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4. HYDROGEN SPECTRUM

SOLUTIONS

TEACHING TASK

JEE MAINS LEVEL QUESTIONS

1. Last line of Lyman series for H–atom has wavelength λ_1 Å, 2nd line of Balmer series has wavelength λ_2 Å then

(A) $\frac{16}{\lambda_1} = \frac{9}{\lambda_2}$ (B) $\frac{16}{\lambda_2} = \frac{3}{\lambda_1}$ (C) $\frac{4}{\lambda_1} = \frac{1}{\lambda_2}$ (D) $\frac{16}{\lambda_1} = \frac{3}{\lambda_2}$

Answer:B

Solution:Last line of the Lyman series:

This corresponds to the transition from n=∞ to n=1.

$$\upsilon_2 = R_H(\frac{1}{2^2} - \frac{1}{\infty^2}) = R_H$$

$$\lambda_1 = \frac{1}{\upsilon_1} = \frac{1}{R_H}$$

The Balmer series transitions end at n=2. The second line corresponds to the transition from n=4 to n=2.

$$\upsilon_2 = R_H(\frac{1}{2^2} - \frac{1}{4^2}) = R_H(\frac{1}{4} - \frac{1}{16}) = \frac{3}{16}R_H$$

$$\lambda_2 = \frac{1}{\upsilon_2} = \frac{16}{3R_H}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{\frac{1}{R_H}}{\frac{16}{3R_H}} = \frac{3}{16}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{3}{16} \rightarrow \frac{16}{\lambda_2} = \frac{3}{\lambda_1}$$

2. For the Hydrogen spectrum, last line of the Lyman series has frequency ν_1, last line of Lymen series of He^+ ion has frequency ν_2 and last line of Balmer series of He^+ ion has frequency ν_3 then

(A) $2(\nu_1 + \nu_3) = \nu_2$ (B) $\nu_1 = \nu_3$ (C) $4\nu_1 = \nu_2$ (D) $\nu_2 = \nu_3$

Answer:A,B,C

Solution: $\upsilon = R(\frac{1}{n_1^2} - \frac{1}{n_2^2})Z^2$

For the Hydrogen spectrum, last line of the Lyman series has frequency ν_1

$n_1=1$ & $n_2=\infty$, $Z=1$

$$\upsilon_1 = R(\frac{1}{1^2} - \frac{1}{\infty^2})1^2$$

$$\upsilon_1 = R$$

last line of Lymen series of He^+ ion has frequency ν_2,

$n_1=1$ & $n_2=\infty$, $Z=2$

$$\upsilon_2 = R(\frac{1}{1^2} - \frac{1}{\infty^2})2^2$$

$$\upsilon_2 = 4R$$

last line of Balmer series of He^+ ion has frequency ν_3,

$n_1=2$ & $n_2=\infty$, $Z=2$

$$\upsilon_3 = R(\frac{1}{2^2} - \frac{1}{\infty^2})2^2$$

$$\upsilon_3 = R$$

(A) $2(\nu_1 + \nu_3) = \nu_2$

$2(R+R)=4R=\nu_2$

(B) $\nu_1 = \nu_3 = R$

(C) $4\nu_1 = \nu_2$

$4\nu_1 = \nu_2 = 4R$

3. Let u_1 be the frequency of the series limit of the Lyman series, u_2 be the frequency of the first line of the Lyman series, and u_3 be the frequency of the series limit of the Balmer series -

(A) $u_1 - u_2 = u_3$ (B) $u_2 - u_1 = u_3$ (C) $u_3 = 1/2\ (u_1 - u_C)$ (D) $u_1 + u_2 = u_3$

Answer:A

Solution: u_1 be the frequency of the series limit of the Lyman series

$n_1=1$ & $n_2=\infty$

$$u_1 = R(\frac{1}{1^2} - \frac{1}{\infty^2})1^2$$

$$u_1 = R$$

u_2 be the frequency of the first line of the Lyman series, $n_1=1$ & $n_2=2$

$$u_2 = R(\frac{1}{1^2} - \frac{1}{2^2})$$
$$u_3 = R(\frac{4-1}{4})$$
$$u_3 = R(\frac{3}{4}) = \frac{3R}{4}$$

u_3 be the frequency of the series limit of the Balmer series, $n_1=2$ & $n_2=\infty$

$$u_3 = R(\frac{1}{2^2} - \frac{1}{\infty^2})$$
$$u_3 = R(\frac{1}{4}) = \frac{R}{4}$$

(A) $u_1 - u_2 = u_3$

LHS $= u_1 - u_2 = R - \frac{3R}{4} = \frac{R}{4} = u_2 =$ RHS(true)

(B) $u_2 - u_1 = u_3$

$\frac{3R}{4} - R = -\frac{R}{4} = -u_3$(False)

(C) $u_3 = 1/2\ (u_1 - u_3)$

$1/2(R - \frac{R}{4}) = \frac{3R}{8} \neq u_3$ (false)

(D) $u_1 + u_2 = u_3$

$R + \frac{3R}{4} = \frac{7R}{4} \neq u_3$ (false)

4. The wave number of electromagnetic radiation emitted during the transition of electron in between two levels of Li^{2+} ion having sum of the principal quantum numbers 4 and difference is 2, will be : (R_H = Rydberg constant)

(A) 3.5 R_H (B) 4 R_H (C) 8 R_H (D) $\frac{8}{9} R_H$

Answer:C

Solution: Li^{2+} ion, Z=3

Given, $n_1+n_2=4$

$n_2-n_1=2$

Add both equations $n_1+n_2+n_2-n_1=6$

$2n_2=6 \rightarrow n_2=3$, So $n_1=1$

$$\upsilon = R(\frac{1}{1^2} - \frac{1}{3^2})3^2$$

$$\upsilon = R(\frac{9-1}{9})9$$

$$\upsilon = R(8) = 8R$$

5. If there are only two H-atoms, each is in 3rd excited state then :
   (A) Maximum number of different photons emitted is 4.
   (B) Maximum number of different photons emitted is 3.
   (C) Minimum number of different photons emitted is 1.
   (D) Minimum number of different photons emitted is 2.

Answer:A,C

Solution:Maximum number of different photons emitted=n+1

n=3

n+1=4

$4 \rightarrow 3$

$3 \rightarrow 2$

$2 \rightarrow 1$ maximum=4

$4 \rightarrow 1$

Minimum directly $4 \rightarrow 1$=1

6. In a H-like sample, electrons make transition from 4th excited state upto 2nd state. Then
   (A) 10 different spectral lines are observed
   (B) 6 different spectral lines are observed
   (C) number of lines belonging to the balmer series is 3
   (D) Number of lines belonging to paschen series is 2.

Answer:B,C,D

Solution:Number of Spectral lines= $\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$

n_2=5,n_1=2

$$\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2} = \frac{(5-2)(5-2+1)}{2}$$

$$= \frac{3(4)}{2} = 6$$

$5 \rightarrow 4, 5 \rightarrow 3, 5 \rightarrow 2, 4 \rightarrow 3, 4 \rightarrow 2, 3 \rightarrow 2$

balmer series $5 \rightarrow 2, 4 \rightarrow 2, 3 \rightarrow 2$ (Total=3)

paschen series $5 \rightarrow 3, 4 \rightarrow 3$ (Total=2)

7. If the shortest wave length of Lyman series of H atom is x, then the wave length of the first line of Balmer series of H atom will be :

(A) 9x/5 (B) 36x/5 (C) 5x/9 (D) 5x/36

Answer:B

Solution:Shortest wavelength of Lyman series:

Corresponds to the transition $n_1=1, n_2=\infty$, wave length=x

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{1^2} - \frac{1}{\infty^2})1^2$$

$$\upsilon = \frac{1}{x} = R(\frac{1}{1^2})$$

$$x = \frac{1}{R}$$

$$R = \frac{1}{x}$$

first line of Balmer series $n_1=2, n_2=3$

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{3^2})1^2$$

$$\upsilon = \frac{1}{\lambda} = R(\frac{9-4}{36})$$

$$\upsilon = \frac{1}{\lambda} = R(\frac{5}{36}) = \frac{5R}{36}$$

$$\lambda = \frac{36}{5R}$$

$$\lambda = \frac{36}{5(\frac{1}{x})} = \frac{36x}{5}$$

8. Change in angular momentum when an electron makes a transition corresponding to the 3rd line of the Balmer series in Li^{2+} ion is

(A) $\frac{h}{2\pi}$ (B) $\frac{2h}{2\pi}$ (C) $\frac{3h}{2\pi}$ (D) $\frac{4h}{2\pi}$

Answer:C

Solution: 3rd line of the Balmer series in Li^{2+} ion

$Z=3, n_1=2, n_2=5$

For the transition $n=5 \rightarrow n=2$

Initial angular momentum (L_i): $L_i = 5.\frac{h}{2\pi}$

Final angular momentum (L_f): $L_f = 2.\frac{h}{2\pi}$

Change in angular momentum

$$\Delta L = L_f - L_i = 2.\frac{h}{2\pi} - 5.\frac{h}{2\pi} = -3.\frac{h}{2\pi}$$

The magnitude of the change is: $|\Delta L| = \left|-3.\frac{h}{2\pi}\right| = \frac{3h}{2\pi}$

9. In a sample of H-atoms, electrons de-excite from a level 'n' to 1. The total number of lines belonging to Balmer series are two. If the electrons are ionised from level 'n' by photons of energy 13 eV. Then the kinetic energy of the ejected photoelectrons will be

(A) 12.15 eV (B) 11.49 eV (C) 12.46 eV (D) 12.63 eV

Answer:A

Solution:Determine the value of n:

The Balmer series corresponds to transitions ending at n=2.

If there are two Balmer lines, the possible transitions are: $n=4 \rightarrow n=2, n=3 \rightarrow n=2$

This implies that the highest initial level is n=4.

The energy of an electron in level n of a hydrogen atom is:

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

$$E_4 = -13.6(\frac{1^2}{4^2}) = -\frac{13.6}{16} = -0.85eV$$

The ionization energy (energy required to remove the electron from n=4) is:

$E_{ionized} = 0 - E_4 = 0 - (-0.85) = 0.85eV$

Kinetic energy of the ejected photoelectrons:

The photon energy is 13 eV, and the ionization energy is 0.85 eV.

By the photoelectric effect:

E=photon energy -ionization energy=13eV-0.85eV=12.15eV

10. The wavelength of the radiation emitted, when in a hydrogen atom electron falls from infinity to stationary state 1, would be (Rydberg constant = 1.097 ´ 10^7 m^{-A}) [AIEEE 2004]

(A) 91 nm (B) 192 nm (C) 406 (D) 9.1 ´ 10^{-6} nm

Answer:A

Solution: n_1=1, n_2=infinite, R= $1.097\times10^7 m^{-1}$

$$\upsilon=\frac{1}{\lambda}=R(\frac{1}{1^2}-\frac{1}{\infty^2})1^2$$

$$\upsilon=\frac{1}{\lambda}=R(1)$$

$$\lambda=\frac{1}{R}=\frac{1}{1.097\times10^7 m^{-1}}=0.9115\times10^{-7}=91.15\times10^{-9}=91nm$$

11. The frequency of light emitted for the transition n = 4 to n = 2 of He^+ is equal to the transition in H atom corresponding to which of the following? [AIEEE 2011]

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

Answer:A

Solution: For He^+, the transition n = 4 to n = 2

$$\upsilon_{He}=R(\frac{1}{2^2}-\frac{1}{4^2})2^2$$

$$\upsilon_{He}=R(\frac{4-1}{16})4=\frac{3R}{4}$$

H atom

$$\upsilon_H=R(\frac{1}{n_1^2}-\frac{1}{n_2^2})1^2=\frac{3R}{4}$$

$$\upsilon_H=\frac{1}{n_1^2}-\frac{1}{n_2^2}=\frac{3}{4}$$

(A) n = 2 to n = 1

$$\upsilon_H=\frac{1}{n_1^2}-\frac{1}{n_2^2}=\frac{1}{1^2}-\frac{1}{2^2}=\frac{4-1}{4}=\frac{3}{4}$$

JEE ADVANCED LEVEL QUESTIONS

MULTI ANSWER TYPE

1. Which of the following statements is correct

A) The wavelength of marginal line of Balmer series = $\frac{4}{R_H}$

B) Last line of lyman series = $\infty \to 1$

C) The wavelength of marginal line of Paschen series $\frac{16}{R_H}$

D) $\frac{1}{\lambda}$ = $R_H \left[\frac{1}{6^2} - \frac{1}{n_2^2}\right]$ where n_2 > 6 in humphry series

Answer:A,B,D

Solution:A) The wavelength of marginal line of Balmer series

n_1=2,n_2=infinite

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{\infty^2}) = \frac{R}{4}$$
$$\lambda = \frac{4}{R}$$

B) Last line of lyman series

n_1=1,n_2=infinite(correct)

C) The wavelength of marginal line of Paschen series

n_1=3,n_2=infinite

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{3^2} - \frac{1}{\infty^2}) = \frac{R}{9}$$
$$\lambda = \frac{9}{R}$$ (false)

D) $\frac{1}{\lambda}$ = $R_H \left[\frac{1}{6^2} - \frac{1}{n_2^2}\right]$ where n_2 > 6 in humphry series

The Humphreys series corresponds to transitions where the electron falls to the n=6 level. The formula for the wavenumber is: $\frac{1}{\lambda}$ = $R_H \left[\frac{1}{6^2} - \frac{1}{n_2^2}\right]$ where n_2 > 6 in humphry series

2. Which of the following statements is incorrect

A) Lines of balmer series (for H atom) lies in the visible range

B) I[st] line of lyman series = 3 $\rightarrow$ 1

C) 1[st] line in Balmer series = $R \times 1 \left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$

D) For lyman series [10.2 eV $\leq (DE)_{lyman} \leq$ 13.6 eV]

Answer:B

Solution:A) Lines of balmer series (for H atom) lies in the visible range(correct)

B) I[st] line of lyman series = 3 $\rightarrow$ 1(false)

I[st] line of lyman series = 2 $\rightarrow$ 1

C) 1[st] line in Balmer series = $R \times 1 \left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$ (correct)

for Balmer series, $n_1=2, n_2=3$

D) For lyman series [10.2 eV $\leq (DE)_{lyman} \leq$ 13.6 eV]

The Lyman series involves transitions to n=1.

Minimum energy transition (n=2 $\rightarrow$ n=1): $\Delta E = 13.6(1-\frac{1}{4}) = 10.2eV$

Maximum energy transition (n= ∞ $\rightarrow$ n=1): $\Delta E = 13.6eV$

The given range [10.2 eV $\leq (DE)_{lyman} \leq$ 13.6 eV] is accurate

STATEMENT TYPE

A) Statement-I, is True, Statement - II is True; Statement - II is a correct explanation for Statement-I

B) Statement - I is True, Statement is True; Statement -II , is NOT a correct explanation for Statement - I

C) Statement - I is True, Statement - II , is False

D) Statement - I is False, Statement - II is True

3. **Statement-1 :** Wave number of a spectral line for an electronic transition is quantised.

Statement-2 : Wave number is directly proportional to the velocity of electron undergoing the transition.

Answer:E

Solution: $\bar{\upsilon} = R(\frac{1}{n_1^2} - \frac{1}{n_2^2})$,Thus, $\bar{\upsilon}$ does not depend on the electron's speed, but rather just on the orbits (n_1 and n_2) between which the transition occurs.

4 **Statement-1 :** A spectral line will be seen for $2p_x$ to $2p_y$ transition.

Statement-2 : Energy is released in the form of wave of light when electron drops from $2p_x$ to $2p_y$ orbital.

Answer:E

Solution:Statement-1:The $2p_x$ and $2p_y$ orbitals are degenerate (same energy level in hydrogen-like atoms).

A transition between them does not involve an energy change (E=0), so no photon is emitted or absorbed.

Conclusion: Statement-1 is False.

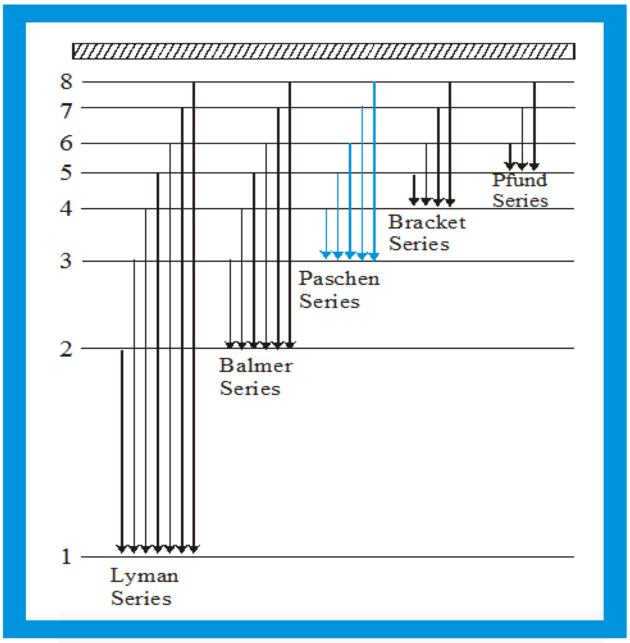
Statement-2:

Even if Statement-1 is false, Statement-2 claims energy is released as light for this transition.

Since E=0, no energy is released, making this statement False.

COMPREHENSION TYPE

The only electron in the hydrogen atom resides under ordinary conditions on the first orbit. When energy is supplied, the electron moves to higher energy orbit depending on the amount of energy absorbed. When this electron returns to any of the lower orbits, it emits energy. Lyman series is formed when the electron returns to the lowest orbit while Balmer series is formed when the electron returns to second orbit. Similarly, Paschen, Brackett and Pfund series are formed when electron returns to the third, fourth and fifth orbits from higher energy orbits respectively (as shown in figure).



Maximum number of lines produced when electrons jump from *n*th level to ground level is equal to $\frac{n(n-1)}{2}$.

For example, in the case of n = 4, number of lines produced is 6. (4 ® 3, 4 ® 2, 4 ® 1, 3 ® 2, 3 ® 1, 2 ® A). When an electron returns from n_2 to n_1 state, the number of lines in the spectrum will be equal to

$$\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

If the electron comes back from energy level having energy E_2 to energy level having energy E_1, then the difference may be expressed in terms of energy of photon as

$$E_2 - E_1 = DE\ , \qquad \lambda = \frac{hc}{\Delta E}, \qquad DE = hn \quad (n\text{ - frequency})$$

Since h and c are constants, DE corresponds to definite energy; thus each transition from one energy level to another will produce a light of definite wavelength. This is actually observed as a line in the spectrum of hydrogen atom.

Wave number of line is given by the formula $\bar{v} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$.

where R is a Rydberg constant ($R = 1.1 \times 10^7\ m^{-A}$)

(i) First line of a series : It is called 'line of longest wavelength' or 'line of shortest energy'.

(ii) Series limit or last line of a series : It is the line of shortest wavelength or line of highest energy.

5. Consider the following statements

1. Spectral lines of He^+ ion belonging to Balmer series are not in visible range.

2. In the balmer series of H-atom maximum lines are in ultra violet region.

3. 2^{nd} line of lyman series of He^+ ion has energy 48.4 eV

The above statements 1, 2, 3 respectively are (T = True, F = False)

(A) T F F (B) F T T (C) T F T (D) T T T

Answer:C

Solution:

1. Spectral lines of He^+ ion belonging to Balmer series are not in visible range:

This statement is True. While the Balmer series for hydrogen (H) atoms is in the visible range, the corresponding series for He^+ ions is not. This is because He^+ has a higher nuclear charge, leading to a different energy level structure and thus different spectral line positions. Specifically, the He^+ Balmer series transitions result in spectral lines in the ultraviolet region.

2. In the Balmer series of H-atom, maximum lines are in the ultraviolet region:

This statement is False. The Balmer series of H-atom has the maximum lines in the visible range. The Balmer series corresponds to electron transitions ending at the n=2 energy level. The lines with shorter wavelengths and higher energies, which are in the ultraviolet region, are part of the Lyman series (transitions to n=1).

Statement 3:

The 2nd line of the Lyman series for He^+ is the transition $n=3 \rightarrow n=1$.

The energy difference is: $\Delta E = 13.6 \times 4(1 - \frac{1}{9}) \approx 48.4 eV$

6. Wave number of the first line of Paschen series in Be^{3+} ion is

(A) $\frac{7R}{16}$ (B) $\frac{7R}{144}$ (C) $\frac{7R}{9}$ (D) $\frac{R}{144}$

Answer:C

Solution:For first line of Paschen series,$n_1=3$,$n_2=4$,Z=4

$$\upsilon = R(\frac{1}{3^2} - \frac{1}{4^2})4^2 = R(\frac{16-9}{9\times16})16 = \frac{7R}{9}$$

INTEGER TYPE

7. The wavelength of marginal line of brackett series = $\frac{x}{R_H}$, Here x is ____

Answer:16

Solution:For marginal line of brackett series n_1=4,n_2=infinite

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{4^2} - \frac{1}{\infty^2}) = \frac{R}{16}$$

$$\lambda = \frac{16}{R} = \frac{x}{R}$$

$$x = 16$$

8. The difference between longest wavelength of Balmer series and longest wavelength of Lyman sereis of hydrogen like species is 59.3 nm. The atomic number of the species is, ________

Answer:3

Solution:longest wavelength of Balmer series

n_1=2,n_2=3

$$\upsilon_B = \frac{1}{\lambda_B} = R(\frac{1}{2^2} - \frac{1}{3^2})Z^2 = R\frac{(9-4)}{36}Z^2 = \frac{5R}{36}Z^2$$

$$\lambda_B = \frac{36Z^2}{5R}$$

longest wavelength of Lyman sereis of hydrogen

n_1=1,n_2=2

$$\upsilon_L = \frac{1}{\lambda_L} = R(\frac{1}{1^2} - \frac{1}{2^2})1^2 = R\frac{(4-1)}{4} = \frac{3R}{4}$$

$$\lambda_L = \frac{4}{3R}$$

$$\lambda_B - \lambda_L = 59.3nm = 59.3\times10^{-9}$$

$$R = 1.097\times10^7 m^{-1}$$

$$\frac{36}{5Z^2(1.097\times10^7 m^{-1})} - \frac{4}{3(1.097\times10^7 m^{-1})} = 59.3\times10^{-9}$$

$$Z = 3$$

9. How many lines of Balmer series of He^+ fall within the wavelength range from 120 nm to 165 nm?

Answer:2

Solution:There are two lines of the Balmer series of He^+ that fall within the wavelength range of 120 nm to 165 nm. Specifically, the first and second lines of the Balmer series for He+ have wavelengths around 121.5 nm and 164 nm respectively

MATRIX MATCHING TYPE

10.

Column-I	Column-II
A) Lyman series	**(p)** maximum number of spectral line observed = 6
(B) Balmer series	**(q)** maximum number of spectral line observed = 3
(C) In a sample of H-atom for 5 upto 2 transition	**(r)** 2^{nd} line has wave number $\frac{8R}{9}$
(D) In a single isolated H-atom for 3 upto 1 transition	**(s)** 2^{nd} line has wave number $\frac{3R}{16}$
	(t) Total number of spectral line is 10.

Answer:A-r,B-s,C-p,D-q

Solution:**A)** Lyman series

2^{nd} line has wave number $= \bar{\upsilon} = R(\frac{1}{1^2} - \frac{1}{3^2}) = R(\frac{9-1}{9}) = \frac{8R}{9}$

(B) Balmer series

2^{nd} line has wave number$= \bar{\upsilon} = R(\frac{1}{2^2} - \frac{1}{4^2}) = R(\frac{4-1}{16}) = \frac{3R}{16}$

(C) In a sample of H-atom for 5 upto 2 transition

Total number of spectral line$= \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2} = \frac{(5-2)(5-2+1)}{2} = \frac{3(4)}{2} = 6$

(D) In a single isolated H-atom for 3 upto 1 transition

Total number of spectral line= $\frac{(n_2-n_1)(n_2-n_1+1)}{2}=\frac{(3-1)(3-1+1)}{2}=\frac{3(2)}{2}=3$

LEARNERS TASK

CONCEPTUAL UNDERSTANDING QUESTIONS (CUQ's)

1. In Hydrogen atom electron is present in the N shell. If it loses energy, a spectral line may be observed in the region

A) infra-red B) visible C) ultra-violet D) any of these

Answer:D

Solution:The N shell corresponds to n=4.

When the electron loses energy, it can transition to lower levels (n=3,2, or 1).

Lyman series ($n\rightarrow 1$): UV region.

Balmer series (n2): Visible region .

Paschen series ($n\rightarrow 3$): Infra-red region.

Thus, spectral lines can appear in any of these regions depending on the transition.

2. The wave number of the H_α - line in Balmer series of hydrogen spectrum is

A) 5R / 36 B) 3R / 16 C) 21R / 100 D) 3R / 4

Answer:A

Solution:Balmer series n_1=2

H_α means n_2-n_1=1

n_2-2=1

n_2=3

$$\upsilon = R(\frac{1}{2^2}-\frac{1}{3^2})1^2 = R\frac{(9-4)}{36}=\frac{5R}{36}$$

3. If the mass of the electron is reduced to half the Rydberg constant

A) remains unchanged B) becomes half

C) becomes double D) becomes one fourth

Answer:B

Solution:The Rydberg constant is directly proportional to the mass of the electron, so if the mass is halved, the constant is halved as well.

4. Rydberg constant is

A) Same for all elements B) Different for different elements

C) A universal constant

D) Is different for lighter elements but same for heavier elements

Answer:D

Solution: The Rydberg constant is not a universal constant; its value varies slightly depending on the element's atomic number. While it's often used as a single value in many calculations, the more precise value does change with the atomic number.

5. Values of n_1 and n_2 for H_β spectral line in the hydrogen emission spectrum

   A) 1 and 2 B) 2 and 3 C) 3 and 2 D) 2 and 4

Answer:D

Solution:For H_β ,n_2-n_1=2

So n_1 =2 and n_2=4

6. In hydrogen spectrum the following series of lines belongs to U.V. region

   A) Balmer series B) Paschen series C) Brackett series D) Lyman series

Answer:D

Solution:The Lyman series in the hydrogen spectrum is the only one that falls entirely in the ultraviolet region.

7. When the electron jumps from n = 5 to n = 2 level, the spectral line observed in the hydrogen spectrum belongs to

   A) Balmer series B) Lyman series C) Bracket series D) Pfund series

Answer:A

Solution:When an electron jumps from n=5 to n=2, it is transitioning to the second energy level, which corresponds to the Balmer series.

8. Which of the following transition is associated with coloured spectral line

   A) n = 5 to n = 3 B) n = 4 to n = 2 C) n = 2 to n = 1 D) n = 3 to n = 1

Answer:B

Solution:In the hydrogen atom, transitions from higher energy levels (n $\geq$3) to the second energy level (n = 2) result in visible light emissions, known as the Balmer series.

9. Among the first lines Lyman, Balmer, Paschen and Brackett series in hydrogen atomic spectra which has higher energy? (E-1999)

   A) Lyman B) Balmer C) Paschen D) Brackett

Answer:A

Solution:The Lyman series corresponds to transitions where electrons fall to the n=1 energy level, which is the ground state. These transitions result in the emission of photons with the highest energy within the hydrogen spectrum, specifically in the ultraviolet (UV) region. Other series (Balmer, Paschen, and Brackett) involve transitions to higher energy levels (n=2, n=3, and n=4 respectively), thus producing photons with lower energies. Therefore, the Lyman series has the highest energy among these series.

10. The wavelength of a spectral line for an electronic transition is inversely proportional to :

(A) number of electrons undergoing transition

(B) the nuclear charge of the atom

(C) the velocity of an electron undergoing transition

(D) the difference in the energy involved in the transition

Answer:D

Solution:The wavelength of a spectral line for an electronic transition is inversely proportional to the difference in the energy levels involved in the transition.

$$\Delta E = E_2 - E_1; \frac{hc}{\lambda} = E_2 - E_1; \lambda \alpha \frac{1}{E_2 - E_1}$$

11. Total no. of lines in Lyman series of H spectrum will be (where n = no. of orbits)

(A) n (B) n – 1 (C) n – 2 (D) n (n + A)

Answer:B

Solution:The total number of lines in the Lyman series = n – 1.

12. The energy of hydrogen atom in its ground state is –13.6 eV. The energy of the level corresponding to n = 5 is:

(A) –0.54 eV (B) –5.40 eV (C) –0.85 eV (D) –2.72 eV

Answer:A

Solution:The energy of an electron in the n-th orbit of a hydrogen atom is given by:

$$E_n = -\frac{13.6eV}{n^2}$$

For n=5

$$E_5 = -\frac{13.6eV}{5^2} = -0.54eV$$

13. The spectrum of He^+ is expected to be similar to that of :

(A) Li^{2+} (B) He (C) H (D) Na

Answer:C

Solution:He^+ (singly ionized helium) has 1 electron, just like hydrogen (H).

Li^{2+} (Z=3) also has a similar pattern but different scaling, while neutral He (Z=2, 2 electrons) has a more complex spectrum due to electron-electron repulsion.

14. No. of visible lines when an electron returns from 5th orbit upto ground state in H spectrum :

(A) 5 (B) 4 (C) 3 (D) 10

Answer:C

Solution:Visible lines in the hydrogen spectrum belong to the Balmer series (transitions ending at n = 2).

When an electron returns from the 5th orbit to lower levels, the visible transitions are:$5\rightarrow2, 4\rightarrow2, 3\rightarrow2$

Thus, 3 visible lines are observed.

JEE MAIN LEVEL QUESTIONS

1. If the wave number of the first line in the Balmer series of hydrogen atom is $15000\ cm^{-1}$, the wave number of the first line of the Balmer series of Li^{2+} is

   A) $1.43\times10^{4}\,cm^{-1}$ B) $1.66\times10^{9}\,cm^{-1}$ C) $13.5\times10^{5}\,cm^{-1}$ D) $1.35\times10^{5}\,cm^{-1}$

Answer:D

Solution:The wave number of the first line in the Balmer series of hydrogen atom=$15000\ cm^{-1}$

$$\upsilon_H = R(\frac{1}{2^2}-\frac{1}{3^2})1^2 = R(\frac{5}{36}) = \frac{5R}{36}$$

$$15000cm^{-1} = \frac{5R}{36}$$

$$R = 15000\times\frac{36}{5} = 108000cm^{-1}$$

The wave number of the first line of the Balmer series of Li^{2+}

$$\upsilon_{Li} = R(\frac{1}{2^2}-\frac{1}{3^2})3^2 = R(\frac{5}{4}) = \frac{5(108000)}{36} = 135000 = 1.35\times10^{5}\,cm^{-1}$$

2. The ratio of highest possible wavelength to lowest possible wavelength of Lyman series is

   A) 4/3 B) 9/8 C) 27/5 D) 16/5

Answer:A

Solution:The Lyman series has transitions ending at n=1.

Highest wavelength (lowest energy): Transition from n=2 $\rightarrow$ n=1

$$\lambda_{max} = \frac{1}{R(1-\frac{1}{4})} = \frac{4}{3R}$$

Lowest wavelength (highest energy): Transition from n=∞ $\rightarrow$ n=1

$$\lambda_{min} = \frac{1}{R}$$

$$\frac{\lambda_{max}}{\lambda_{min}} = \frac{\frac{4}{3R}}{\frac{1}{R}} = \frac{4}{3}$$

3. Which of the following lines will have a wave no. equal in magnitude to the value of R in the H - Spectral series

A) limiting line of Balmer series B) limiting line of Lyman series

C) first line of Lyman series D) first line of Balmer series

Answer:A

Solution:For the limiting line of the Lyman series: $n_1=1, n_2=$infinite

Substituting these values into the formula, we get: $\upsilon = R(\frac{1}{1^2} - \frac{1}{\infty^2}) = R$

4. What is the lowest energy of the spectral line emitted by the hydrogen atom in the Lyman series? (h=Plank constant; C=Velocity of light; R=Rydberg constant).

A) $\frac{5hcR}{36}$ B) $\frac{4hcR}{3}$ C) $\frac{3hcR}{4}$ D) $\frac{7hcR}{144}$

Answer:C

Solution:The lowest energy line in the Lyman series corresponds to the smallest transition (n=2 $\rightarrow$ n=1).

The energy difference is: $\Delta E = E_2 - E_1 = -13.6(\frac{1}{4} - 1) = \frac{3}{4} \times 13.6eV$

Converting to wavelength: $\Delta E = h\upsilon = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E} = \frac{4}{3R}$

$$E = \frac{3}{4} \times hcR$$

5. What is the wavelength of H_β line in Balmer series of hydrogen spectrum?

(R = Rydberg constant) (M-2000)

A) 36/5R B) 5R/36 C) 3R/16 D) 16/3R

Answer:D

Solution: H_β line in Balmer series

$n_1=2, n_2=4$

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{4^2}) = \frac{4-1}{16}R = \frac{3R}{16}$$

$$\lambda = \frac{16}{3R}$$

6. A gas of mono atomic hydrogen is excited by an energy of 12.75 eV/atom. Which spectral lines of the following are formed in Lyman, Balmer and Paschen series respectively.

A) 3, 2, 1 B) 2, 3, 1 C) 1, 3, 2 D) 1, 2, 3

Answer:A

Solution:Energy provided: 12.75 eV/atom.

Ground state energy of H-atom (n=1): -13.6 eV.

Energy after excitation: -13.6 + 12.75 = -0.85 eV.

Determine the excited level (n):

$$E_n = -\frac{13.6eV}{n^2} \Rightarrow -0.85 = -\frac{13.6eV}{n^2} \Rightarrow n^2 = 16 \Rightarrow n = 4$$

Lyman:$4 \to 1, 3 \to 1, 2 \to 1$(3 possibilities)

Balmer:$4 \to 2, 3 \to 2$(2 possibilities)

Paschen:$4 \to 3$(1 possibilities)

7. In Balmer series of lines of hydrogen spectrum, the first line from the red end corresponds to which one of the following inter-orbit jumps of the electron for Bohr orbits in an atom of hydrogen ?

(A) 5 ® 2 (B) 4 ® 1 (C) 2 ® 5 (D) 3 ® 2

Answer:D

Solution:The first line from the red end in the Balmer series has the longest wavelength (lowest energy).

This corresponds to the smallest energy transition in the Balmer series, which is $3 \to 2$ (the H α line)..

8. When an excited hydrogen atom returned to its ground state, some visible quanta were observed along with other quanta . Which of the following transitions must have occurred?

(A) 2 ® 1 (B) 3 ® 1 (C) 3 ® 2 (D) 4 ® 2

Answer:A

Solution:There must have been a shift from $2 \to 1$.

This is due to the fact that when an electron de-excites by moving from a higher level to a lower level, visible quanta are recorded in the Balmer series. The transition $2 \to 1$ is produced when the electron de-excites to the ground state after reaching the second level. Now, the quanta released will be in the UV zone

9. Which transition in Li^{2+} would have the same wavelength as the 2 ® 4 transition in He^+ ion ?

(A) 4 ® 2 (B) 2 ® 4 (C) 3 ® 6 (D) 6 ® 2

Answer:C

Solution:He^+,Z=2,n_1=2,n_2=4

Li^{2+} ,Z=3

$$R(\frac{1}{n_1^2}-\frac{1}{n_2^2})3^2 = R(\frac{1}{2^2}-\frac{1}{4^2})2^2 = \frac{3R}{4}$$

$$\frac{1}{n_1^2}-\frac{1}{n_2^2}=\frac{1}{12}$$

$n_1 = 3, n_2 = 6$

10. The number of possible lines of Paschen series when electron jumps from 7^{th} excited state upto ground state (in hydrogen like atom) is :

(A) 2 (B) 5 (C) 4 (D) 3

Answer:B

Solution:The Paschen series corresponds to electron transitions ending at the n=3 energy level. When an electron jumps from the 7th excited state (n=8) to the ground state (n=1) in a hydrogen-like atom, the possible transitions within the Paschen series are: 8 to 3, 7 to 3, 6 to 3, 5 to 3, and 4 to 3. Therefore, there are 5 possible lines.

11. In a sample of H-atom electrons make transition from 5^{th} excited state upto ground state, producing all possible types of photons, then number of lines in infrared region are

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

Answer:C

Solution: 5^{th} excited state,n=6

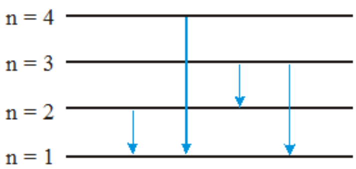
Paschen:6 $\rightarrow$3,5$\rightarrow$3,4$\rightarrow$3=3lines(Near infra red)

Brackett:6$\rightarrow$4,5$\rightarrow$4=2 line(Infrared)

Pfund:6$\rightarrow$5=1 line(Far infrared)

Total number of lines in infrared region =6

12. Suppose that a hypothetical atom gives a red, green, blue and violet line spectrum . Which jump according to figure would give off the red spectral line.



(A) 3 ® 1 (B) 2 ® 1 (C) 4 ® 1 (D) 3 ® 2

Answer:D

Solution:Red light = Lowest energy transition in the visible spectrum.

3 $\rightarrow$ 2 is the smallest energy gap among the options and matches the hydrogen H α (red) line.

Transitions to n=1 are UV, not visible.

13. The difference between the wave number of 1^{st} line of Balmer series and last

line of paschen series for Li^{2+} ion is :

(A) $\frac{R}{36}$ (B) $\frac{5R}{36}$ (C) 4R (D) $\frac{R}{4}$

Answer:D

Solution:Wave Number for 1st Line of Balmer Series

$$\upsilon_B = R(\frac{1}{2^2} - \frac{1}{3^2})3^2 = \frac{5R}{4}$$

Wave Number for Last Line of Paschen Series

$$\upsilon_p = R(\frac{1}{3^2} - \frac{1}{\infty^2})3^2 = R$$

$$\upsilon_B - \upsilon_p = \frac{5R}{4} - R = \frac{R}{4}$$

14. The electron present in 5th orbit in excited hydrogen atoms returned back to ground state. The no. of lines which appear in Lyman series of hydrogen spectrum

A) 5 B) 10 C) 4 D) 6

Answer:C

Solution:5th orbit n_2=5,n_1=1

$5 \rightarrow 1, 4 \rightarrow 1, 3 \rightarrow 1, 2 \rightarrow 1$

15. Which one of the following statement is ***not*** correct ?

A) Rydberg's constant and wave number have same units

B) Lyman series of hydrogen spectrum occur in the ultraviolet region

C) The angular momentum of the electron in the ground state hydrogen atom is equal to $\frac{h}{2\pi}$

D) The radius of first Bohr orbit of hydrogen atom is 2.116 x 10^{-8} cm.

Answer:D

Solution:The Radius of hydrogen atom of n^{th}Bohr orbit $r_n = \frac{0.529 \times 10^{-8}}{Z} = 0.529 \times n^2 A^0$

For first Bohr orbit in hydrogen atom, n = 1and Z = 1

$$r_1 = \frac{0.529 \times 1^2 A^0}{1} = 0.529 A^0$$

ADVANCED LEVEL QUESTIONS

MULTI CORRECT ANSWER TYPE

1. H-atom in its ground state is excited by means of monochromatic radiation of wavelength $970.6\overset{0}{A}$ then

A) The H-atom excited to 4th level

B) Longest wavelength of spectral line when excited atom returns to grand state is $1.875\times10^4\overset{0}{A}$

C) Shortest wavelength of spectral line when excited atom returns to ground state is $1.875\times10^4\overset{0}{A}$

D) None of these

Answer:A

Solution:

$$\lambda = 970.6A^0 = 97nm$$

$$\Delta E = \frac{1242}{\lambda} = \frac{1242}{97} = 12.75eV$$

$$\Delta E = 13.6Z^2(\frac{1}{1^2} - \frac{1}{n^2})$$

A)

$$12.75eV = 13.6(1)^2(\frac{1}{1^2} - \frac{1}{n^2})$$

$$n = 4$$

B) Longest wavelength of spectral line when excited atom returns to grand state is $1.875\times10^4\overset{0}{A}$

Longest Wavelength (Smallest Energy Transition)

n=2 $\rightarrow$ n=1

$$\frac{1}{\lambda} = R(\frac{1}{1^2} - \frac{1}{2^2}) = \frac{3R}{4} \rightarrow \lambda = \frac{4}{3(109678)} = 0.000012156 = 1215.6A^0$$

C) Shortest wavelength of spectral line when excited atom returns to ground state is $1.875\times10^4\overset{0}{A}$

The shortest wavelength corresponds to the largest energy transition, which is n=4 $\rightarrow$ n=1:

$$\frac{1}{\lambda} = R(\frac{1}{1^2} - \frac{1}{4^2}) = \frac{15R}{16} \rightarrow \lambda = \frac{16}{15(109678)} = 0.0000097254 = 972.5A^0$$

STATEMENT TYPE

A) Statement-I, is True, Statement - II is True; Statement - II is a correct explanation for Statement-I

B) Statement - I is True, Statement is True; Statement -II , is NOT a correct explanation for Statement - I

C) Statement - I is True, Statement - II , is False

D) Statement - I is False, Statement - II is True

2. **Statement-I :** Limiting line in the balmer series has a wavelength of 36.4 mm.

Statement-II : Limiting lines is obtained for a jump of electron from n = ¥ to n = 2 for Balmer series.

Answer:D

Solution: $\frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{\infty^2}) = \frac{R}{4} \rightarrow \lambda = \frac{4}{109678} = 0.00003647 = 0.3647\,mm$ =364.nm

3. **Statement-1:** Humphry series discovered in H-atomic spectra has lowest energy radiations among all series.

Statement-2 : Lowest state for this series is n_1 = 6.

Answer:A

Solution: For Humphry series, (n_2=7,8,9....) and n_1=6.

COMPREHENSION TYPE

Wave number of line is given by the formula $\bar{v} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$.

where R is a Rydberg constant (R = 1.1 × 10^7 m^{-A})

(i) First line of a series : It is called 'line of longest wavelength' or 'line of shortest energy'.

(ii) Series limit or last line of a series : It is the line of shortest wavelength or line of highest energy.

4. Last line of Brackett series for H–atom has wavelength λ_1Å and 2^{nd} line of lyman series has wavelength λ_2Å, then

A) $\frac{128}{\lambda_1} = \frac{9}{\lambda_2}$ B) $\frac{16}{\lambda_1} = \frac{9}{\lambda_2}$ C) $\frac{4}{\lambda_1} = \frac{1}{\lambda_2}$ D) $\frac{128}{\lambda_1} = \frac{8}{\lambda_2}$

Answer:A

Solution:Last line of Brackett series for H–atom has wavelength λ_1Å

$$\frac{1}{\lambda_1}=R(\frac{1}{4^2}-\frac{1}{\infty^2})=\frac{R}{4}\rightarrow\lambda_1=\frac{16}{R}$$

2nd line of lyman series has wavelength λ_2Å

$$\frac{1}{\lambda_2}=R(\frac{1}{1^2}-\frac{1}{3^2})=\frac{9}{8R}\rightarrow\lambda_2=\frac{9}{8R}$$

$$\frac{\lambda_1}{\lambda_2}=\frac{\frac{16}{R}}{\frac{9}{8R}}=\frac{16\times 8}{9}=\frac{128}{9}$$

$$\frac{\lambda_1}{\lambda_2}=\frac{128}{9}\rightarrow\frac{9}{\lambda_2}=\frac{128}{\lambda_1}$$

5. Wave number of the first line of Paschen series in Be^{3+} ion is

A) $\frac{7R}{16}$ B) $\frac{7R}{144}$ C) $\frac{7R}{9}$ D) $\frac{R}{144}$

Answer:C

Solution:n_1=3,n_2=4,Z=4

$$\upsilon=\frac{1}{\lambda}=R(\frac{1}{3^2}-\frac{1}{4^2})4^2=\frac{7R}{9}$$

INTEGER TYPE

6. 1st line in Balmer series has a value = $\frac{xR}{36}$, here the value of x is_____

Answer:5

Solution:n_1=2,n_2=3

$$\upsilon=\frac{1}{\lambda}=R(\frac{1}{2^2}-\frac{1}{3^2})=\frac{5R}{36}$$

x=5

7. How many Balmer lines of H-atom can be present within the wavelength range 94.5 nm to 130 nm?

Answer:0

Solution:Balmer lines of H-atom

We can calculate the wavelengths for transitions from n=3, 4, 5, and 6 to n=2:

For n=3: 1/λ = R (1/4 - 1/9) => λ ˜ 656.3 nm

For n=4: 1/ λ = R (1/4 - 1/16) => λ ˜ 486.1 nm
For n=5: 1/? = R (1/4 - 1/25) => λ ˜ 434.1 nm
For n=6: 1/? = R (1/4 - 1/36) => λ ˜ 410.2 nm

The calculated wavelengths for n=3, 4, 5, and 6 are 656.3 nm, 486.1 nm, 434.1 nm, and 410.2 nm respectively. However, these are not within the specified range of 94.5 nm to 130 nm.

These are the Lyman lines

$$\hbar\omega = E_H\left(\frac{1}{1} - \frac{1}{n^2}\right) n = 2, 3, 4....$$

For $n = 2$ we get $\lambda = 121.11nm$

For $n = 3$ we get $\lambda = 102.2nm$

For $n = 4$ we get $\lambda = 96.9nm$

For $n = 5$ we get $\lambda = 94.64nm$

For $n = 6$ we get $\lambda = 93.45nm$

Thus at the level of accuaracy of our calculation, there are four lines

$121.1nm, 102.2nm, 96.9nm$ and $94.64nm$.

MATCHING TYPE

8. If the shorted wavelength of sperical line of H-atom in Lyman series is x, then match the following for Li^{2+}

List - I	List - II
A) Shortest wavelength in Lyman series	P) $\frac{4x}{5}$
B) Longest wavelength in Lyman series	Q) $\frac{4x}{9}$
C) Shortest wavelength in Balmer series	R) $\frac{x}{9}$
D) Longest Wavelength in Balmer series	S) $\frac{4x}{27}$

Answer:A-R,B-S,C-Q,D-P

Solution:the shorted wavelength of sperical line of H-atom in Lyman series is x,

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{1^2} - \frac{1}{\infty^2}) = R \rightarrow \lambda = x = \frac{1}{R}$$

A) Shortest wavelength in Lyman series

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{1^2} - \frac{1}{\infty^2})3^2 = 9R \rightarrow \lambda = \frac{1}{9R} = \frac{x}{9}$$

B) Longest wavelength in Lyman series

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{1^2} - \frac{1}{2^2})3^2 = \frac{27R}{4} \rightarrow \lambda = \frac{4}{27R} = \frac{4x}{27}$$

C) Shortest wavelength in Balmer series

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{\infty^2})3^2 = \frac{9R}{4} \rightarrow \lambda = \frac{4}{9R} = \frac{4x}{9}$$

D) Longest Wavelength in Balmer series

$$\upsilon = \frac{1}{\lambda} = R(\frac{1}{2^2} - \frac{1}{3^2})3^2 = \frac{5R}{4} \rightarrow \lambda = \frac{4}{5R} = \frac{4x}{5}$$

9. In case of Hydrogen spectrum Rydberg's formula is $\bar{\vartheta} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]; n_1 < n_2$

Column-I	**Column-II**
A) Lyman series	P) $n_2 = 2$
B) Balmer series	Q) $n_2 = 3$
C) Paschen series	R) $n_2 = 4$
D) Bracket series	S) $n_2 = 5$

Answer:A-P,B-Q,C-R,D-S

Solution:

For Lyman series (n_1=1), the initial level (n_2) starts from n_2 =2.

For Balmer series (n_1 =2), $n_2$starts from 3.

For Paschen series (n_1=3), $n_2$starts from 4.

For Brackett series (n_1=4),n_2 starts from 5.

KEY

			TEACHING TASK						
			JEE MAINS LEVEL QUESTIONS						
1	2	3	4	5	6	7	8	9	10
B	A,B,C	A	C	A,C	B,C,D	B	C	A	A
11									
A									
			JEE ADVANCED LEVEL QUESTIONS						
1	2	3	4	5	6	7	8	9	
A,B,D	B	E	E	C	C	16	3	2	
10-A-r,B-s,C-p,D-q									
			LEARNERS TASK						
			CUQ'S						
1	2	3	4	5	6	7	8	9	10
D	A	B	D	D	D	A	B	A	D
11	12	13	14						
B	A	C	C						
			JEE MAIN LEVEL QUESTIONS						
1	2	3	4	5	6	7	8	9	10
D	A	A	C	D	A	D	A	C	B
11	12	13	14	15					
C	D	D	C	D					
			ADVANCED LEVEL QUESTIONS						
1	2	3	4	5	6	7	8		
A	D	A	A	C	5	0	A-R,B-S,C-Q,D-P		
9									
A-R,B-S,C-Q,D-P									