PHYSICS

The following questions consist of two statements each, printed as Assertion and Reason. While answering these questions you are to choose any one of the following four responses.

(A) If both Assertion and Reason are true and the Reason is correct explanation of the Assertion.

(B) If both Assertion and Reason are true but Reason is not correct explanation of the Assertion.

(C) If Assertion is true but the Reason is false.

(D) If Assertion is false but Reason is true

Q.1 **Assertion :** According to classical theory, the proposed path of an electron in Rutherford atom model will be parabolic.

Reason : According to electromagnetic theory, an accelerated particle continuously emits radiation.

Sol. **[D]**

Assertion is false but reason is true.

According to classical electromagnetic theory, an accelerated charge continuously emits radiation. As electrons revolving in circular paths are constantly experiencing centripetal acceleration, hence, they will be losing their energy continuously and the orbital radius will go on decreasing and form spirals and finally the electron will fall on the nucleus.

Q.2 **Assertion** : Total energy of revolving electron in any stationary orbit is negative.

Reason : Energy is scalar quantity which can be +ve or –ve. **[B]**

Q.3 **Assertion** : Balmer series lies in the visible region of electromagnetic spectrum.

Reason : For balmer series $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{K^2}\right)$

where K = 3, 4, 5,..... **[B]**

Q.4 **Assertion** : An electron in hydrogen atom passes from n = 4 to n = 1 level. The maximum number of photons that can be emitted is 6.

Reason : No. of photons emitted can never be more than 5. **[C]**

Q.5 **Assertion** : In outer most stationary orbit, energy of electron is least negative.

Reason : In such an orbit, electron is at maximum distance from the nucleous. **[B]**

Q.6 **Assertion :** The wavelength of first Balmer line of deuterium is slightly more than that of hydrogen.

Reason : In the centre of mass of an atom reference frame both nucleus and electron are non-stationary. **[D]**

Sol. $\frac{1}{\lambda} \propto R \propto \mu$

$\Rightarrow \mu_D > \mu_H$

Q.7 **Assertion :** In a hydrogen atom energy of emitted photon corresponding to transition from n = 2 to n = 1 is much greater as compared to transition from n = ∞ to n = 2.

Reason : Wavelength of photon is directly proportional to the energy of emitted photon. **[C]**

Q.8 **Statement-1/Assertion :** In outer most orbit energy of electron is most negative.

Statement-2/ Reason : In such orbit electron is at maximum distance from nucleus. **[A]**

Q.9 **Assertion :** Magnetic moment of an atom is due to both, the orbital motion and spin motion of every electron.

Reason : A charged particle produces a magnetic field. **[C]**

Q.10 **Assertion :** Total energy in an orbit is negative in an atom.

Reason : Electron is bounded by electrostatic attraction between electron and nucleus. **[A]**

Sol. Both Assertion & Reason are correct & Reason is the correct explanation of Assertion.

Q.11 **Statement I :** Distance of closest approach for free target is more than that for fixed target.
Statement II : Total energy is conserved for free target but not for fixed target. **[C]**

Q.12 **Assertion :** Between any two given energy levels, the number of absorption transition is always less than number of emission transition.
Reason : Absorption transition starts from the lowest energy level only and may end at any higher level. But emission transitions may starts from any higher energy level and end at any energy level below it.

Sol. **[A]**
Both (A) and (R) are true and (R) is the correct explanation of (A).

Q.13 **Assertion :** An electron in hydrogen atom passes from n = 4 to n =1 level. The maximum number of photons that can be emitted is 6.
Reason : Maximum number of photons emitted in any case can only be 4.

Sol. **[C]** (A) is true but (R) is false.

Q.14 **Statement I :** Total energy of revolving electron in any stationary orbit is negative.
Statement II : Energy is a scalar quantity and it can take positive and negative value.

Sol. **[B]**
Total energy is negative because electron is bound to the atom due to coulomb attraction. And in bound system energy is negative.

Q.15 **Statement I :** In outermost stationary orbit, energy of electron is least negative.
Statement II : In outermost orbit, electron is at maximum distance from nucleus.

Sol. **[B]**
At outermost orbit total energy is zero and electron is free from atom.

Q.16 **Statement I :** e^- can absorb 10.2eV energy in its ground state in H-atom
Statement II : e^- can only absorb energy equal to energy difference between two levels in bounded state.

Sol. **[D]**
e^- can absorb only those energies which are just equal to energy difference

Q.17 **Statement I :** Balmer series lies in the visible region of electro magnetic spectrum.
Statement II : For Balmer series $\lambda = \frac{3648 \text{Å} n^2}{n^2 - 4}$
where n = 3, 4, 5,.... and wavelength of visible light-ranges from 3800 Å to 7200Å. **[A]**

Q.18 **Statement-I :** In a hydrogen atom energy of emitted photon corresponding to transition from n = 2 to n = 1 is much greater as compared to transition from n = ∞, to n = 2
Statement-II : Wavelength of photon is directly proportional to the energy of emitted photon

Sol.[C] Lyman series - its energy is in the ultra violet region
Balmer series - its energy is in vissible region

Q.19 **Statement I :** In a hydrogen atom, the fraction 1836/1837 of the atomic mass is carried by the positive charge.
Statement II : In hydrogen atom, electron (m_e) revolves around proton (m_p = 1836 m_e) **[A]**

Q.20 **Statement I :** In outermost orbit energy of electron is most negative.
Statement II : In such orbit electron is at maximum distance from nucleus. **[D]**

PHYSICS

Q.1 **Column I** **Column II**

(A) Binding energy of electron in doubly ionised lithium atom — (P) 340 eV

(B) Energy that can remove electron from first excited state of triply ionised beryllium atom — (Q) 3.4 eV

(C) Ionisation energy of tetra ionised boron — (R) 122.4 eV

(D) Energy obtained in assembling singly ionised helium atom so that the atom can be in ground state or other exited states — (S) 54.4 eV

Ans. **(A) $\rightarrow$ R ; (B) $\rightarrow$ P,R,S ; (C) $\rightarrow$ P ; (D) $\rightarrow$Q,S**

Q.2 **COLUMN I** **COLUMN II**

COLUMN I	COLUMN II
(A) Angular speed	(P) $\propto \frac{n^3}{Z^2}$
(B) Time period	(Q) $\propto n$
(C) Angular momentum	(R) $\propto \frac{Z^2}{n^3}$
(D) Magnetic moment	(S) $\propto \frac{Z^3}{n^5}$
(E) Magnetic Field	

Ans. **A $\rightarrow$ R ; B $\rightarrow$ P ; C $\rightarrow$ Q ; D $\rightarrow$ Q ; E $\rightarrow$ S**

Q.3 Some laws / processes are given in **Column** I . Match these with the physical phenomena given in **Column** II. **[IIT -JEE 2007]**

Column-I

(A) Transition between two atomic energy levels

(B) Electron emission from a material

(C) Mosley's law

(D) Change of photon energy into kinetic energy of electrons

Column-II

(P) Characteristic X -rays

(Q) Photoelectric effect

(R) Hydrogen spectrum

(S) β-decay

Ans. **A $\rightarrow$ P, R; B $\rightarrow$ Q, S; C$\rightarrow$ P; D $\rightarrow$ R, Q**

Q. 4 **Column - I** **Column II**

(A) Binding Energy of electron in triply ionised Lithium atom — (P) 340 eV

(B) Energy that can remove electron from first excited state of tetra ionised Beryllium atom — (Q) 3.4 eV

(C) Ionisation energy of pentaionised Boron — (R) 122.4eV

(D) Energy obtained in assembling singly ionised Helium atom so that the atom can be in ground state or other excited states — (S) 54.4 eV

Sol. **A $\rightarrow$ R, B $\rightarrow$ S, C $\rightarrow$ P, D $\rightarrow$ Q, S**

Ionisation energy or Binding energy

$E_0 = Z^2.(13.6 \text{ eV})$

Z = 3 for Lithium. $E_0 = (3)^2 (13.6)$

$= 9 \times 13.6$

$E_0 = 122.4$ eV

Energy of electron in any state in any atom is –

$$E = -\frac{Z^2}{n^2} \times 13.6 \text{ eV}$$

For Z = 4, n = 2; i.e., for Beryllium in first excited state

$$E = -\frac{16}{4} \times 13.6$$

E = – 54.4 eV

Energy required is $E_{req} = -E = 54.4$ eV

• Ionisation energy of pentaionised Boron is

$E_0 = (Z)^2 \times (13.6) = (5)^2 \times 13.6$

$E_0 = 25 \times 13.6 = 340$ eV

• When a system is assembled from its constituents energy is released (obtained)

For He^+ atom in ground state, $E_1 = \frac{4 \times (13.6)}{(1)} =$ 54.4 eV

For He^+ atom in third excited, $E_2 = \frac{4 \times 13.6}{(4)^2}$

$$E_2 = \frac{13.6}{4} = 3.4 \text{ eV}$$

Q.5 Column-I contains the process of emission of electrons while column-II contains the method to achieve emission. Match column I and II.

Column I	Column II
(A) Thermionic emission	(P) By irradiating with light
(B) Photoelectric emission	(Q) By applied strong electric field
(C) Field emission	(R) By colliding accelerated electrons on metals
(A) Secondary emission	(S) By heating

Ans. **A → S; B → P ; C → Q ; D → R**

Q. 6

Column - I	Column II
(A) Binding energy of electron in triply ionised Lithium in atom	(P) 340 eV
(B) Energy that can remove electron from first excited state of tetra ionised Berlyllium atom	(Q) 3.4 eV
(C) Ionisation energy of pentaionised Boron	(R) 122.4 eV
(D) Energy obtained in assembling singly ionised Helium atom so that the atom can be in ground state or other excited states	(S) 54.4 eV

Sol. **A → R; B → P,R,S; C → P; D → Q, S**

Ionisation energy or Binding energy

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Energy of electron in any state in any atom is –

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Q.7 Some laws / processes are given in **Column** I. Match these with the physical phenomena given in **Column** II. **[IIT - 2007]**

Column I	**Column** II
(A) Transition between two atomic energy levels	(P) Characteristic X-rays
(B) Electron emission from a material	(Q) Photoelectric effect
(C) Mosley's law	(R) Hydrogen spectrum
(D) Change of photon energy into kinetic energy	(S) β-decay of electrons

Ans. **A → (P, R)** **B → (Q, S) ;**
C → (P) **D → (R, Q)**

Q.8 The energy, the magnitude of linear momentum, magnitude of angular momentum and orbital radius of an electron in a hydrogen atom corresponding to the quantum number n are E, p, L and r respectively. Then according to Bohr's theory of hydrogen atom match the expressions in Column-I with statement in Column-II**:**

Column -I	Column-II
(A) Epr	(P) is independent of n
(B) $\frac{p}{E}$	(Q) is directly proportional to n
(C) Er	(R) is inversely proportional to n
(D) pr	(S) is directly proportional to L

Sol. **A → P, S;** **B → Q, S;**
C → Q, S; **D → S**

Q.9

Column I	Column II
(a) Ultraviolet light	(p) $n = 6 \rightarrow n = 3$
(b) Visible light	(q) $n = 3 \rightarrow n = 1$
(c) Infrared radiation	(r) $n = 4 \rightarrow n = 2$
(d) Micro wave	(s) $n = 7 \rightarrow n = 6$

(A) $a \rightarrow p$, $b \rightarrow q$, $c \rightarrow r$, $d \rightarrow s$
(B) $a \rightarrow q$, $b \rightarrow r$, $c \rightarrow p$, $d \rightarrow s$
(C) $a \rightarrow q$, $b \rightarrow p$, $c \rightarrow r$, $d \rightarrow s$
(D) $a \rightarrow s$, $b \rightarrow r$, $c \rightarrow q$, $d \rightarrow p$ **[B]**

Q.10

Column-I	Column-II
(a) Radius of orbit is related with atomic number (Z)	(p) is proportional to Z
(b) Current associated due to orbital motion of electron with atomic number (Z)	(q) is inversely proportional to Z
(c) Magnetic field at the centre due to orbital motion of electron related with Z	(r) is proportional to Z^2
(d) Velocity of an electron related with atomic number (Z)	(s) is proportional to Z^3

(A) $a \rightarrow q$, $b \rightarrow p$, $c \rightarrow s$, $d \rightarrow r$
(B) $a \rightarrow r$, $b \rightarrow s$, $c \rightarrow p$, $d \rightarrow q$
(C) $a \rightarrow r$, $b \rightarrow q$, $c \rightarrow p$, $d \rightarrow s$
(D) $a \rightarrow q$, $b \rightarrow r$, $c \rightarrow s$, $d \rightarrow p$ **[D]**

Q.11 Column – I is a physical quantity related to orbiting electron in a hydrogen like atom, the term Z and n given in column II have usual meaning in Bohr's theory.

Column-I	Column-II
(A) Frequency of orbiting electron	(P) is directly proportional to Z^2
(B) Angular momentum of orbiting electron	(Q) is directly proportional to n
(C) Magnetic moment of orbiting electron	(R) is inversely proportional to n^3
(D) The average current due to orbiting of electron	(S) is independent of Z
	(T) is different for different hydrogen like atom

Sol. A $\rightarrow$ P,R,T ; B $\rightarrow$ Q,S ; C $\rightarrow$ Q,S ; D $\rightarrow$ P,R,T

Q.12 Match the following -

Column-I	Column-II
(A) Atomic excitation	(P) Absorption spectrum
(B) Lyman series	(Q) Independent of mass of electron
(C) Rydberg constant	(R) Inelastic collision
(D) Speed of electron	(S) Dependent on mass of electron

Sol. A $\rightarrow$ R B $\rightarrow$ P C $\rightarrow$ S D $\rightarrow$ Q

Q.13 For transition of electrons match the following -

Column-I	Column-II
(A) n = 5 to n = 2	(P) Lyman series
(B) n = 8 to n = 4	(Q) Brackett series
(C) n = 3 to n = 1	(R) Paschen series
(D) n = 4 to n = 3	(S) Balmer series

Sol. A $\rightarrow$ S B $\rightarrow$ Q C $\rightarrow$ P D $\rightarrow$ R

Q.14 Match the following -

Column-I	Column-II
(A) Energy of second excited state of hydrogen	(P) – 3.4 eV
(B) Energy of fourth state of He^+	(Q) + 13.6 eV
(C) Energy of first excited state of Li^{2+}	(R) – 1.5 eV
(D) Excitation energy of hydrogen atom	(S) None

4. A $\rightarrow$ R B $\rightarrow$ P C $\rightarrow$ S D $\rightarrow$ Q

Q.15 Match the following column -

Column I	Column II
(a) Orbital current (i)	(p) $\propto n^3/Z^2$
(b) Magnetic field (B)	(q) $\propto Z^2/n^2$
(c) Kinetic energy (K)	(r) $\propto Z^2/n^3$
(d) Time period (T)	(s) $\propto Z^3/n^5$

Sol.[B] $a \to r, \quad b \to s, \quad c \to q, \quad d \to p$

$$i = 1\text{ mA}\frac{Z^2}{n^3}\ ;\ B = 12.5\text{ tesla}\ \frac{Z^3}{n^5}\ ;\ K = 13.6\text{ eV}\ \frac{Z^2}{n^2}\ ;$$

$$T = 1.5 \times 10^{-16}\text{ s}\ \frac{n^3}{Z^2}$$

Q.16 Match the Column :

Column - I	**Column - II**
(A) Atomic excitation	(P) Absorption spectrum
(B) Lyman series	(Q) Independent of mass of electron
(C) Rydberg constant	(R) Inelastic collision
(D) Bohr's atomic model	(S) Dependent on mass of electron
(E) Speed of electron	(T) Stationary orbit

Sol. (A) $\to$ (R), (B) $\to$ (P), (C) $\to$ (S), (D) $\to$ (T), (E) $\to$ (Q)

Q.17 Match the column :

Column-I	**Column-II**
(p) Angular momentum	(a) $\frac{nh}{2\pi}$
(q) Total energy of atom	(b) $-13.6\frac{Z^2}{n^2}$
(r) Potential energy of atom	(c) $-13.6\frac{n^2}{Z^2}$
	(d) $2 \times \left(-13.6\frac{Z^2}{n^2}\right)$
	(e) $\frac{1}{2} \times \left(-13.6\frac{Z^2}{n^2}\right)$

(A) $p \to a, \quad q \to b, \quad r \to d$

(B) $p \to a, \quad q \to d, \quad r \to e$

(C) $p \to q, \quad q \to e, \quad r \to c$

(D) none of these

Sol.[A] Remember.

Q.18 E, p and r are the energy, linear momentum and orbit radius of an electron in a hydrogen atom corresponding to quantum number n. Then the correct matching of Column-I from Column-II is –

Column-I	**Column-II**
(a) $\frac{E}{p}$	(p) n^3
(b) Epr	(q) n^2
(c) $\frac{r}{p}$	(r) $\frac{1}{n}$
(d) Er	(s) None of these

Sol. **[a $\to$ r, b $\to$ r, c $\to$ p, d $\to$ s]**

$E \propto \frac{1}{n^2}$; $p \propto \frac{1}{n}$; $r \propto n^2$

$\frac{E}{p} \propto \frac{1}{n}$ and $Epr \propto \frac{1}{n}$

$\frac{r}{p} \propto n^3$ and Er = constant.

Q.19 f_1 is maximum frequency of Lyman series, f_2 is minimum frequency Lyman series and f_3 is maximum frequency of Balmer series. Then match columns :

Column –I	**Column-II**
(a) f_1	(P) Greater than f_3
(b) f_2	(Q) is negative
(c) $(f_2 - f_1)$	(R) less than f_2
(d) $(f_1 - f_2)$	(S) is equal to f_3

Sol.[A] $f \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow f = k\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

k = constant.

for f_1

$n_1 = 1;\ n_2 \to \infty; \quad \therefore\ f_1 = k$

for f_2

$n_1 = 1;\ n_2 = 2$

$f_2 = \frac{3k}{4}$

for f_3

$n_1 = 2;\ n_2 \to \infty$

$f_3 = \frac{k}{4}$

$\therefore\ f_1 - f_2 = f_3$

Ans. $a \to P,\ b \to P,\ c \to Q,\ d \to S$

Q. 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 to 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 the nth orbit is proportional to n^{-2}

(D) energy is proportional to m^3 (m = mass of electron) **[A,B]**

Sol. $|F| = \frac{du}{dr} = \frac{Ke^2}{r^4}$ . . . (1)

$\frac{Ke^2}{r^4} = \frac{mv^2}{r}$ . . . (2)

and $mvr = \frac{nh}{2\pi}$ . . . (3)

By (2) and (3)

$r = \frac{Ke^2 4\pi^2}{h^2}\frac{m}{n^2} = k_1\frac{m}{n^2}$ . . . (4)

Total energy = 1/2 (potential energy)

$= \frac{-Ke^2}{6r^3} = \frac{-Ke^2}{6\left(\frac{K_1 m}{n^2}\right)^3} = \frac{-Ke^2 n^6}{6K_1^3 m^3}$

Total energy $\propto n^6$

Total energy $\propto m^{-3}$

Q. 2 If electron of the hydrogen atom is replaced by another particle of same charge but of double the mass, then choose correct option (s) -

(A) Bohr radius will increase to double value

(B) Ionisation energy of the atom will be doubled

(C) Speed of the new particle in a given state will be one fourth of what electron will possess in the same orbit

(D) Gap between energy levels will now be doubled **[B,D]**

Sol. $r \propto \frac{1}{m}$

$E_n \propto m$

mvr = constant for an orbit

$\therefore v \propto m$

Q. 3 If potential energy in hydrogen atom with electron in ground state is taken to be 13.6 eV, then -

(A) Potential energy in the first excited state would be 34 eV

(B) Total energy in the first excited state would be 37.4 eV

(C) Kinetic energy in the first excited state would be 44.2 eV

(D) Total energy in the ground state would be 27.2 eV **[A,B,D]**

Sol. In Ground state

KE = + 13.6 eV, PE = – 27.2 eV,

TE = – 13.6 eV

First excited state

KE = + 3.4 eV, PE = – 6.8 eV, TE = – 3.4 eV

Now PE and TE both will be increased by

13.6 – (– 27.2) = 40.8 eV

KE remains unchanged being independent of reference.

Q.4 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. It makes a transition to quantum state n, a photon of energy 40.8 eV is emitted, then –

(A) Z = 2 (B) Z = 4

(C) n = 1 (D) n = 2 **[B,D]**

Sol. $\Delta E = 204 = 13.6\ Z^2\left(\frac{1}{1} - \frac{1}{4n^2}\right)$

$40.8 = 13.6\ Z^2\left(\frac{1}{n^2} - \frac{1}{4n^2}\right)$

Solving we get,

Z = 4 and n = 2

Q.5 A mumesic atom is a hydrogen atom with electron replaced by muon whose mass is 210 times of mass of electron, then –

(A) Bohr radius of the mumesic atom is 0.0023 Å

(B) Ground state energy of mumesic atom is 2856 eV

(C) angular momentum in ground state is $\frac{h}{2\pi}$

(D) angular momentum in ground state is $\frac{(210)h}{2\pi}$

Sol. **[A,B,C]**

Radius of electron is given as :

$r \propto \frac{1}{m}$

$\frac{r}{r_0} = \frac{m_e}{m_\mu}$

$r = r_0\left(\frac{1}{210}\right) = 0.53Å \times \frac{1}{210} = 0.0023Å$

Energy: $E \propto m$

$E = E_0\left(\frac{m_\mu}{m_e}\right) = 13.6 \times 210 = 2856$ eV

Angular momentum is given as

$L = mvr = \frac{nh}{2\pi}$

For n = 1 : ground state

$L = \frac{h}{2\pi}$

Q.6 A positronium atom consists of a positron and electron revolving around their common centre of mass. Then as compared to hydrogen atom positronium atom has –

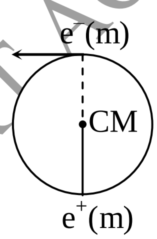
(A) Ground state energy half of hydrogen atom

(B) Rydberg constant half of hydrogen atom

(C) radius of first orbit of electron double that in case of hydrogen atom

(D) velocity of electron in first orbit same as in case of hydrogen atom

Sol. **[A,B,C,D]**



Reduced mass

$\mu = \frac{m_1 m_2}{m_1 + m_2} = \frac{m}{2}$

Energy : $E_0 \propto m$

$\therefore$ $E_0' \propto \mu \propto m/2$

$E_0'/E_0 = 1/2$

Rydberg constant

$R_y = E_0/hc \propto m$

$R_y' \propto \mu$

$R_y' / R_y = \mu/m = 1/2$

Radius of orbit –

$r = \frac{n^2}{Z}\ \frac{h^2\varepsilon_0}{\pi e^2 m}$

n = 1, Z = 1

$r = \frac{h^2\varepsilon_0}{\pi e^2 m} \propto \frac{1}{m}$

$r' \propto 1/\mu$

$r'/r = m/\mu = m/m/2 = 2$

Velocity of electron :

$v = e^2/h\varepsilon_0$

hence for positronium atom & hydrogen atom velocity of electron is same in both cases.

Q.7 In Bohr atom an electron is in the n^{th} state –

(A) Number of ways in which the atom can de-excite to ground state is 2^{n-2}

(B) Possible number of different photons that can be emitted is 2^{n-2}

(C) Minimum number of atoms required to obtain all possible number of photons is 2^{n-2}

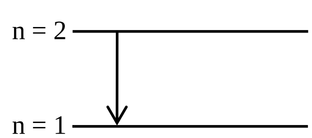
(D) Possible number of different photons that can be emitted is $\frac{n(n-1)}{2}$

Sol. **[A,C,D]**

Different possible number of photons = $\frac{n(n-1)}{2}$

No. of ways of de-excitation is 2^{n-2}

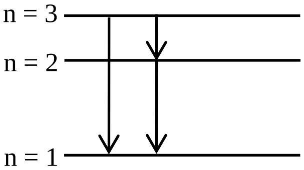
Let n = 2



$2^{n-2} = 2^{2-2} = 2^0$ = one way of de-excitation

$\frac{n(n-1)}{2} = 1$ photon

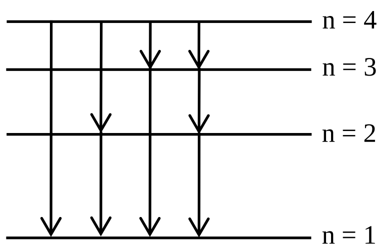
Let n = 3



$2^{n-2} = 2^{3-2} = 2^1 = 2$ = two ways of de-excitation

$\frac{n(n-1)}{2} = \frac{3 \times 2}{2} = 3$ photons of different types can possibly be emitted.

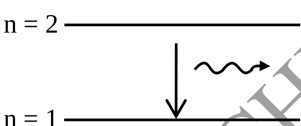
Let n = 4



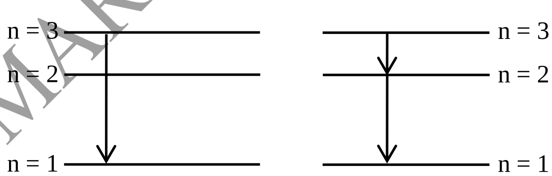
$2^{4-2} = 2^2 = 4$ = four ways of de-excitation.

$\frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6$ photons of different types can possibly be emitted.

$\boxed{\text{when } n = 2}$ To obtain one photon one atom is required

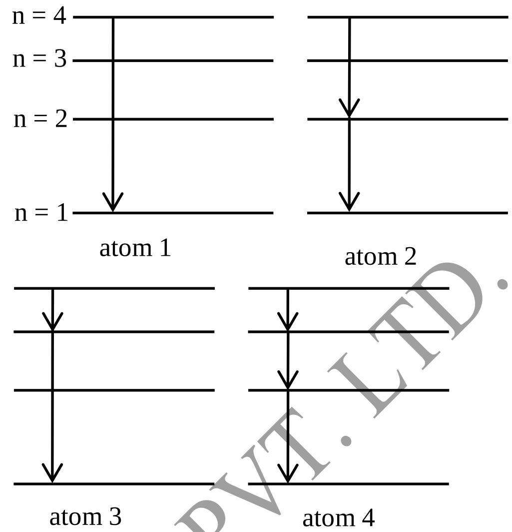


$\boxed{\text{when } n = 3}$ Three different possible photons; minimum two atoms are required



atom 1 atom 2

$\boxed{\text{when } n = 4}$ Six different possible photons; minimum four atoms are required



Q.8 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

Sol. **[B,C,D]**

Ground state n = 1

first excited state n = 2

$KE = \frac{1}{4\pi\varepsilon_0} \frac{e^2}{2r} (Z = 1)$

$\therefore\ KE = \frac{14.4 \times 10^{-10}}{2r}$ eV

Now $r = 0.53\, n^2$ A° (Z = 1)

$(KE)_1 = \frac{14.4 \times 10^{-10}}{2 \times 0.53 \times 10^{-10}}$ eV = 13.58 eV

$\therefore\ (KE)_2 = \frac{14.4 \times 10^{-10}}{2 \times 0.53 \times 10^{-10} \times 4}$ eV = 3.39 eV

KE decreases by = 10.2 eV

Now $PE = \frac{-1}{4\pi\varepsilon_0} \frac{e^2}{r} = \frac{-14.4 \times 10^{-10}}{r}$ eV

$\therefore\ (PE)_1 = \frac{-14.4 \times 10^{-10}}{0.53 \times 10^{-10}}$ eV = –27.1 eV

$(PE)_2 = \frac{-14.4 \times 10^{-10}}{0.53 \times 10^{-10} \times 4}$ = –6.79 eV

$\therefore$ PE increases by = 20.4 eV

Now Angular momentum ; L = mvr = $\frac{nh}{2\pi}$

$L_2 - L_1 = \frac{h}{2\pi} = \frac{6.6\times10^{-34}}{6.28} = 1.05 \times 10^{-34}$ J-sec.

Q.9 An electron orbiting in a circular orbit around the nucleus of an atom:
(A) has a magnetic dipole moment
(B) exerts an electric force on the nucleus equal to that on it by the nucleus
(C) does produces a magnetic induction at the nucleus
(D) has a net energy inversely proportional to its distance from the nucleus

[A, B, C, D]

Q.10 Which of the following products in a hydrogen atom is independent of the principle quantum number n ?
(A) U × n (B) E × r
(C) E × n (D) U × r **[B,D]**

Q.11 In the Bohr model of the hydrogen atom, let R, v and E represent the radius of the orbit, speed of e^- and total energy of the e^- respectively. Which of the following quantities is proportional to the quantum no. n ?
(A) vR (B) RE (C) V/E (D) R/E

[A,C]

Q.12 Let A_n be the area enclosed by the nth orbit in a hydrogen atom. The graph of $\ln\left(\frac{A_n}{A_1}\right)$ against ln(n) will–
(A) pass through origin
(B) be a straight line with slope 4
(C) be monotonically increasing nonlinear curve
(D) be a circle **[A,B]**

Q.13 Whenever a hydrogen atom emits a photon in the Balmer series–
(A) it may emit another photon in the Balmer series
(B) it must emit another photon in the lyman series
(C) the second photon if emitted will have a wavelength of about 122·4 nm
(D) it may emit a second photon, but the wavelength of this photon cannot be predicted **[B,C]**

Q.14 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. Then the posible 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) $n_1 = 6, n_2 = 3$

[A,D]

Q.15 Which of the following physical quantities in hydrogen atom are independent of the quantum number n. The symbols have their usual meanings
(A) nv (B) Ev
(C) Er (D) vr **[A,C]**

Sol. $v \propto \frac{1}{n}$

$E \propto \frac{1}{n^2}$

$r \propto n^2$

Q.16 The electron in a hydrogen atom makes a transition $n_1 \to n_2$ when n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are – **[IIT -JEE 1998]**
(A) $n_1 = 4, n_2 = 2$ (B) $n_1 = 8, n_2 = 2$
(C) $n_1 = 8, n_2 = 1$ (D) $n_1 = 6, n_2 = 3$

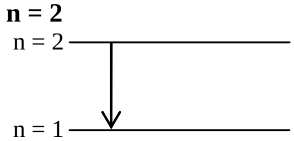
[A,D]

Q.17 In Bohr atom an electron is in the n^{th} state –
(A) Number of ways in which the atom can de-excite to ground state is 2^{n-2}
(B) Possible number of different photons that can be emitted is 2^{n-2}
(C) Minimum number of atoms required to obtain all possible number of photons is 2^{n-2}
(D) Possible number of different photons that can be emitted is = $\frac{n(n-1)}{2}$

[A,C,D]

Sol. Different possible number of photons = $\frac{n(n-1)}{2}$

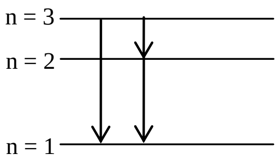
No. of ways of de-excitation is 2^{n-2}
Let n = 2



$2^{n-2} = 2^{2-2} = 2^0$ = one way of de-excitation

$\frac{n(n-1)}{2} = 1$ photon

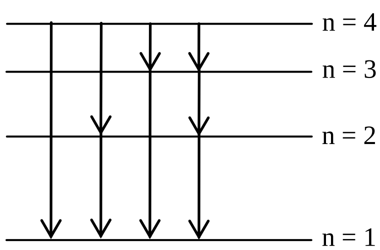
Let n = 3



$2^{n-2} = 2^{3-2} = 2^1 = 2$ = two ways of de-excitation

$\frac{n(n-1)}{2} = \frac{3 \times 2}{2} = 3$ photons of different types can possibly be emitted.

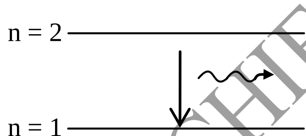
Let n = 4



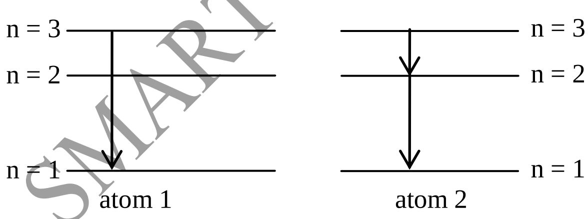
$2^{4-2} = 2^2 = 4$ = four ways of de-excitation.

$\frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6$ photons of different types can possibly be emitted.

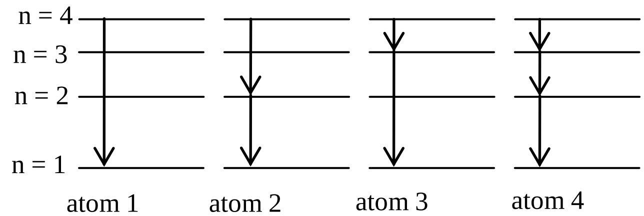
$\boxed{\text{when } n = 2}$ To obtain one photon one atom is required



$\boxed{\text{when } n = 3}$ Three different possible photons; minimum two atoms are required



$\boxed{\text{when } n = 4}$ Six different possible photons; minimum four atoms are required



Q.18 A mumesic atom is a hydrogen atom with electron replaced by muon whose mass is 210 times of mass of electron –

(A) Bohr radius of the mumesic atom is 0.0023 Å

(B) Ground state energy of mumesic atom is 2856 eV

(C) angular momentum in ground state is $\frac{h}{2\pi}$

(D) angular momentum in ground state is $\frac{(210)h}{2\pi}$ **[A,B,C]**

Sol. Radius of electron is given is:

$r \propto \frac{1}{m}$

$\frac{r}{r_0} = \frac{m_e}{m_\mu}$

$r = r_0\left(\frac{1}{210}\right) = 0.53\text{Å} \times \frac{1}{210} = 0.0023\text{Å}$

Energy: $E \propto m$

$E = E_0\left(\frac{m_\mu}{m_e}\right) = 13.6 \times 210 = 2856$ eV

Angular momentum is given as

$L = mvr = \frac{nh}{2\pi}$

For n = 1 : ground state

$L = \frac{h}{2\pi}$

Q.19 In Bohr atom an electron is in the n^{th} state –

(A) Number of ways in which the atom can de-excite to ground state is 2^{n-2}

(B) Possible number of different photons that can be emitted is 2^{n-2}

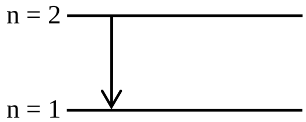
(C) Minimum number of atoms required to obtain all possible number of photons is 2^{n-2}

(D) Possible number of different photons that can be emitted is $\frac{n(n-1)}{2}$ **[A,C,D]**

Sol. Different possible number of photons = $\frac{n(n-1)}{2}$

No. of ways of de-excitation is 2^{n-2}

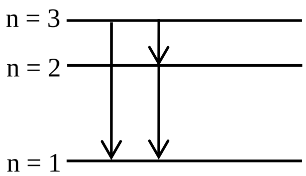
Let n = 2



$2^{n-2} = 2^{2-2} = 2^0$ = one way of de-excitation

$\frac{n(n-1)}{2}$ = 1 photon

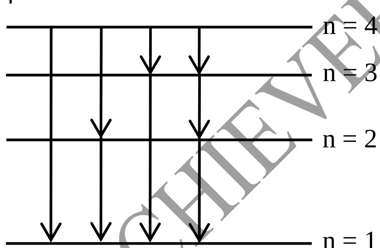
Let n = 3



$2^{n-2} = 2^{3-2} = 2^1 = 2$ = two ways of de-excitation

$\frac{n(n-1)}{2} = \frac{3\times 2}{2}$ = 3 photons of different types can possibly be emitted.

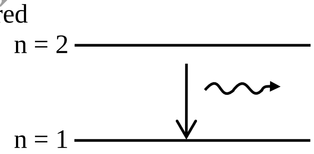
Let n = 4



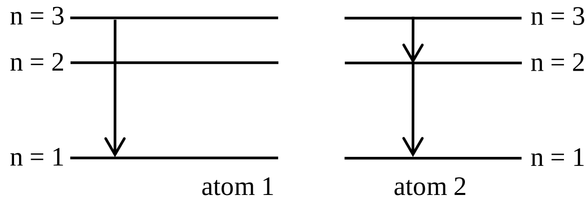
$2^{4-2} = 2^2 = 4$ = four ways of de-excitation.

$\frac{n(n-1)}{2} = \frac{4\times 3}{2}$ = 6 photons of different types can possibly be emitted.

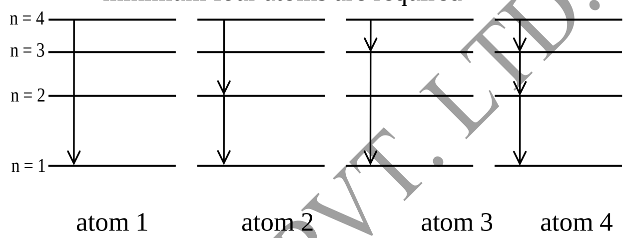
$\boxed{\text{when } n = 2}$ To obtain one photon one atom is required



$\boxed{\text{when } n = 3}$ Three different possible photons; minimum two atoms are required



$\boxed{\text{when } n = 4}$ Six different possible photons; minimum four atoms are required



Q.20 The electron in a hydrogen atom makes a transition from 2nd excited state to the ground state. Then-

(A) It's K.E. increases and total energy decreases

(B) Both its K.E. and total energy increases

(C) Frequency of emitted photons may be 4.6×10^{14} Hz

(D) Frequency of emitted photons must be 2.9×10^{15} Hz **[A,C]**

Sol. $\nu = CRZ^2 \left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$

$= 3 \times 10^8 \times 1.1 \times 10^7 \times 1 \left(\frac{1}{4} - \frac{1}{9}\right)$

$= 3.3 \times 10^{15} \times \frac{5}{36}$

$= \frac{16.5}{36} \times 10^{15}$

$\nu_{3\to 1} = 3 \times 10^8 \times 1.1 \times 10^7 \left(1 - \frac{1}{9}\right)$

$= 2.9 \times 10^{15}$ Hz

PHYSICS

Q.1 Find the quantum number 'n' corresponding to exciting state of He^+ ion if on transition to the ground state that ion emits two photons in succession with wavelength 1026.7 Å and 304 Å. ($R = 1.096 \times 10^7$ / m)

Sol.[6] According to conservation of energy

$$\frac{hc}{\lambda_1}+\frac{hc}{\lambda_2} = RchZ^2\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$$

n = 6.03

quantum number = 6

Q.2 The binding energy of an electron in the ground state of He atom is equal to 24.6 eV. The energy required to remove both the electrons (if the ionisation energy of hydrogen is 13.6 eV) is $N \times 10^1$ eV then N is equal to –

Sol. **[8]**

$$\text{Binding Energy} = 24.6 + 13.6 \times 2^2\left[\frac{1}{1^2}-\frac{1}{\infty}\right]$$

= 79 eV

Q.3 The ratio between total acceleration of the electron in singly ionized helium atom and hydrogen atom when both in ground state is -

Sol. **[8]** $a = \frac{V^2}{r} \Rightarrow a \propto \frac{(Z)^2}{(1/Z)} \Rightarrow a \propto Z^3$

Q.4 The shortest wavelength of the Brackett series of a hydrogen like atom of atomic number Z is same as the shortest wavelength of the Balmer series of hydrogen atom, then the value of Z is -

Sol. **[2]** Shortest wavelength of Brackett corresponds to n = 4 and n = ∞ and shortest wavelength of Balmer series corresponds to n = 2 and n = ∞

$$\therefore (Z^2)\left(\frac{13.6}{16}\right) = \frac{13.6}{4} \Rightarrow Z = 2$$

Q.5 A 100 eV electron collides with a stationary helium ion (He^+) in its ground state and exits to a higher level. After the collision, He^+ ions emits two photons in succession with wavelength 1085 Å and 304 Å. Calculate the energy of the electron after the collision (in 10^{-1} eV). Given $h = 6.63 \times 10^{-34}$ Js.

Sol. **[5]**

The energy of the electron in the n^{th} state of He^+ ion of atomic number Z is given by

$E_n = -(13.6)\text{ eV}\frac{Z^2}{n^2}$ for H^+ ion Z = 2. Therefore

$$E_n = -\frac{(13.6\text{eV})\times(2)^2}{n^2} = \frac{54.4}{n^2}\text{eV}$$

The energies E_1 and E_2 of the two emitted photons in eV are

$$E_1 = \frac{12431}{1085}\text{eV} = 11.4\text{ eV}$$

and $E_2 = \frac{12431}{304}$ eV= 40.9 eV

Thus total energy $E = E_1 + E_2 = 11.4 + 40.9 = 52.3$ eV

Let n be the principle quantum number of exited state.

Now we have for the transition from n = n to n = 1

$$E = -(54.4)\text{ eV}\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$$

But E = 52.3 eV. Therefore

$$52.3\text{ eV} = 54.4\text{ eV} \times\left(\frac{1}{1^2}-\frac{1}{n^2}\right)$$

$$\text{or } 1-\frac{1}{n^2} = \frac{52.3}{54.4} = 0.96$$

Which gives $n^2 = 25$ or n = 5

The energy of the incident electron = 100 eV (given). The energy supplied to He^+ ion = 52.3 eV. Therefore, the energy of the electrons left after the collision = 100 – 52.3 = 47.7 eV.

Q.6 A 100 eV electron collides with a stationary helium ion (He^+) in its ground state and excites to a higher level. After the collision, He^+ ions emits two photons in succession with wavelength 1085 Å and 304 Å. Also the energy of the electron after the collision is 6 × ….. eV (approximately). Given $h = 6.63 \times 10^{-34}$ Js.

Sol.[8] The energy of the electron in the n^{th} state of He^+ ion of atomic number Z is given by

$$E_n = -(13.6)\text{eV }\frac{Z^2}{n^2}$$

for He^+ ion Z – 2. Therefore

$$E_n = -\frac{(13.6eV)\times(2)^2}{n^2} = -\frac{54.4}{n^2}eV$$

The energies E_1 and E_2 of the two emitted photons in eV are $E_1 = \frac{12431}{1085}eV = 11.4$ eV

and $E_2 = \frac{12431}{304}eV = 40.9$ eV

Thus total energy $E = E_1 + E_2$

$= 11.4 + 40.9 = 52.3$ eV

Let n be the principle quantum number of excited state. Now we have for the transition from n = n to n = 1

$$E = -(54.4)\ eV\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$$

But E = 52.3 eV.

Therefore 52.3 eV = 54.4eV × $\left(1 - \frac{1}{n^2}\right)$

or $1 - \frac{1}{n^2} = \frac{52.3}{54.4} = 0.96$

which gives $n^2 = 25$ or n – 5

The energy of the incident electron = 100eV (given). The energy supplied to He^+ ion = 52.3eV.

Therefore, the energy of the electrons left after the collision = 100 – 52.3 = 47.7eV

PHYSICS

Q.1 Hydrogen atom emits blue light when it changes from n = 4 to n = 2 level. Which colour of light would the atom emit when it changes n = 5 to n = 2

(A) Red (B) Yellow
(C) Green (D) Violet **[D]**

Q.2 The ionisation potential of mercury is 10.39 volt. To gain energy sufficient enough to ionise mercury,an electron must travel in an electric field of 1.5×10^6 V/m, a distance of -

(A) $\frac{10.39}{1.5\times10^6}$ m
(B) $10.39 \times 1.5 \times 10^6$ m
(C) $10.39 \times 1.6 \times 10^{-19}$ m
(D) $\frac{10.39\times1.6\times10^{-19}}{1.5\times10^6}$ m **[A]**

Q.3 A hydrogen atom in its fourth excited state de-excites to ground state. The number of different possible ways of de-excitation are –

(A) 3 (B) 6
(C) 8 (D) 10 **[B]**

Q.4 The energy required to remove the electron from second execited state of Triply ionised Lithium is –

(A) 54.4 eV (B) 51 eV
(C) 40.8 eV (D) 122.4 eV **[C]**

Q.5 A hydrogen atom has electron in the fourth energy level. The number of different possible photons lie in which of following series –

(A) 3 Lyman, 2 Balmer, 1 Paschen
(B) 2 Lyman, 1 Balmer, 1 Paschen
(C) 2 Lyman, 1 Paschen, 1 Brackett
(D) 1 Lyman, 1 Balmer, 1 Paschen **[A]**

Q.6 According to Bohr correspondence principle when quantum number is very large –

(A) frequency of revolution of electron in an orbit is equal to the frequency of photon emitted when electron jumps from that orbit to next lower orbit
(B) classical physics approaches quantum physics
(C) wavelength of electron De Broglie wavelength does not depend on kinetic energy of electron
(D) Energy of electrons are not quantized **[A]**

Sol. Frequency of revolution of electron is $f \propto \frac{1}{n^3}$

frequency of photon emitted

$$\nu \propto \left(\frac{1}{(n-1)^2} - \frac{1}{n^2}\right)$$

$$\nu \propto \left[\frac{n^2-(n-1)^2}{n(n-1)]^2}\right]$$

$$\nu \propto \frac{[(2n-1)]}{n^2(n-1)^2}$$

when n >> 1

$$\nu \propto \frac{2n}{n^4}$$

$$\nu \propto \frac{1}{n^3}$$

Q.7 In a transition to a state of excitation energy 10.19ev, a hydrogen atom emits a 4890Aº photon. The Binding energy of the initial state is -

(A) 1.51 ev (B) 3.4 ev
(C) 0.54 ev (D) 0.87 ev **[D]**

Sol. Energy of emitted photon is

$E = \frac{hc}{\lambda}$ = 2.54 ev

The excitation energy is the energy to excite the atom to a level above the ground state.
Therefore the energy level is
E = – 13.6 + 10.19 = – 3.41 eV
Photon arises from transition between energy state such that

$E_i - E_f = h\nu = 2.54$ eV

$E_i = 2.54 + E_f$

$E_i = 2.54 + (E) = 2.54 - 3.41$eV = – 0.87eV

Q.8 According to Bohr model, magnetic field at centre (at the nucleus) of a hydrogen atom due to motion of electron in the n^{th} orbit is proportional to -

(A) $1/n^3$ (B) $1/n^5$

(C) n^5 (D) n^3 **[B]**

Sol. $B = \frac{\mu_0 i}{2r}$; magnetic field at centre of hydrogen atom i.e. at nucleus.

$i = \frac{e}{T} = ef = \alpha\ z^2/n^3$

$r \alpha n^2/Z$

$B \alpha i/r \alpha Z^3/n^5$

$B \alpha 1/n^5$

Q.9 The shortest wavelength of the Braqkett series of a hydrogen like atom (atomic number = Z) is the same as the shortest wavelength of the Balmar series of hydrogen atom. The value of Z is –

(A) 2 (B) 3

(C) 4 (D) 6 **[A]**

Sol. Shortest wavelength of Bracket series corresponds to the transition of electron $n_1 = 4$ and $n_2 = \infty$ and the shortest wavelength of Balmer series corresponds to the transition of electron between $n_1 = 2$ and $n_2 = \infty$. So

$$(Z^2)\left(\frac{13.6}{16}\right) = \left(\frac{13.6}{4}\right)$$

$\therefore\ Z^2 = 4$ or $Z = 2$

Q. 10 Assume an imaginary world, where angular momentum is quantized to even multiple $\hbar$. Find the longest possible wavelength emitted by Hydrogen in the visible spectrum.

(A) 700nm (B) 484 nm

(C) 600nm (D) 584 nm **[B]**

Sol. $Mvr = 2n\hbar$

or $mv = \frac{2n\hbar}{r}$

$mv^2 = \frac{m^2v^2}{n} = \frac{(2n\hbar)^2}{mr^2}$

$\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{mv^2}{r}$

or $\frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{(2n\hbar)}{mr^2(r)}$

or $r = \frac{(2n\hbar)24\pi\varepsilon_0}{mZe^2}$

$be = k + e = \frac{-Ze^2}{8\pi\varepsilon_0 r} = \frac{-Z^2e^4m}{8\pi\varepsilon_0(2n\hbar)^2 4\pi\varepsilon_0}$

$= \frac{-Z^2e^4m}{32\varepsilon_0 n^2h^2}$

$BE = \frac{-3.4}{n^2}$ eV for Hydrogen. To find longest wavelength $h\nu = 3.4\left[1-\frac{1}{4}\right]$

$= 3.4 \times \frac{3}{4} = 2.55$

$\lambda\ (nm) = \frac{1250}{2.55} = 484$ nm

Q.11 The ground state and first excited state energies of hydrogen atom are – 13.6 eV and –3.4 eV respectively. If potential energy in ground state is taken to be zero, then :

(A) Potential energy in the first excited state would be 20.4eV

(B) total energy in the first excited state would be 23.8 eV

(C) kinetic energy in the first excited state would 3.4 eV

(D) all of the above **[D]**

Q.12 When hydrogen like atom in excited state make a transition from excited state to ground state. Most energetic photons have energy E_{max} = 52.224 eV and least energetic photon have energy E_{min} = 1.224 eV. Find the atomic number -

(A) 4 (B) 6

(C) 2 (D) 8 **[C]**

Sol. Max energy is liberated for transition $E_n \rightarrow 1$ minimum energy for $E_n \rightarrow E_{n-1}$

Hence $\frac{E_1}{n^2} - E_1 = 52.224$ eV .....(i)

$\frac{E_1}{n^2} - \frac{E_1}{(n-1)^2} = 1.224$ eV.....(ii)

Solving (i) and (ii)

$E_1 = -54.4$eV

$E_1 = \frac{-13.6Z^2}{1^2}$

Z = 2

Q.13 Find the quantum number 'n' corresponding to the exciting state of He^+ ion. If on transition to the ground state that ion emits two photons in succession with wavelength 1026.7Å and 304 Å. (assume $R = 1.096 \times 10^7$/m).

(A) 4 (B) 6

(C) 2 (D) 1 **[B]**

Sol. $\frac{nc}{\lambda_1} + \frac{nc}{\lambda_2} = RchZ^2\left(\frac{1}{1^2} - \frac{1}{n^2}\right)$

put λ_1 = 1026.7 Å & λ_1 = 304 Å

Z = 2

Calculate n, n = 6

Q.14 α-particles are projected towards the nuclei of the following metals, with the same kinetic energy. Towards, which metal, the distance of closest approach is minimum ?

(A) Cu (Z = 29) (B) Ag (Z = 47)

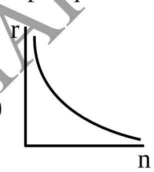
(C) Au (Z = 79) (D) Pd (Z = 46) **[A]**

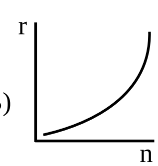
Q.15 The distance of closest approach of an α-particle fired towards a nucleus with momentum p, is r. What will be the distance of closest approach when the momentum of α-particle is 2p ?

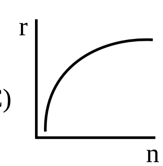
(A) 2r (B) 4r

(C) r/2 (D) r/4 **[D]**

Q.16 Which of the following curves may represent radius of orbit in H-atom as a function of principal quantum number ?

(A) 

(B) 

(C) 

(D) None **[B]**

Q.17 How many times larger is the spacing between the energy levels with n = 3 and n = 4 than the spacing between the energy levels with n = 8 and n = 9 for a hydrogen like atom or ion ?

(A) 0.71 (B) 0.41

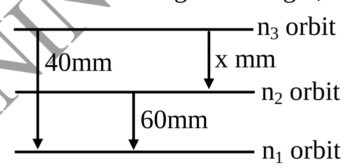
(C) 2.43 (D) 14.82 **[D]**

Q.18 Balmer gives an equation for wavelength of visible radiation of H-spectrum as $\lambda = \frac{kn^2}{n^2 - 4}$. The value of k in terms of Rydberg's constant R, is -

(A) R (B) 4R

(C) R/4 (D) 4/R **[D]**

Q.19 For an atom of ion having single electron, the following wavelengths are observed. What is the value of missing wavelength, x ?



(A) 20 (B) 40

(C) 60 (D) 120 **[D]**

Q.20 If an electron drops from 4th orbit to 2nd orbit in an H-atom, then -

(A) it gains 2.55 eV of potential energy

(B) it gains 2.55 eV of total energy

(C) it emits a 2.55 eV electron

(D) it emits a 2.55 eV photon **[D]**

Q.21 A H-atom moving with speed v makes a head on collision with a H-atom in rest. Both atoms are in ground state. The minimum value of velocity v for which one of atom may excite is -

(A) 6.25×10^4 m/s (B) 8×10^4 m/s

(C) 7.25×10^4 m/s (D) 13.6×10^4 m/s **[A]**

Q.22 Which of the following is wrong about spin of electron according to quantum mechanics ?

(A) It is related to intrinsic angular momentum

(B) Spin is rotation of electron about its own axis

(C) Value of spin quantum number must not be 1

(D) + $\frac{1}{2}$ value of spin quantum number represents up spin **[B]**

Q.23 What would happen, if the electrons in an atom were stationary ?
(A) The electrons will be pulled into the nucleus due to coulomb's attractive force.
(B) The structure of the atom would be more stable.
(C) The atom would be negatively charged.
(D) The rest portion of the atom would have been circulating around the electrons. **[A]**

Q.24 An α-particle of energy 5 MeV is scattered through 180º by a stationary uranium nucleus. The distance of closest approach is of the order of -
(A) 1Å (B) 10^{-10} cm
(C) 10^{-12} cm (D) 10^{-14} cm **[C]**

Q.25 In a head-on collision between an alpha particle and a gold nucleus, the distance of closest approach is 4×10^{-14} m. Calculate the energy of the α-particle in MeV –
(A) 5.2 (B) 5.0 (C) 5.69 (D) 5.86
[C]

Q.26 A proton moves with a speed of 7.45×10^5 m/s directly towards a free proton originally at rest. Find the distance of closest approach for the two protons. Take mass of a proton = 1.67×10^{-27} kg –
(A) 10^{-11} m (B) 10^{-12} m **[B]**
(C) 10^{-10} m (D) 10^{-9} m

Q.27 Consider a gold atom (Z = 79) model of radius 7×10^{-15} m according to Thomson. Find the strength of the electric field at the middle point of a radius, consider only positive charge –
(A) 2.1×10^{21} N/C (B) 3.2×10^{21} N/C
(C) 1.16×10^{21} N/C (D) 4.12×10^{21} N/C
[C]

Q.28 The Bohr radius of an atom of nuclear charge Z is of order –
(A) $\frac{\hbar}{Z\alpha mc}$ (B) $\frac{Z\alpha\hbar}{mc}$
(C) $\frac{mc}{Z\alpha\hbar}$ (D) $\frac{m\alpha}{Zc\hbar}$ **[A]**

Note : α is the fine structure constant $e^2/\hbar c$.

Sol. The Bohr radius for a hydrogen-like atom of nuclear charge Z and one electron outside complete shells is $\frac{\hbar}{me^2Z} = \frac{\hbar}{Z\alpha mc}$. Thus the correct answer is (A)

Q.29 The energy of an excited hydrogen atom is –3.4 eV. The angular momentum of the electron in that orbit according to Bohr's model will be :
(A) 2.11×10^{-36} J-s (B) 2.11×10^{34} J-s
(C) 2.11×10^{-34} J-s (D) none of these
[C]

Q.30 A hydrogen atom rises from its n = 1 state to the n = 4 state by absorbing energy. The energy absorbed by the atom in this transition is :
(A) 12.75 eV (B) 12.01 eV
(C) 1.89 eV (D) –3.4 eV **[A]**

Q.31 What is the wavelength of the radiation emitted when the electron in a H-atom jumps from n = ∞ to n = 2 ?
(A) 400 nm (B) 420 nm
(C) 350 nm (D) 365 nm **[D]**

Q.32 Find the binding energy of a H-atom in the state n = 2 –
(A) 2.1 eV (B) 3.4 eV
(C) 4.2 eV (D) 2.8 eV **[B]**

Q.33 Calculate the value of the first excitation potential of He^+ ion –
(A) 40.8 V (B) 20.4 V
(C) 10.2 V (D) 81.6 V **[A]**

Q.34 The angular momentum of an electron in an orbit is quantized because it is a necessary condition for the compatibility with:
(A) the wave nature of electron
(B) particle nature of electron
(C) Paulli's exclusion behaviour
(D) none of the above **[A]**

Sol. $mvr = \frac{nh}{2\pi}$

$\therefore \frac{h}{mv} = \frac{(2\pi r)}{n}$

$\frac{h}{mv}$ = de-Broglie wavelength

Q.34 If n >> 1, then the dependence of frequency of a photon, emitted as a result of transition of electron from n^{th} orbit to (n–1)th orbit, on n will be-
(A) $\upsilon \propto \frac{1}{n}$ (B) $\upsilon \propto \frac{1}{n^2}$

(C) $\upsilon \propto \frac{1}{n^3}$ (D) $\upsilon \propto \frac{1}{v^3}$ **[C]**

Q.36 In which of the following systems will the radius of the first orbit be minimum ?
(A) hydrogen atom
(B) deuterium atom
(C) singly ionized helium
(D) doubly ionized lithium **[D]**

Q.37 In which of the following systems will the wavelength corresponding to n = 2 to n = 1 be minimum ?
(A) H atom (B) D atom
(C) He^+ (D) Li^{+2} **[D]**

Q.38 As one consider orbits with higher values of n in a hydrogen atom, the electric potential energy of the atom.
(A) decreases (B) increases
(C) remains the same (D) does not increase
[B]

Q.39 The energy of an atom (ion) in its ground state is –54.4 eV. It may be –
(A) H (B) D
(C) He^+ (D) Li^{+2} **[C]**

Q.40 The radius of the shortest orbit in a one electron system is 18 pm. It may be–
(A) H (B) D
(C) He^+ (D) Li^{+2} **[D]**

Q.41-A A hydrogen atom in ground state absorbs 10.2 eV of energy. The orbital angular momentum of the electron is increased by -
(A) 1.05×10^{-34} Js (B) 2.11×10^{-34} Js
(C) 3.16×10^{-34} Js (D) 4.22×10^{-34} Js

Sol. **[A]**
$\Delta E = E_2 - E_1 = 10.2\text{eV} = -3.4\text{eV} + 13.6\text{eV}$
so, $n_2 = 2$ & $n_1 = 1$
$$\Delta L = \frac{2h}{2\pi} - \frac{h}{2\pi} = \frac{h}{2\pi} = \frac{6.63\times10^{-34}}{2\times3.14}\ \text{J.s}$$
$= 1.05 \times 10^{-34}$J.s

Q.41-B A particle moving with a velocity 1/10th of that of light will cross a nucleus in about-
(A) 10^{-47} s (B) 10^{-21} s
(C) 10^{-12} s (D) 10^{-8} s

Sol.. **[B]**
$$t = \frac{2r}{v} = \frac{210^{-15}\text{m}}{3\times10^{7}\text{m/s}} = \frac{2}{3}\times10^{-22}\text{s}$$

Q.42 The shortest wavelength of the Brackett series of a hydrogen like atom (atomic number = Z) is the same as the shortest wavelength of the Balmar series of hydrogen atom. The value of Z is:
(A) 2 (B) 3
(C) 4 (D) 6 **[A]**

Sol. Shortest wavelength of Brackett series corresponds to the transition of electron between $n_1 = 4$ and $n_2 = \infty$ and the shortest wavelength of Balmer series corresponds to the transition of electron between $n_1 = 2$ and $n_2 = \infty$, So,
$$(Z^2)\left(\frac{13.6}{16}\right) = \left(\frac{13.6}{4}\right)$$
$\therefore Z^2 = 4$ or $Z = 2$

Q.43 The binding energy of the deuteron is of order –
(A) 10^6 eV (B) 10^8 eV
(C) 10^{10} eV (D) None of these
[A]

Sol. The uncertainty principle gives $2pr \sim \hbar$, where p is the momentum of each nucleon and r is their separation, or
$$p \sim \frac{\hbar}{2r}.$$
The binding energy is then
$$\frac{p^2}{2m} \sim \frac{\hbar^2c^2}{8r^2mc^2} = \frac{(6.6\times10^{-16}\times3\times10^{10})^2}{8\times(1.4\times10^{-13})^2\times940\times10^6}$$
$= 2.7 \times 10^6$ eV.

Q.44 The binding energy of the ground state of positronium is a factor **f** times that of a hydrogen atom. **f** =
(A) 1 (B) $\frac{1}{2}$
(C) 2 (D) $\frac{1}{4}$ **[B]**

Sol. An electron moving in the field of a proton or positron has potential energy $-\frac{e^2}{\tau}$, for which the radial Schrodinger equation gives eigenvalue

$E_n = -\frac{\mu e^2}{2\hbar^2 n^2}$, n = 1, 2, 3, …..,

where μ is the reduced mass of the orbiting electron. For the positronium $\mu = \frac{1}{2} m_e$, for hydron atom $\mu \approx m_e$. Hence

$$f = \frac{E_p}{E_h} = \frac{\frac{1}{2} m_e}{m_e} = \frac{1}{2}.$$

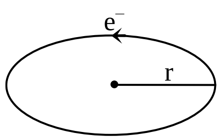
Q.45 When an electron revolves around the nucleus, then ratio of magnetic moment to angular momentum is –

(A) $\frac{e}{2m}$ (B) $\frac{2e}{m}$

(C) e/m (D) $(e/m)^2$ **[A]**

Sol. Angular momentum : $L = n\frac{h}{2\pi} = mvr$

Magnetic moment : $\mu = iA = \frac{e}{2\pi r} v \times \pi r^2$



$$\mu = \frac{e(vr)}{2}$$

$$\mu = \frac{e}{2}\left(\frac{L}{m}\right)$$

$$\boxed{\frac{\mu}{L} = \frac{e}{2m}}$$

Q.46 When an electron makes transition from one energy level to the other in an atom then which of the following quantities is conserved ?

(A) Angular momentum

(B) Linear momentum

(C) Mechanical energy

(D) None of the above **[D]**

Sol. Change in angular momentum

$\Delta L = (n_f - n_i)h/2\pi$

Since velocity of electron is

$v \propto \frac{1}{n}$

Hence linear momentum changes

Difference in energy between energy levels is released as electromagnetic energy.

Q.47 An α - particle after passing through a potential difference of V-volts collides with a nucleus. If the atomic number of the nucleus is Z then the distance of closest approach of α-particle to the nucleus will be -

(A) $14.4 \frac{Z}{V}$ Å (B) $14.4 \frac{Z}{V}$ m

(C) $14.4 \frac{Z}{V}$ cm (D) all of these **[A]**

Sol. K.E. = P.E. = qV

$2eV = \frac{K(Ze)(2e)}{d} = qV$

$\therefore d = \frac{9\times10^9 \times Z \times e \times 2e}{2eV}$

$\therefore d = \frac{9\times10^9 \times 1.6\times10^{-19} \times Z}{V}$

$d = 14.4 \times 10^{-10}\left(\frac{Z}{V}\right)$ m

Q.48 The wavelength of first line of Balmer series is 6563 Å. The wavelength of first line of Lyman series will be –

(A) 1215.4 Å (B) 2500 Å

(C) 7500 Å (D) 600 Å **[A]**

Sol. $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$$\frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5R}{36}$$

$$\frac{1}{\lambda_2} = R\left[\frac{1}{1} - \frac{1}{4}\right] = R\left(\frac{3}{4}\right) = \frac{3}{4}R$$

$$\therefore \frac{\lambda_2}{\lambda_1} = \frac{5/36}{3/4} = \frac{5}{36} \times \frac{4}{3} = \frac{5}{27}$$

$$\therefore \lambda_2 = \frac{5}{27}\lambda_1$$

$$\lambda_2 = \frac{5}{27} \times 6563\text{Å} = 1215.4\text{Å}$$

Q.49 The order of energies of energy levels A, B and C is $E_A < E_B < E_C$. If the wavelength corresponding to transition $C \rightarrow B$, $B \rightarrow A$ and $C \rightarrow A$ are λ_1, λ_2 and λ_3 respectively, then which of the following relation is correct ?

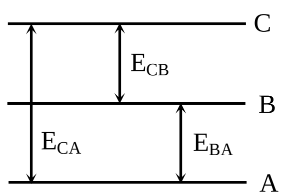
(A) $\lambda_1 + \lambda_2 + \lambda_3 = 0$

(B) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

(C) $\lambda_3 = \lambda_1 + \lambda_2$

(D) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$ **[D]**

Sol. $E_{CA} = E_{CB} + E_{BA}$



$$\frac{1}{\lambda_3} = \frac{\lambda_1 + \lambda_2}{\lambda_1\lambda_2}$$

$$\therefore \quad \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$$

Q.50 Which the following series fall in the visible range of electromagnetic spectrum ?

(A) Brackett series (B) Lyman series

(C) Balmer series (D) Paschan series **[C]**

Sol. $\frac{1}{\lambda} = R\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$

Balmer Series; $n_f = 2$; $n_i = 3, 4, 5.....$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left[\frac{5}{36}\right]$$

$$\lambda = \frac{36}{5} \times \frac{10^{-7}}{1.097}\text{ m}$$

$$\lambda = 6.56 \times 10^{-7}\text{ m}$$

$$\boxed{\lambda = 656 \times 10^{-9}\text{ m}}$$

This wavelength falls in visible range

PHYSICS

Q.1 Calculate the smallest wavelength of radiation that may be emitted by (a) hydrogen, (b) He^+ and (c) Li^{++}

Ans. (a) 91 nm (b) 23 nm (c) 10 nm

Q.2 Find the radius and energy of a He^+ ion in the states (a) n = 1, (b) n = 4 and (c) n = 10,

Ans. (a) 0.265 Å, – 54.4 eV
(b) 4.24 Å, – 3.4 eV
(c) 26.5 Å, – 0.544 eV

Q.3 (a) Find the first excitation potential of He^+ ion. (b) Find the ionization potential of Li^{++} ion.

Ans. (a) 40.8 V, (b) 122.4 V

Q.4 Show that the ratio of the magnetic dipole moment to the angular momentum (L = mvr) is a universal constant for hydrogen-like atoms and ions. Find its value.

Ans. $\frac{e}{2m} = 8.8 \times 10^{10}$ C/Kg

Q.5 Determine the value of orbital frequency in the first orbit of He^+.

Ans. 2.64×10^{16} Hz

Q.6 Considering hydrogen molecule to be monoatomic, at what temperature would average translational kinetic energy be sufficient to raise the atom from ground state to 1st excited state ?

Ans. 8×10^4 K

Q.7 The ionization energy of a hydrogen-like Bohr atom is 4 Rydberg.
(i) What is the wavelength of radiation emitted when the electron jumps from the first excited state to the ground state?
(ii) What is the radius of the first orbit for this atom ?

Ans. (i) 304 Å , (ii) 0.265 Å

Q.8 A single electron orbits around a stationary nucleus of charge +Ze where Z is a constant and e is the magnitude of electronic charge. It requires 47.2 eV to excite the electron from the second to the third Bohr orbit. Find :
(i) the value of Z,
(ii) the energy required to excite the electron from the third to the fourth Bohr orbit,
(iii) the wavelength of the electromagnetic radiation required to remove the electron from the first Bohr orbit to infinity,
(iv) the kinetic energy, potential energy and the angular momentum of the electron in the first Bohr orbit and
(v) the radius of the first Bohr orbit.

Ans. (i) 5 , (ii) 16.53 eV, (iii) 3.6×10^{-9} m,
(iv) 340 eV, – 680 eV, 1.05×10^{-34} kg m^2s^{-1}
(v) 0.1058 Å

Q.9 To what series does the spectral line of atomic hydrogen belong if its wave number is equal to the difference between the wave number of the following two lines of the Balmer series: 486.1 nm and 410.2 nm ? What is the wavelength of that line ?

Ans. (i) The Brackett series , (ii) λ = 26271Å°

Q.10 An electron in an unexcited hydrogen atom acquires an energy of 12. 1 eV. To what energy state did it go ? How many spectral lines may be emitted in the course of its transition to lower energy levels? Calculate corresponding wavelengths.

Ans. n = 3, 3 spectra lines, $\frac{4}{3r}, \frac{9}{8r}, \frac{36}{5r}$

Q.11 Calculate the Rydberg constant R if He^+ ions are known to have the wavelength difference between the first (of the longest wavelength) lines of the Balmer and Lyman series equal to $\Delta\lambda$ = 133.7 nm.

Ans. $R = \dfrac{88}{15z^2\Delta\lambda} = 1.097 \times 10^7\ m^{-1}$

Q.12 Suppose in an imaginary world the angular momentum is quantized to be even integral multiples of $h/2\pi$. What is the longest possible wavelength emitted by hydrogen atoms in visible range in such a world according to Bohr's model ?

Ans. 487 nm

Q.13 (a) Show that for large value of n, the frequency of radiation emitted when a H-atom de-excites from level n to level (n-1) equals the classical frequency of revolution of the electron in the orbit.

(b) Determine the value of ionization potential of the ground state of Li^{++} atom.

Ans. 122 V

Q.14 For hydrogen-like systems, find the magnetic moment μ_n corresponding to the motion of an electron along the n-th orbit and the ratio of the magnetic and mechanical moments μ_n/M_n. Calculate the magnetic moment of an electron occupying the first Bohr orbit.

Ans. $\dfrac{ne\hbar}{2m}$, $\dfrac{nh}{2\pi}$ and 9.23×10^{-24} amp-m^2

Q.15 A particle of mass m moves along a circular orbit in a centro-symmetrical potential field $U(r) = kr^2/2$. Using the Bohr quantization condition, find the permissible orbital radii and energy levels of the particle.

Ans. $r = \sqrt{n\hbar/m\omega}$ and $E = n\omega\hbar$

Q.16 Find the maximum coulomb force that can act on the electron due to the nucleus in a hydrogen atom.

Ans. 8.2×10^{-8} N

Q.17 Find the maximum angular speed of the electron of a hydrogen atom in a stationary orbit.

Ans. 4.1×10^{16} rad/sec

Q.18 A uniform magnetic field B exist in a region. An electron projected perpendicular to the field goes in a circle . Assuming Bohr's quantization rule for angular momentum, calculate (a) the smallest possible radius of the electron (b) the radius of the nth orbit and (c) the minimum possible speed of the electron.

Ans. (a) $\sqrt{\dfrac{h}{2\pi eB}}$, (b) $\sqrt{\dfrac{nh}{2\pi eB}}$, (c) $\sqrt{\dfrac{heB}{2\pi m^2}}$

Q.19 Electrons are emitted from an electron gun at almost zero velocity and are accelerated by an electric field E through a distance of 1.0 m. The electrons are now scattered by an atomic hydrogen sample in the ground state. What should be the minimum value of E so that red light of wavelength 656.3 nm may be emitted by the hydrogen ?

Ans. 12.1 V/m

Q.20 (a) Some of the energy levels of a hypothetical one electron atom, like hydrogen, are as follows :

n:	1	2	3	4	....	∞
E_n(eV) :	–18.5	–4.6	–2.6	–1.16	....	0

Calculate the wavelength of emitted photon when the electron jumps from n = 4 to n = 2. (b) In which spectroscopic range does it belong ?

Ans. (a) 3610 Å (b) Ultra Violet region