s) :
(A) The gas is lithium.
(B) The gas is helium.
(C) The work function of photo–cathode is 8.5 eV.
(D) The work function of photo–cathode is 5.5 eV.

4. Hydrogen atoms absorbs radiation of wavelength λ_0 and consequently emit radiations of 6 different wavelengths of which two wavelengths are shorter than λ_0.
(A) The final excited state of the atoms is n = 4
(B) The initial state of the atoms may be n = 2
(C) The initial state of the atoms may be n = 3
(D) There are three transitions belonging to Lyman series.

5. For a certain radioactive substance, it is observed that after 4 hours, only 6.25% of the original sample is left undecayed. If follows that
(A) the half life of the sample is 1 hour
(B) the mean life of the sample is $1/\ln 2$ hour
(C) the decay constant of the sample is ln 2 hour^{-1}
(D) after a further 4 hours, the amount of the substance left over would by only 0.39% of the original amount

6. Let ν_1 be the frequency of the series limit 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 limit of the Balmer series
(A) $\nu_1 - \nu_2 = \nu_3$
(B) $\nu_2 - \nu_1 = \nu_3$
(C) $\nu_3 = \frac{1}{2}(\nu_1 + \nu_2)$
(D) $\nu_1 + \nu_2 = \nu_3$

2. An electron in a hydrogen atom makes a transition from n = n_1 to n = n_2. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are
(A) $n_1 = 4, n_2 = 2$
(B) $n_1 = 8, n_2 = 2$
(C) $n_1 = 8, n_2 = 1$
(D) $n_1 = 6, n_2 = 3$

3. Whenever a hydrogen atom emits a photon in the Balmer series,
(A) it may emit another photon in Balmer series
(B) it must emit another photon in Lyman series
(C) the second photon, if emitted, will have a wavelength of about 122 nm
(D) it may emit a second photon, but the wavelength of this photon cannot be predicted

4. When an electron moving at a high speed strikes a metal surface, which of the following are possible ?
(A) the entire energy of the electron may be converted into an X-ray photon
(B) any fraction of the energy of the electron may be converted into an X-ray photon
(C) the entire energy of the electron may get converted to heat
(D) the electron may under go elastic collision with the metal surface

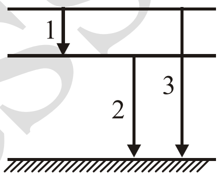
5. There are two radioactive nuclei A and B. A is an alpha emitter and B is a beta emitter. Their disintegration constants are in ratio of 1 : 2. What should be the ratio of number of atoms of A and B at any time t so that probabilities of getting alpha and beta particle are same at that instant

(A) 2 : 1 (B) 1 : 2
(C) 3 (D) e^{-1}

6. An electron in hydrogen atom first jumps from second excited state to first excited state and then from first excited state to ground state. Let the ratio of wavelength, momentum and energy of photons emitted in these two cases be a, b and c respectively. Then

(A) $c = \frac{1}{a}$ (B) $a = \frac{9}{4}$
(C) $b = \frac{5}{27}$ (D) $c = \frac{5}{27}$

7. The wavelengths and frequencies of photons in transitions 1, 2 and 3 for hydrogen like atom are λ_1, λ_2, λ_3, ν_1, ν_2 and ν_3 respectively. Then



(A) $n_3 = n_1 + n_2$ (B) $n_3 = \frac{n_1 n_2}{n_1 + n_2}$
(C) $l_3 = l_1 + l_2$ (D) $l_3 = \frac{l_1 l_2}{l_1 + l_2}$

8. When the intensity of a light source is increased,
(A) the number of photons emitted by the source in unit time increases
(B) the total energy of the photons emitted per unit time increases
(C) more energetic photons are emitted
(D) faster photons are emitted

9. If the wavelength of light in an experiment on photoelectric effect is doubled,
(A) the photoelectric emission will not take place
(B) the photoelectric emission may or may not take place
(C) the stopping potential will increase
(D) the stopping potential will decrease

10. 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 a 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

COMPREHENSION

I : [Question No. 1 to 3]

Many unstable nuclei can decay spontaneously to a nucleus of lower mass but different combination of nucleons. The process of spontaneous emission of radiation is called radioactivity. Three types of radiations are emitted by radioactive substance.

Radioactive decay is a statistical process. Radioactivity is independent of all external conditions.

The number of decay per unit time or decay rate is called activity. Activity exponentially decreases with time.

Mean life time is always greater than half lift time.

1. Choose the correct statement about radioactivity :
   (A) Radioactivity is statistical process
   (B) Radioactivity is independent of high temperature and high pressure
   (C) When a nucleus undergoes α or β decay, its atomic number changes
   (D) All of these

2. If the decay constants of a radioactive element for α and β decay are λ_1 and λ_2 respectively. The total decay constant (λ) is :
   (A) $\frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$ (B) $\frac{\lambda_1\lambda_2}{\lambda_1-\lambda_2}$
   (C) $\lambda_1+\lambda_2$ (D) $\lambda_1-\lambda_2$

3. The activity of radioactive substance is R_1 at time t_1 and R_2 at time t_2 (> t_1) the decay constant λ is
   (A) $R_1t_1 = R_2t_2$ (B) $R_2 = R_1e^{-\lambda(t_2-t_1)}$
   (C) $R_2 = R_1e^{-\lambda(t_1-t_2)}$ (D) $\frac{R_1-R_2}{t_2-t_1} = \text{constant}$

II : [Question No. 4 to 6]

All nuclei consist of two type of particles protons and neutrons. Nuclear force is the strongest force. Stability of nucleus is determined by the neutron–proton ratio or mass defect or Binding energy per nucleons or packing fraction. Shape of nucleus calculated by quadrupole moment. Spin of nucleus depends on even or odd mass number. Volume of nucleus depends on the mass number. Whole mass of atom (nearly 99%) is centred at the nucleus. Magnetic moment of nucleus measured by the nuclear magnetons.

4. The correct statement(s) about nuclear force is/are
   (A) Charge independent (B) Short ranges forces
   (C) Non conservative force (D) All option are correct

5. Volume (V) of the nucleus is related with mass number (A) as
   (A) $V \propto A^2$ (B) $V \propto A^{1/3}$
   (C) $V \propto A^{2/3}$ (D) $V \propto A$

6. The mass defect in a particular nuclear reaction is 0.5 gram. The amount of heat energy liberated in Joule is
   (A) 4.5×10^{13} Joule (B) 45×10^{16} Joule
   (C) 45×10^{15} Joule (D) 0.5×931 Joule

MATCH THE FOLLOWING

1. Match the following :

Column I		Column II	
(A)	Particle behaviour of light	(p)	Reflection
(B)	Electron microscope	(q)	Refraction
(C)	X–ray photon	(r)	Interference
(D)	Spectrum	(s)	Photoelectric effect

2. Some quantities related to the photoelectric effect are mentioned under Column I and Column II. Match each quantity in Column I with the corresponding quantities in Column II on which it depends.

Column I		Column II	
(A)	Saturation current	(p)	Frequency of light
(B)	Stopping potential	(q)	Work function
(C)	de-Broglie wavelength of photoelectron	(r)	Area of photosensitive plate
(D)	Force due to radiation falling on the photo–plate.	(s)	Intensity of light (at constant frequency)

3. Match the following :

Column I		Column II	
(A)	β decay	(p)	For atoms of high atomic number
(B)	Fusion	(q)	Mass energy equivalence
(C)	Fission	(r)	For atoms of low atomic number
(D)	Exothermic nuclear reaction	(s)	Involves weak forces

11. Answers to the Subjective Assignment

LEVEL – I

1. 42

2. $\frac{1}{\lambda} = \frac{2}{\ln(4/3)}$ sec

3. 0.6887 A^0

4. 1.84×10^{-6} Amp

5. -0.055 V

6. 9.1×10^{14} per sec, 6.0×10^{-19} J, 4.0×10^{-19} J

7. 0.148 m.

8. (a) 5.23×10^{-19} J, 3.27 eV (b) 1.5 eV (c) 0.7289×10^{6} m/s

9. 1 MW

10. 1.81×10^{-7} m

LEVEL – II

1. n = 2.

2. 42, 28, 17.5 KV

3. 35.24 A^0

4. 2eV, $(12400/\lambda)$eV,

5. 29

6. 310.5 A^0, 1242 A^0

7. 3×10^{20} m^{-2} sec^{-1}

8. 3.125×10^{16}, 356.3 gm

9. $\frac{eh}{4\pi m}$; $\frac{ehB}{8\pi m}$

10. $N_2 = N_0 \frac{\lambda_1}{\lambda_2 - \lambda_1}\left[e^{-\lambda_1 t} - e^{-\lambda_2 t}\right]$

12. Answers to the Objective Assignment

LEVEL – I

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

LEVEL – II

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

COMPREHENSION

1.	(D)	2.	(C)
3.	(B)	4.	(D)
5.	(D)	6.	(A)

MATCH THE FOLLOWING

1. (A) – (p), (q), (s); (B) – (r); (C) – (p), (q), (r), (s); (D) – (q)

2. (A) – (s); (B) – (p), (q); (C) – (p), (q); (D) – (p), (r), (s)

3. (A) – (q), (s); (B) – (q), (r); (C) – (p), (q); (D) – (q)