Atoms and Nuclei

Question1

A radioactive element having half-life 30 min . is undergoing beta decay. The fraction of radioactive element remains undecayed after 90 min . will be

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Options:

A.

$\frac{1}{2}$

B.

$\frac{1}{4}$

C.

$\frac{1}{8}$

D.

$\frac{1}{16}$

Answer: C

Solution:

We use the formula:

$\frac{\mathrm{N}}{\mathrm{N}_0}=\left(\frac{1}{2}\right)^{\frac{t}{T}}$

Here, $t=90$ min (total time passed), and $T=30$ min (half-life).

So, $\frac{t}{T}=\frac{90}{30}=3$

Substitute this in the formula: $\frac{N}{N_0} = \left(\frac{1}{2}\right)^3 = \frac{1}{8}$

This means after 90 minutes, $\frac{1}{8}$ of the radioactive element is still left, or not decayed.

Question2

The ratio of the total energy of the 2^{nd} orbit electron for the hydrogen atom (^1H) to that of a helium ion (He^+) is :

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Options:

A.

4

B.

2

C.

$\frac{1}{2}$

D.

$\frac{1}{4}$

Answer: D

Solution:

Step 1: Recall energy formula for hydrogen-like species

For a hydrogen-like atom/ion (nuclear charge Z):

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

Step 2: Energy of electron in H atom ($Z = 1, n = 2$)

$E_{\text{H},n=2} = -\frac{13.6(1)^2}{2^2} = -\frac{13.6}{4} = -3.4$ eV

Step 3: Energy of electron in He^+ ion ($Z = 2, n = 2$)

$E_{\text{He}^+, n=2} = -\frac{13.6(2)^2}{2^2} = -\frac{13.6\times4}{4} = -13.6 \text{ eV}$

Step 4: Ratio

We are asked for the ratio of the **total energies** (taking the values as they are, not just magnitudes unless specified).

$\frac{E_{\text{H}, n=2}}{E_{\text{He}^+, n=2}} = \frac{-3.4}{-13.6} = \frac{1}{4}$

✅ **Final Answer:**

Option D: $\frac{1}{4}$

Question3

The magnetic moment of electron due to orbital motion is proportional to ($\mathrm{n}=$ principal quantum number)

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Options:

A.

n

B.

n^2

C.

$\frac{1}{n}$

D.

$\frac{1}{\mathrm{n}^2}$

Answer: A

Solution:

Step 1. Recall expression for orbital magnetic moment

An electron in the nth Bohr orbit has current loop behavior. The orbital magnetic moment is

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

where L is the orbital angular momentum.

Step 2. Angular momentum in Bohr model

From Bohr's quantization condition:

$L_n = n\hbar.$

So,

$\mu_n = \frac{e}{2m}(n\hbar).$

Step 3. Relation to Bohr magneton

$\mu_B = \frac{e\hbar}{2m}.$

So,

$\mu_n = n\mu_B.$

Answer:

The orbital magnetic moment is **proportional to** n.

✅ **Correct option: A.** n

Question4

The frequencies for series limit of Balmer and Paschen series are ' V_1 ' and ' V_3 ' respectively. If frequency of first line of Balmer series ' V_2 ' then the relation between V_1, V_2 and V_3 is

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Options:

A.

$\mathrm{v}_1 - \mathrm{v}_3 = 2\mathrm{v}_1$

B.

$v_1 + v_2 = v_3$

C.

$\mathrm{v}_1-\mathrm{v}_2=\mathrm{v}_3$

D.

$v_1+v_3=v_2$

Answer: C

Solution:

$v=RZ^2\left(\frac{1}{n^2}-\frac{1}{m^2}\right)$

Series limit of Balmer: $\mathrm{n}=2,\ \mathrm{m}=\infty$

$\therefore \mathrm{v}_1=\frac{\mathrm{RZ}^2}{4}$

Series limit of Paschen: $\mathrm{n}=3,\ \mathrm{m}=\infty$

$\therefore \quad v_2=\frac{RZ^2}{9}$

1^{st} line of Balmer series: $\mathrm{n}_1=2, \mathrm{n}_2=3$

$\therefore \quad \mathrm{v}_3=\mathrm{RZ}^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right)=\frac{\mathrm{RZ}^2}{4}-\frac{\mathrm{RZ}^2}{9}=\mathrm{v}_1-\mathrm{v}_2$

Question5

A radio active element has rate of disintegration 8000 disintegrations per minute at a particular instant. After four minutes it becomes 2000 disintegrations per minute. The decay constant per minute is

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Options:

A.

$0.8 \log_e 2$

B.

$0.6 \log_e 2$

C.

$0.5 \log_e 2$

D.

$0.2 \log_e 2$

Answer: C

Solution:

Given:

- Initial rate of disintegration: $R_0 = 8000$ disintegrations/minute
- Rate after $t = 4$ minutes: $R = 2000$

Decay law for activity R:

$R = R_0 e^{-\lambda t}$

So,

$\frac{R}{R_0} = e^{-\lambda t}$

$\frac{2000}{8000} = e^{-\lambda(4)}$

$\frac{1}{4} = e^{-4\lambda}$

Take logarithm:

$-4\lambda = \ln\left(\frac{1}{4}\right) = -\ln 4$

$\lambda = \frac{\ln 4}{4}$

Now,

$\ln 4 = \ln(2^2) = 2 \ln 2$

So,

$\lambda = \frac{2 \ln 2}{4} = \frac{1}{2} \ln 2 = 0.5 \ln 2$

✅ **Correct Option: C.** $0.5 \log_e 2$

Question6

In Paschen series, wavelength of first line is ' λ_1 ' and for Brackett series, wavelength of first line is ' λ_2 ' then ratio $\frac{\lambda_1}{\lambda_2}$ is

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Options:

A. $\frac{7}{400}$

B. $\frac{9}{144}$

C. $\frac{81}{175}$

D. $\frac{108}{509}$

Answer: C

Solution:

Using Rydberg's formula,

$\frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{\mathrm{n}_1^2} - \frac{1}{\mathrm{n}_2^2}\right)$

For Paschen series, $\mathrm{n}_1 = 3$ and $\mathrm{n}_2 = 4$

$\frac{1}{\lambda_1} = R\left(\frac{1}{9} - \frac{1}{16}\right) = \frac{7R}{16\times9}$

For Brackett series,

$\mathrm{n}_1 = 4$ and $\mathrm{n}_2 = 5$

$$\frac{1}{\lambda_2} = \mathrm{R}\left(\frac{1}{16} - \frac{1}{25}\right) = \frac{9\mathrm{R}}{16 \times 25}$$

$$\frac{\lambda_1}{\lambda_2} = \frac{9\mathrm{R}}{16 \times 25} \times \frac{16 \times 9}{7\mathrm{R}} = \frac{81}{175}$$

Question7

The ratio of energies of photons produced due to transition of electron of hydrogen atom from its (i) third to 2^{nd} energy level and (ii) highest energy level to 3^{rd} level is

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Options:

A. 3 : 2

B. 5 : 4

C. 5 : 3

D. 8 : 3

Answer: B

Solution:

Case (i): Electron transition from $n = 3 \to n = 2$.

Photon energy:

$E = 13.6 \left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$ eV.

So,

$E_{(3\to2)} = 13.6 \left(\frac{1}{2^2} - \frac{1}{3^2}\right)$.

$= 13.6 \left(\frac{1}{4} - \frac{1}{9}\right)$.

$= 13.6 \left(\frac{9-4}{36}\right)$.

$= 13.6 \cdot \frac{5}{36}$.

$= \frac{68}{36} = \frac{17}{9}$ eV.

Case (ii): Transition from highest energy level ($n = \infty$) to $n = 3$.

Energy of photon:

$E = 13.6 \left(\frac{1}{3^2} - \frac{1}{\infty^2}\right)$.

$= 13.6 \cdot \frac{1}{9}$.

$= \frac{13.6}{9} = \frac{136}{90} = \frac{68}{45}$ eV.

Now ratio:

$\frac{E_{(3\to2)}}{E_{(\infty\to3)}} = \frac{\frac{17}{9}}{\frac{68}{45}}$.

Simplify:

$= \frac{17}{9} \cdot \frac{45}{68}$.

$= \frac{17 \cdot 45}{9 \cdot 68}$.

$= \frac{17 \cdot 5}{68}.$

$= \frac{85}{68}.$

$= \frac{85}{68}.$

Divide numerator and denominator by 17:

$= \frac{5}{4}.$

Final Answer:

$\boxed{5:4}$

That matches **Option B**. ✅

Question8

In hydrogen atom in its ground state, the first Bohr orbit has radius ' r_1 '. When the atom is raised to one of its excited states, the electrons orbital velocity becomes one-third. The radius of that orbit is

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Options:

A. $2r_1$

B. $3r_1$

C. $4r_1$

D. $9r_1$

Answer: D

Solution:

From Bohr's theory:

Velocity \& radius in nth orbit:

$V_n = \frac{V_1}{n} \& r_n = r_1 n^2$

From given,

$$V_n = \frac{V_1}{3} \Rightarrow \frac{V_1}{n} = \frac{V_1}{3}$$
$$\therefore n = 3$$

So, the electron is in the third Bohr orbit.

$$r_n = r_1 n^2 = r_1 (3)^2$$
$$\therefore \quad r_n = 9 r_1$$

Question9

A radioactive element has rate of disintegration 9000 disintegration per minute at a particular instant. After two minutes it becomes 3000 disintegration per minute. The decay constant per minute is

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Options:

A. $0.5 \log_c 3$

B. $0.2 \log_e 3$

C. $0.5 \log_e 2$

D. $0.2 \log_e 2$

Answer: A

Solution:

We know that, $\mathrm{N(t)} = \mathrm{N_0 e}^{-\lambda s}$

In 2 mins the activity reduces from 9000 d.p.m. to 3000 d.p.m. ,

$$3000 = 9000 \mathrm{e}^{-2\lambda}$$
$$\frac{3000}{9000} = \mathrm{e}^{-2\lambda}$$
$$\frac{1}{3} = \mathrm{e}^{-2\lambda}$$

Taking $\log_e$ on both sides,

$$\log_e\left(\frac{1}{3}\right) = -2\lambda$$
$$-\log_e(3) = -2\lambda$$
$$\lambda = \frac{1}{2}\log_e(3) = 0.5\log_e 3$$

Question10

In hydrogen atom, transition from the state $n = 6$ to $n = 1$ results in ultraviolet radiation. Infrared radiation will be obtained in the transition

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Options:

A. $n = 3$ to $n = 1$

B. $n = 4$ to $n = 2$

C. $n = 6$ to $n = 2$

D. $n = 5$ to $n = 3$

Answer: D

Solution:

Step 1: Recall hydrogen energy level formula

For hydrogen:

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

The energy of the photon emitted in a transition $n_i \to n_f$ is:

$$\Delta E = 13.6\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)\text{ eV}$$

Step 2: Ultraviolet vs Visible vs Infrared

- Large energy difference → higher frequency → shorter wavelength → ultraviolet.
- Moderate energy difference → visible.
- Small energy difference → longer wavelength → infrared.

Step 3: Analyze options

- **(A)** $n = 3 \to n = 1$:

$\Delta E = 13.6\left(1 - \frac{1}{9}\right) = 13.6 \times \frac{8}{9} \approx 12.1\,\text{eV}$.

This corresponds to wavelength $\lambda \approx 1240/12.1 \approx 102\,\text{nm}$.

That is deep **UV**. Not IR.

- **(B)** $n = 4 \to n = 2$:

$\Delta E = 13.6\left(\frac{1}{4} - \frac{1}{16}\right) = 13.6 \times \frac{3}{16} = 2.55\,\text{eV}$.

$\lambda \approx 1240/2.55 \approx 486\,\text{nm} \longrightarrow$ **visible (blue-green)**. Not IR.

- **(C)** $n = 6 \to n = 2$:

$\Delta E = 13.6\left(\frac{1}{4} - \frac{1}{36}\right) = 13.6 \times \frac{8}{36} \approx 3.02\,\text{eV}$.

$\lambda \approx 1240/3.02 \approx 410\,\text{nm}$. **Visible (violet)**. Not IR.

- **(D)** $n = 5 \to n = 3$:

$\Delta E = 13.6\left(\frac{1}{9} - \frac{1}{25}\right) = 13.6 \times \frac{16}{225} = 0.967\,\text{eV}$.

$\lambda \approx 1240/0.967 \approx 1280\,\text{nm}$. That's **Infrared**.

✅ **Correct Answer: Option D ($n = 5 \to n = 3$)**

Question11

A radioactive element ${}^{242}_{92}\text{X}$ emits two α particles, one electron and two positrons. The product nucleus is represented by ${}^{234}_{\text{p}}\text{Y}$. The value of P is

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Options:

A. 87

B. 85

C. 92

D. 96

Answer: A

Solution:

We are given:

A nucleus $^{242}_{92}X$.

It undergoes the following emissions:

- **Two α-particles** (helium nuclei: $^{4}_{2}\text{He}$):
- Each α emission decreases the **mass number** A by 4 and the **atomic number** Z by 2.
- So, two α particles:
  - Decrease in A: $2 \times 4 = 8$.
  - Decrease in Z: $2 \times 2 = 4$.

Thus after two α emissions:

$A = 242 - 8 = 234, \quad Z = 92 - 4 = 88.$

Intermediate nucleus: $^{234}_{88}$.

- **One electron (β^-) emission**:
- A β^- is emission of an electron when a neutron $\rightarrow$ proton.
- So **atomic number Z increases by 1**, mass number unchanged.

After this:

$A = 234, \quad Z = 88 + 1 = 89.$

- **Two positron (β^+) emissions**:
- Each β^+ emission: proton $\rightarrow$ neutron, so **atomic number Z decreases by 1**.

Two positrons $\rightarrow$ decrease Z by 2.

After this:

$A = 234, \quad Z = 89 - 2 = 87.$

Final nucleus: $^{234}_{87}Y$.

So, the value of P is:

$\boxed{87}$

Correct Option: A (87). ✅

Question12

The activity of radioactive sample is measured as $\mathrm{N_0}$ counts per minute at time $\mathrm{t} = 0$, and $\frac{\mathrm{N_0}}{\mathrm{e}}$ counts per minute at time $\mathrm{t} = 3$ minute, The activity reduces to half its value in time (in minute)

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Options:

A. $\frac{1}{3}\log_e 2$

B. $3\log_e 2$

C. $3\log_{10} 2$

D. $\frac{3}{\log_{10} 2}$

Answer: B

Solution:

Step 1: Write the decay law

The activity at time t is given by:

$N(t) = N_0 e^{-\lambda t}$

where λ is the decay constant.

Step 2: Find decay constant from given data

At $t = 3$ min,

$N(3) = \frac{N_0}{e}$

So,

$\frac{N_0}{e} = N_0 e^{-3\lambda}$

Cancel N_0:

$\frac{1}{e} = e^{-3\lambda}$

$e^{-1} = e^{-3\lambda}$

$-1 = -3\lambda \quad \Rightarrow \quad \lambda = \frac{1}{3}$

So, the decay constant is:

$\lambda = \frac{1}{3}$ per minute

Step 3: Find half-life

The half-life is:

$T_{1/2} = \frac{\ln 2}{\lambda}$

Substitute $\lambda = \frac{1}{3}$:

$T_{1/2} = \frac{\ln 2}{1/3} = 3 \ln 2$

Final Answer:

$\boxed{3 \ln 2}$

That corresponds to **Option B** ✅

Question13

In hydrogen atom, the energy of electron in first and third orbit is ' E_1 ' and' E_3 ' respectively. If $E_3 = xE_1$ then the value of x will be

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Options:

A. $\frac{1}{9}$

B. $\frac{1}{64}$

C. $\frac{1}{27}$

D. $\frac{1}{8}$

Answer: A

Solution:

For the hydrogen atom,

energy of an electron in the first orbit = E_1,

energy of an electron in the third orbit = E_3.

If $E_3 = xE_1$, find x.

Step 1: Formula for energy in hydrogen atom

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

So, the energy is inversely proportional to n^2.

Step 2: Write E_1 and E_3

$E_1 = -\frac{13.6}{1^2} = -13.6\,\text{eV}$

$E_3 = -\frac{13.6}{3^2} = -\frac{13.6}{9} = \frac{E_1}{9}$

Step 3: Express E_3 in terms of E_1

$E_3 = \frac{1}{9}E_1$

So:

$x = \frac{1}{9}$

✅ **Answer: Option A $\frac{1}{9}$**

Question14

A radioactive element A decays into radioactive element C by the following processes in succession.

$\mathrm{A} \rightarrow \mathrm{B} + {}_2\mathrm{H}_\mathrm{e}^4; \mathrm{B} \rightarrow \mathrm{C} + 2\mathrm{e}^-$ Then elements

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Options:

A. A and B are isobars.

B. A and C are isobars.

C. A and C are isotopes.

D. A and B are isotopes.

Answer: C

Solution:

$A \rightarrow B + {}_2He^4; B \rightarrow C + 2e^-$

Let A be : ${}_zA^A$

In $A \rightarrow B$ decay, ${}_2He^4$ is released

$\therefore$ $A \rightarrow B$ is alpha decay reaction

$\therefore$ ${}_zA^{\wedge} \rightarrow {}_{z-2}B^{\wedge-4} + {}_2He^4$

In $B \rightarrow C$ decay, $2e^-$is released

$\therefore$ $B \rightarrow C$ is β^-decay x action

$z - 2\,B^{N-4} \rightarrow {}_zC^{\Lambda-4}$ ($\because$ As each β^-decay increases Z by 1)

Now A and C have the same atomic number but different mass numbers.

$\therefore$ A and C are isotope.

Question15

${}_{88}R_a^{226}$ is converted into ${}_{82}P_b^{206}$ by emission of alpha (α) and beta (β) particles. The number of alpha and beta particles emitted are respectively

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Options:

A. 5, 4

B. 4, 5

C. 6, 4

D. 4, 6

Answer: A

Solution:

Ra-226 ($^{226}_{88}Ra$) decays to Pb-206 ($^{206}_{82}Pb$) by emission of α and β particles. We need to find how many α's and β's are emitted.

Step 1: Write data

- Initial: $A = 226, Z = 88$.
- Final: $A = 206, Z = 82$.

Step 2: Effect of alpha and beta emissions

- An α-particle emission: decreases mass number by 4, atomic number by 2. ($A \to A - 4, Z \to Z - 2$)
- A β^--particle emission: mass number unchanged, atomic number increases by 1 ($Z \to Z + 1$).

Step 3: Compare initial and final mass numbers

Mass number difference: $226 - 206 = 20$.

- Each α reduces mass number by 4.
- To reduce by 20, we need $\frac{20}{4} = 5$ α emissions.

So number of $\alpha = 5$.

Step 4: Effect on atomic number

After 5 α decays, atomic number decreases by $5 \times 2 = 10$.

Initial $Z = 88$. After 5 α, $Z = 88 - 10 = 78$.

But final Z must be 82.

So we must increase atomic number from 78 to 82 $\longrightarrow$ increase by 4.

Each β^- increases Z by 1. Thus, 4 β^- emissions.

Step 5: Answer

- Number of α: 5
- Number of β^-: 4

So the correct answer = **Option A: 5,4** ✅

Question16

Out of the following transitions in hydrogen atom, identify the transition which emits photons of highest frequency.

Options:

A. n = 1 to n = 2

B. n = 2 to n = 1

C. $n = 2$ to $n = 6$

D. $n = 6$ to $n = 2$

Answer: B

Solution:

Step 1: Recall the formula

The energy difference between two levels in the hydrogen atom is:

$\Delta E = 13.6\,\text{eV}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

(for $n_2 > n_1$).

The emitted photon frequency is directly proportional to this energy difference:

$\nu = \frac{\Delta E}{h}$

So the larger the energy difference, the higher the frequency.

Step 2: Analyze each option

- **Option A:** $n = 1 \to n = 2$

This describes excitation (absorption), not emission. Even if it did produce a photon, this is absorption, not emission.

- **Option B:** $n = 2 \to n = 1$

This is emission. Energy difference:

$\Delta E = 13.6\left(1 - \frac{1}{4}\right) = 13.6\left(\frac{3}{4}\right) = 10.2\,\text{eV}$

- **Option C:** $n = 2 \to n = 6$

This would be excitation (absorption), not emission.

- **Option D:** $n = 6 \to n = 2$

This is emission. Energy difference:

$\Delta E = 13.6\left(\frac{1}{4} - \frac{1}{36}\right) = 13.6\left(\frac{9-1}{36}\right) = 13.6 \times \frac{8}{36} = 13.6 \times \frac{2}{9} \approx 3.02\,\text{eV}$

Step 3: Compare

- $n = 2 \to n = 1$: $\Delta E = 10.2\,\text{eV}$
- $n = 6 \to n = 2$: $\Delta E = 3.02\,\text{eV}$

So the photon from $n = 2 \to n = 1$ has higher frequency (larger energy).

✅ **Final Answer:**

Option B: $n = 2 \to n = 1$

Question17

Using Bohr's quantization condition, the rotational kinetic energy in the third orbit for a diatomic molecule is ($h =$ Planck's constant, $\mathrm{I} =$ moment of inertia of diatomic molecule)

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Options:

A. $\frac{9h^2}{8\pi^2 I}$

B. $\frac{3\ \mathrm{h}^2}{8\pi^2 \mathrm{I}}$

C. $\frac{6h^2}{8\pi I}$

D. $\frac{12h^2}{7\pi^2 I}$

Answer: A

Solution:

We are tasked to find the **rotational kinetic energy in the third orbit** for a **diatomic molecule** using Bohr's quantization condition.

Step 1: Bohr’s quantization condition for angular momentum

$L = n\frac{h}{2\pi}, \quad n = 1, 2, 3, \ldots$

Step 2: Rotational kinetic energy in terms of angular momentum

For a rotating rigid body (diatomic molecule modeled as a rigid rotor), the rotational kinetic energy is

$E = \frac{L^2}{2I}$

Step 3: Substitute quantized angular momentum

$E_n = \frac{1}{2I}\left(n\frac{h}{2\pi}\right)^2$

$E_n = \frac{n^2h^2}{8\pi^2 I}$

Step 4: Energy in the third orbit $(n = 3)$

$E_3 = \frac{3^2h^2}{8\pi^2 I} = \frac{9h^2}{8\pi^2 I}$

✅ **Final Answer:**

Option **A**:

$$\boxed{\frac{9h^2}{8\pi^2 I}}$$

Question18

Which of the following transitions in hydrogen atom emit photons of highest frequency? (n = principle quantum number)

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Options:

A. $\mathrm{n}=1$ to $\mathrm{n}=3$

B. $\mathrm{n}=2$ to $\mathrm{n}=4$

C. $\mathrm{n}=5$ to $\mathrm{n}=3$

D. $\mathrm{n}=2$ to $\mathrm{n}=1$

Answer: D

Solution:

The frequency of the emitted photon is directly proportional to the energy difference between the two levels:

$E = h\nu$

For the hydrogen atom, the energy of the n^{th} level is:

$E_n = -13.6 \frac{1}{n^2}$ eV

The energy difference during a transition from n_i to n_f ($n_i > n_f$) is:

$$\Delta E = E_{n_f} - E_{n_i} = -13.6 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \text{eV}$$

Here, a larger value of $|\Delta E|$ means a higher frequency photon is emitted.

Now, let us calculate $|\Delta E|$ for each option:

Option A: $\mathrm{n} = 1$ to $\mathrm{n} = 3$ (Actually, this is absorption, not emission, since n increases.)

Option B: $\mathrm{n} = 2$ to $\mathrm{n} = 4$ (Also absorption.)

Option C: $\mathrm{n} = 5$ to $\mathrm{n} = 3$ (Emission, n decreases.)

Option D: $\mathrm{n} = 2$ to $\mathrm{n} = 1$ (Emission.)

Let us consider only emission (from higher n to lower n): Options C and D.

Option C: $n_i = 5$ **to** $n_f = 3$

$\Delta E = -13.6 \left(\frac{1}{3^2} - \frac{1}{5^2} \right)$

$= -13.6 \left(\frac{1}{9} - \frac{1}{25} \right)$

$= -13.6 \left(\frac{25-9}{225} \right)$

$= -13.6 \times \frac{16}{225}$

$= -0.967$ eV

Since emission, take absolute value: 0.967 eV.

Option D: $n_i = 2$ **to** $n_f = 1$

$\Delta E = -13.6 \left(\frac{1}{1^2} - \frac{1}{2^2} \right)$

$= -13.6 \left(1 - \frac{1}{4} \right)$

$= -13.6 \times \frac{3}{4}$

$= -10.2$ eV

Absolute value: 10.2 eV.

10.2 eV (Option D) is much greater than 0.967 eV (Option C).

Answer:

Option D ($n = 2$ to $n = 1$) emits photons of the highest frequency.

Question19

Two radioactive materials A and B having decay constant ' 7λ ' and ' λ ' respectively, initially have same number of nuclei. The time taken to have the ratio of number of nuclei of material B to that of A as ' e ' is

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Options:

A. $\frac{1}{\lambda}$

B. $\frac{1}{6\lambda}$

C. $\frac{1}{7\lambda}$

D. $\frac{1}{8\lambda}$

Answer: B

Solution:

Let the initial number of nuclei of both A and B be N_0.

The number of nuclei left after time t for any radioactive material is given by:

$N = N_0 e^{-\lambda t}$

For material A (decay constant $= 7\lambda$):

$N_A = N_0 e^{-7\lambda t}$

For material B (decay constant $= \lambda$):

$N_B = N_0 e^{-\lambda t}$

We are told that the ratio $\frac{N_B}{N_A} = e$ at time t.

So,

$\frac{N_B}{N_A} = \frac{N_0 e^{-\lambda t}}{N_0 e^{-7\lambda t}} = \frac{e^{-\lambda t}}{e^{-7\lambda t}}$

$\frac{N_B}{N_A} = e^{-\lambda t + 7\lambda t} = e^{6\lambda t}$

Given:

$e^{6\lambda t} = e$

Take natural logarithm (log base e) on both sides:

$6\lambda t = 1$

$t = \frac{1}{6\lambda}$

Correct answer:

Option B: $\boxed{\frac{1}{6\lambda}}$

Question20

The ratio of angular momentum of an electron in n^{th} orbit of hydrogen atom to the velocity of electron in n^{th} orbit is proportional to

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Options:

A. n^2

B. $\frac{1}{\mathrm{n}^2}$

C. n^3

D. $\frac{1}{\mathrm{n}^3}$

Answer: A

Solution:

For hydrogen atom, according to Bohr's model:

Step 1: Angular momentum in the n^{th} orbit

$L = mv_n r_n = n\frac{h}{2\pi}$

Step 2: Velocity of electron in the n^{th} orbit

The velocity in the n^{th} orbit is:

$v_n = \frac{2\pi k e^2}{nh}$

where k is Coulomb's constant and e is the electron charge.

Step 3: Ratio of angular momentum to velocity

We want:

$\frac{L}{v_n}$

From above,

- $L = n\frac{h}{2\pi}$
- $v_n = \frac{2\pi ke^2}{nh}$

So,

$\frac{L}{v_n} = \frac{n\frac{h}{2\pi}}{\frac{2\pi ke^2}{nh}} = n\frac{h}{2\pi} \cdot \frac{nh}{2\pi ke^2} = \frac{n^2h^2}{4\pi^2ke^2}$

This ratio is **proportional to** n^2.

Final Answer:

Option A: $\boxed{n^2}$

Question21

In hydrogen atom spectrum, when an electron jumps from second excited state to the first excited state, the wavelength of radiation emitted is ' λ '. If the electron jumps from the third excited state to the second orbit, the wavelength of radiation emitted will be $\frac{20\lambda}{x}$. The value of x is

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Options:

A. 18

B. 27

C. 21

D. 36

Answer: B

Solution:

According to Rydberg's formula,

$$\frac{1}{\lambda}=\mathrm{R}\left(\frac{1}{\mathrm{n}_1^2}-\frac{1}{\mathrm{n}_2^2}\right) \qquad \ldots(i)$$

When electron jumps from 2^{nd} excited state to first excited state,

$\mathrm{n}_2=3, \mathrm{n}_1=2$, we get

$$\frac{1}{\lambda}=\mathrm{R}\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$$

When electron jumps from 3^{rd} exited state to 2^{nd} orbit, $\mathrm{n}_2=4, \mathrm{n}_1=2, \lambda=\lambda_0$, we get:

$$\begin{aligned}
& \frac{1}{\lambda_0} && =R\left(\frac{1}{4^2}-\frac{1}{2^2}\right) \\
\therefore \quad & \frac{\lambda_0}{\lambda} && =\frac{R\left(\frac{1}{2^2}-\frac{1}{3^2}\right)}{R\left(\frac{1}{2^2}-\frac{1}{4^2}\right)}=\frac{5}{36} \times \frac{16}{3}=\frac{20}{27} \\
\therefore \quad & \lambda_0 && =\frac{20}{27} \lambda \\
\Rightarrow \quad & x=27
\end{aligned}$$

Question22

In hydrogen spectrum, the ratio of wavelengths of the last line of Lyman series and that of the last line of Balmer series is

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Options:

A. 1

B. 0.5

C. 0.25

D. 0.2

Answer: C

Solution:

Let us find the ratio step by step.

Step 1: Formula for Wavelength in Hydrogen Spectrum

The wavelength of a spectral line in the hydrogen spectrum is given by:

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

For hydrogen, $Z = 1$, and R is the Rydberg constant.

Step 2: Lyman Series

- Lyman series: $n_1 = 1$

The last line corresponds to the transition from $n_2 = \infty$ to $n_1 = 1$.

So,

$$\frac{1}{\lambda_L} = R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R(1-0) = R$$

Therefore,

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

Step 3: Balmer Series

- Balmer series: $n_1 = 2$

The last line corresponds to the transition from $n_2 = \infty$ to $n_1 = 2$.

So,

$$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = R\left(\frac{1}{4} - 0\right) = \frac{R}{4}$$

Therefore,

$$\lambda_B = \frac{1}{R/4} = \frac{4}{R}$$

Step 4: Ratio Calculation

The required ratio:

$$\text{Ratio} = \frac{\lambda_L}{\lambda_B} = \frac{\frac{1}{R}}{\frac{4}{R}} = \frac{1}{4} = 0.25$$

Final Answer:

Option C: 0.25

Question23

For the following reaction, the particle ' x ' is ${}_6\mathrm{C}^{11} \longrightarrow {}_5\mathrm{B}^{11} + \beta + \mathrm{X}$

Options:

A. proton

B. neutrino

C. anti neutrino

D. neutron

Answer: B

Solution:

Given reaction is:

$_6\mathrm{C}^{11} \longrightarrow {}_5\mathrm{B}^{11} + \beta + X$

Let's break it down step-by-step:

1. **Identify β particle:**

A β particle in nuclear reactions usually refers to a **beta-minus (β^-) particle**, which is an electron (e^-).

2. **Write nuclear equations:**

A general β^- decay reaction is:

$^A_ZX \rightarrow {}^A_{Z+1}Y + \beta^- + \bar{\nu}$

Where:

- X is the parent nucleus,
- Y is the daughter nucleus,
- β^- is the emitted electron,
- $\bar{\nu}$ is the **anti-neutrino**.

1. **Apply to given reaction:**

In this reaction:

- The atomic number decreases: from 6 (Carbon) to 5 (Boron)
- This fits **beta-plus (β^+) decay**, not beta-minus

But the question writes β (generic). However, with decrease in atomic number, it should be β^+ (positron), not β^-. But let's carry forward with the usual nuclear conventions, where

$^A_ZX \rightarrow {}^A_{Z-1}Y + \beta^+ + \nu$

Here, the neutrino (ν) is emitted along with the β^+.

4. **Determine particle 'X'**

Comparing with the general reaction:

- For **beta-positive** (β^+) decay,

  ${}_{6}^{11}\mathrm{C} \rightarrow {}_{5}^{11}\mathrm{B} + \beta^+ + \nu$

Thus, $X = \nu =$ **neutrino**.

Final Answer:

Option B: neutrino

Question24

The frequency of revolution of an electron in the n^{th} orbit of hydrogen atom is

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Options:

A. directly proportional to n^2

B. inversely proportional to n^2

C. directly proportional to n^3

D. inversely proportional to n^3

Answer: D

Solution:

According to Bohr's atomic model, the radius of the electron's orbit in the nth level is:

$r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m_e Z e^2}$

The speed of the electron in the nth orbit is:

$v_n = \frac{Ze^2}{2\varepsilon_0 nh}$

Finding angular frequency:

The angular frequency (ω) is the speed divided by the radius:

$$\omega = \frac{v}{r} = \frac{\left(\frac{Ze^2}{2\varepsilon_0 nh}\right)}{\left(\frac{\varepsilon_0 n^2 h^2}{\pi m_e Ze^2}\right)} = \frac{\pi m_e e^4}{2\varepsilon_0^2 h^3 n^3}$$

Finding frequency of revolution:

The frequency (f) is ω divided by 2π:

$$f = \frac{\omega}{2\pi} = \frac{\left(\frac{\pi m_e e^4}{2\varepsilon_0^2 h^3 n^3}\right)}{2\pi} = \frac{m_e e^4}{4\varepsilon_0^2 h^3 n^3}$$

Relation to n:

$$\therefore \quad f \propto \frac{1}{n^3}$$

Question25

If ' λ_1 ' and ' λ_2 ' are the wavelengths of the first member of the Balmer and Paschen series, in hydrogen atom respectively, then the ratio of respective frequencies, f_1/f_2, is

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Options:

A. 20 : 7

B. 27 : 5

C. 50 : 9

D. 108 : 7

Answer: A

Solution:

First, let us identify the transitions for the first members of the **Balmer** and **Paschen** series in the hydrogen atom:

- **Balmer series** (visible): transitions to $n_2 = 2$
- First member: $n_1 = 3$ to $n_2 = 2$
- **Paschen series** (infrared): transitions to $n_2 = 3$
- First member: $n_1 = 4$ to $n_2 = 3$

Let wavelengths be:

- λ_1 = Balmer, $3 \to 2$
- λ_2 = Paschen, $4 \to 3$

The **wavelength** for a transition in the hydrogen atom is given by the Rydberg formula:

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

For the **first Balmer line** $(3 \to 2)$:

$$\frac{1}{\lambda_1} = R_H \left(\frac{1}{2^2} - \frac{1}{3^2}\right) = R_H \left(\frac{1}{4} - \frac{1}{9}\right)$$

Calculate:

$$\frac{1}{4} - \frac{1}{9} = \frac{9-4}{36} = \frac{5}{36}$$

So,

$$\frac{1}{\lambda_1} = R_H \cdot \frac{5}{36}$$

For the **first Paschen line** $(4 \to 3)$:

$$\frac{1}{\lambda_2} = R_H \left(\frac{1}{3^2} - \frac{1}{4^2}\right) = R_H \left(\frac{1}{9} - \frac{1}{16}\right)$$

Calculate:

$$\frac{1}{9} - \frac{1}{16} = \frac{16-9}{144} = \frac{7}{144}$$

So,

$$\frac{1}{\lambda_2} = R_H \cdot \frac{7}{144}$$

The **frequency** is given by $f = \dfrac{c}{\lambda}$

Therefore,

$$f_1 = \frac{c}{\lambda_1}, \quad f_2 = \frac{c}{\lambda_2}$$

$$\frac{f_1}{f_2} = \frac{\lambda_2}{\lambda_1}$$

From above:

$$\frac{1}{\lambda_1} = R_H \cdot \frac{5}{36} \implies \lambda_1 = \frac{36}{5R_H}$$

$$\frac{1}{\lambda_2} = R_H \cdot \frac{7}{144} \implies \lambda_2 = \frac{144}{7R_H}$$

Therefore,

$$\frac{f_1}{f_2} = \frac{\lambda_2}{\lambda_1} = \frac{\frac{144}{7R_H}}{\frac{36}{5R_H}} = \frac{144}{7} \times \frac{5}{36}$$

$$= \frac{144 \times 5}{7 \times 36}$$

$$= \frac{720}{252}$$

$$= \frac{720 \div 36}{252 \div 36} = \frac{20}{7}$$

Correct answer:

$\boxed{20 : 7}$

So, the answer is **Option A**.

Question26

The ratio of the wavelength of the last line of Paschen series to that of Balmer series is

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Options:

A. $\frac{9}{4}$

B. $\frac{3}{2}$

C. $\frac{2}{3}$

D. $\frac{4}{9}$

Answer: A

Solution:

Step 1: Formula for wavelength in hydrogen spectrum (Rydberg formula)

The wavelength of a spectral line is given by:

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

where:

- R = Rydberg constant
- Z = atomic number (for hydrogen, $Z = 1$)
- n_1 = lower energy level
- n_2 = higher energy level, $n_2 > n_1$

Step 2: Balmer series "last line"

Balmer series: $n_1 = 2$, $n_2 = \infty$ (last line means limit, $n_2 \to \infty$):

So, for the last line:

$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - 0\right) = R \cdot \frac{1}{4}$

So,

$\lambda_B = \frac{1}{R} \times 4 = \frac{4}{R}$

Step 3: Paschen series "last line"

Paschen series: $n_1 = 3$, $n_2 = \infty$ (last line):

So,

$\frac{1}{\lambda_P} = R\left(\frac{1}{3^2} - 0\right) = R \cdot \frac{1}{9}$

So,

$\lambda_P = \frac{1}{R} \times 9 = \frac{9}{R}$

Step 4: Ratio of wavelengths

Ratio $= \frac{\lambda_P}{\lambda_B} = \frac{\frac{9}{R}}{\frac{4}{R}} = \frac{9}{4}$

Step 5: Final Answer

Correct option: A $\boxed{\frac{9}{4}}$

Question27

In the second orbit of hydrogen atom, the energy of an electron is ' E '. In the third orbit of helium atom, the energy of the electron will be (atomic number of helium $= 2$)

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Options:

A. $\frac{4\mathrm{E}}{9}$

B. $\frac{4\mathrm{E}}{3}$

C. $\frac{16\mathrm{E}}{9}$

D. $\frac{16\mathrm{E}}{3}$

Answer: C

Solution:

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

$$\therefore \quad \frac{E_H}{E_{He}} = \frac{(Z^2)_H}{(n)_H^2} \times \frac{(n_{He})^2}{(Z^2)_{He}}$$

$$= \frac{1}{2^2} \times \frac{3^2}{2^2} = \frac{9}{16}$$

$$\therefore \quad E_{He} = \frac{16}{9} E_H = \frac{16}{9} E$$

Question28

Two radioactive substances A and B have decay constants ' 5λ ' and ' λ ' respectively. At $t = 0$, they have the same number of nuclei. The ratio of number of nuclei of A to those of B will be $\left(\frac{1}{e}\right)^2$ after a time interval

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Options:

A. $\frac{1}{42}$

B. 4λ

C. 2λ

D. $\frac{1}{2\lambda}$

Answer: D

Solution:

Number of nuclei remained after time t can be written as $N = N_0 e^{-\lambda t}$

$N_1 = N_0 e^{-5\lambda t}$ .... (i)

and $N_2 = N_0 e^{-\lambda t}$ .... (ii)

Dividing equation (i) by equation (ii), we get,

$$\frac{N_1}{N_2}=e^{(-5\lambda+\lambda)t}=e^{-4\lambda t}=\frac{1}{e^{4\lambda\lambda}}$$

$$\frac{N_1}{N_2}=\left(\frac{1}{e}\right)^2=\frac{1}{e^2} \quad \text{... [Given]}$$

$$\therefore \quad \frac{1}{e^2}=\frac{1}{e^{4\lambda\lambda}}$$

$$\therefore \quad 2=4\lambda t \Rightarrow t=\frac{2}{4\lambda}=\frac{1}{2\lambda}$$

Question29

In M_O is the mass of an oxygen isotope ${}_8O^{17}$ and M_p and M_N are the mass of proton and mass of neutron respectively, then the nucleus binding energy of the isotope is

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Options:

A. M_oC^2

B. $(M_o - 8M_P)C^2$

C. $(M_o - 17M_N)C^2$

D. $(M_o - 8M_P - 9M_N)C^2$

Answer: D

Solution:

Number of protons $= 8$

Number of neutrons $= 17 - 8 = 9$

Binding energy,

$$BE=\left(M_{\text{nucleus}}-M_{\text{nucleons}}\right)C^2$$

$$=\left(M_o-8M_p-9M_N\right)C^2$$

Question30

Frequency of the series limit of Balmer series of hydrogen atom of Rydberg's constant ' R ' and velocity of light ' C ' is

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Options:

A. $\frac{\mathrm{RC}}{4}$

B. RC

C. $\frac{4}{\mathrm{RC}}$

D. 4 RC

Answer: A

Solution:

Wavelength of Balmer series is given as,

$\frac{1}{\lambda}=\mathrm{R}\left(\frac{1}{\mathrm{n}^2}-\frac{1}{\mathrm{m}^2}\right)$ where $\mathrm{n}=2$

For series limit, $m=\infty$

$\therefore \quad \frac{1}{\lambda}=\mathrm{R}\left(\frac{1}{4}-\frac{1}{\infty}\right)=\mathrm{R}\left(\frac{1}{4}\right)$

Now, $\nu=\frac{\mathrm{C}}{\lambda}$

$\therefore \quad \nu=\frac{R C}{4}$

Question31

Acceleration of an electron in the first Bohr's orbit is proportional to $\mathrm{m}=$ mass of electron, $\mathrm{r}=$ radius of the orbit, $\mathrm{h}=$ Planck's constant)

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Options:

A. $\frac{\mathrm{m^3r^3}}{\mathrm{h^2}}$

B. $\frac{h^2}{m^2r^3}$

C. $\frac{\mathrm{h^2}}{\mathrm{mr^3}}$

D. $\frac{\mathrm{mr^3}}{\mathrm{h^2}}$

Answer: B

Solution:

The acceleration of an electron in the first Bohr's orbit can be analyzed through the centripetal acceleration formula, which is given by:

$a = \frac{v^2}{r}$

where v is the tangential velocity of the electron in its orbit, and r is the radius of the orbit.

In Bohr's model, the angular momentum L of the electron is quantized and given by:

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

where m is the mass of the electron, r is the radius of the orbit, n is the principal quantum number (for the first orbit, $n = 1$), and h is Planck's constant.

Solving for the velocity v from the angular momentum expression:

$v = \frac{h}{2\pi mr}$

Substitute this back into the centripetal acceleration formula:

$a = \frac{v^2}{r} = \frac{\left(\frac{h}{2\pi mr}\right)^2}{r} = \frac{h^2}{4\pi^2m^2r^3}$

Since the constant part $\frac{1}{4\pi^2}$ is omitted when considering proportionality, the acceleration a is proportional to:

$\frac{h^2}{m^2r^3}$

Therefore, the correct option is:

Option B: $\frac{h^2}{m^2r^3}$

Question32

In the given reaction

$_zX^A \rightarrow {}_{z+1}Y^A \rightarrow {}_{z-1}\mathrm{K}^{A-4} \rightarrow {}_{z-1}\mathrm{K}^{A-4}$

radioactive radiations are emitted in the sequence

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Options:

A. α, β, γ

B. β, α, γ

C. γ, α, β

D. β, γ, α

Answer: B

Solution:

$_zX^A \xrightarrow{_{-1}\beta^0} {}_{z+1}Y^A \xrightarrow{_2He^4(\alpha)} {}_{z-1}K^{A-4} \xrightarrow{_0\gamma^0} {}_{z-1}K^{A-4}$

$\therefore$ The sequence is β, α and γ.

Question33

A radioactive substance has half-life of 60 minute. During 3 hour, the amount of substance decayed would be

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Options:

A. 8.5%

B. 25%

C. 12.5%

D. 87.5%

Answer: D

Solution:

$$N = N_0 \left(\frac{1}{2}\right)^{\frac{1}{\pi/2}}$$

$$\therefore \quad \frac{N}{N_0} = \left(\frac{1}{2}\right)^{\frac{1}{{}_{\pi}T/2}}$$

$$\therefore \quad \frac{\mathrm{N}}{\mathrm{N}_0} = \left(\frac{1}{2}\right)^{\frac{3\times60}{60}} = \left(\frac{1}{2}\right)^3$$

$$\therefore \quad \frac{\mathrm{N}}{\mathrm{N}_0} = \frac{1}{8}$$

$$\text{The amount of substance decayed } = 1 - \frac{\mathrm{N}}{\mathrm{N}_0}$$

$$1 - \frac{N}{N_0} = 1 - \frac{1}{8} = \frac{7}{8} = 87.5\%$$

Question34

The ratio of the areas of the electron orbits for the second excited state to the first excited state for the hydrogen atom is

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Options:

A. 3 : 2

B. 9 : 4

C. 16 : 81

D. 81 : 16

Answer: D

Solution:

$$r_n \propto n^2 \Rightarrow A_n \propto n^4 \text{ where, } A_n = \text{ area}$$

$$\therefore \quad \frac{A_3}{A_2} = \left(\frac{3}{2}\right)^4 = \frac{81}{16}$$

Question35

In a hydrogen atom in its ground state, the first Bohr orbit has radius r_1. The electron's orbital speed becomes one-third when the atom is raised to one of its excited states. The radius of the orbit in that excited state is

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Options:

A. $3r_1$

B. $4r_1$

C. $9\pi_1$

D. $16\mathrm{r}_1$

Answer: C

Solution:

The radius of the Bohr orbit in a hydrogen atom is given by the equation:

$r_n = n^2 \cdot r_1$

where r_n is the radius of the orbit in the n-th excited state, and r_1 is the radius of the first Bohr orbit in the ground state, which is approximately 5.29×10^{-11} meters.

The orbital speed of an electron in the Bohr model is inversely proportional to the principal quantum number n:

$v_n = \frac{v_1}{n}$

If the electron's orbital speed becomes one-third of its speed in the ground state, we have:

$\frac{v_1}{n} = \frac{v_1}{3}$

This simplifies to:

$n = 3$

Substituting $n = 3$ into the equation for the radius:

$r_n = 3^2 \cdot r_1 = 9 \cdot r_1$

Thus, the radius of the orbit in the excited state is:

Option C

$9 \cdot r_1$

Question36

The angular momentum of the electron in the third Bohr orbit of hydrogen atom is ' l '. Its angular momentum in the fourth Bohr orbit is

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Options:

A. $4l$

B. $\frac{4}{3}l$

C. $\frac{5}{4}l$

D. $\frac{3}{2}l$

Answer: B

Solution:

Angular momentum of an electron in the nth Bohr orbit of hydrogen atom,

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

$$\Rightarrow L \propto n$$

$$\therefore \quad \frac{L_1}{L_2} = \frac{l}{L'} = \frac{3}{4}$$

$$L' = \frac{4}{3}l$$

Question37

The ratio of energies of photons produced due to transition of electron of hydrogen atom from its (a) second to first energy level and (b) highest energy level to second level is

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Options:

A. 1 : 3

B. 1 : 2

C. 3 : 1

D. 4 : 1

Answer: C

Solution:

Let E_1 be the energy of the first energy level,

then $E_2 = \frac{E_1}{4}$

For highest level $E_\infty = 0$

$$\begin{aligned} \therefore \quad & E_2 - E_1 = \frac{E_1}{4} - E_1 = -\frac{3}{4} E_1 \\ & E_\infty - E_2 = 0 - \frac{E_1}{4} = -\frac{E_1}{4} \\ \therefore \quad & \frac{E_2 - E_1}{E_\infty - E_2} = 3 : 1 \end{aligned}$$

Question38

If 'T' is the half life of a radioactive substance then its instantaneous rate of change of activity is proportional to

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Options:

A. T

B. T^{-2}

C. T^{+2}

D. T^{-1}

Answer: B

Solution:

The instantaneous rate of change of activity of a radioactive substance is derived based on its half-life, T.

Let's break it down step by step:

Activity Relationship:

$R=-\frac{dN}{dt}=\lambda N$

Here, R is the activity, λ is the decay constant, and N is the number of undecayed nuclei.

Rate of Change of Activity:

$\frac{dR}{dt}=\frac{d}{dt}(\lambda N)=\lambda\frac{dN}{dt}=\lambda(-\lambda N)=-\lambda^2 N$

Linking Decay Constant to Half-Life:

$\lambda=\frac{\log_e 2}{T_{1/2}}$

This expression relates the decay constant λ to the half-life $T_{1/2}$.

Substitute the Decay Constant:

$\lambda^2 N=\frac{(\log_e 2)^2 N}{T_{1/2}^2}$

Proportionality of Rate of Change:

$\frac{dR}{dt}\propto\frac{1}{T_{1/2}^2}$

Thus, the instantaneous rate of change of activity is inversely proportional to the square of the half-life, $T_{1/2}^2$.

Question39

Radius of first orbit in H -atom is ' a_0 ' Then, de-Broglie wavelength of electron in the third orbit is

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Options:

A. $3 \pi a_0$

B. $6 \pi a_0$

C. $9 \pi a_0$

D. $12 \pi a_0$

Answer: B

Solution:

Radius for n^{th} orbit, $r_n = a_0 \times n^2$

For third orbit,

$$r_3 = a_0 \times 3^2$$
$$= 9 a_0$$

Also, $mvr = \frac{nh}{2\pi}$

$$\Rightarrow \quad mv = \frac{nh}{2\pi r} = \frac{3h}{2\pi \times 9a_0}$$

$$\lambda = \frac{h}{mv} = \frac{h}{3h} \times 2\pi \times 9a_0 = 6\pi a_0$$

Question40

In the Bohr model of hydrogen atom, the centripetal force is furnished by the coulomb attraction between the proton and the electron. If ' r_0 ' is the radius of the ground state orbit, ' m ' is the mass, ' e ' is the charge on the electron and ' ε_0 ' is the permittivity of vacuum, the speed of the electron is

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Options:

A. zero

B. $\frac{e}{\sqrt{\varepsilon_0 r_0 \text{ m}}}$

C. $\frac{e}{\sqrt{4\pi\varepsilon_0 r_0 \text{ m}}}$

D. $\frac{\sqrt{4\pi\varepsilon_0 r_0 \text{ m}}}{e}$

Answer: C

Solution:

Given, Centripetal Force = Coulomb attraction

$\frac{mv^2}{r_0} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r_0^2}$

$\therefore \quad v = \frac{e}{\sqrt{4\pi\varepsilon_0 r_0 \text{ m}}}$

Question41

If the ionisation energy for the hydrogen atom is 13.6 eV , then the energy required to excite it from the ground state to the next higher state is nearly

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Options:

A. 10.2 eV

B. 13.6 eV

C. -10.2 eV

D. -3.4 eV

Answer: A

Solution:

Minimum energy required to excite from ground state,

$E_{\min} = 13.6\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = 10.2 \text{ eV}$

Question42

Using Bohr's model, the orbital period of electron in hydrogen atom in n^{th} orbit is (m = mass of electron, h = Planck's constant, e = electronic charge, ε_0 = permittivity of free space)

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Options:

A. $\frac{2\varepsilon_0^2 n^2 h^2}{me^4}$

B. $\frac{4\varepsilon_0^2 n^2 h^2}{me^2}$

C. $\frac{4\varepsilon_0^2 n^3 h^3}{me^4}$

D. $\frac{4\varepsilon_0 n^2 h^2}{\pi me^2}$

Answer: C

Solution:

r = radius of n^{th} orbit $= \frac{n^2 h^2}{\pi m Z e^2}$

v = speed of e^- in n^{th} orbit $= \frac{Ze^2}{2\varepsilon_0 nh}$

$T = \frac{2\pi r}{v}$

Substituting values of v and r,

$\therefore \quad T = \frac{4\varepsilon_0^2 n^3 h^3}{mZZ^2 e^4}$

For hydrogen, $Z = 1$

$\therefore \quad T = \frac{4\varepsilon_0^2 n^3 h^3}{me^4}$

Question43

The spectral series observed for hydrogen atom found in visible region is

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Options:

A. Lyman

B. Balmer

C. Paschen

D. Brackett

Answer: B

Solution:

The hydrogen spectral series that lies in the **visible** region is the **Balmer series** (option **B**).

Question44

In hydrogen atom, if V_n and V_p are orbital velocities in n^{th} and p^{th} orbit respectively, then the ratio $V_p : V_n$ is

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Options:

A. $p : n$

B. $n : p$

C. $p^2 : n^2$

D. $n^2 : p^2$

Answer: B

Solution:

Velocity of electron in n^{th} orbit of hydrogen atom, $V_n = \frac{e^2}{2\varepsilon_0 hn}$

$$\therefore \quad V_n \propto \frac{1}{n}$$

$$\therefore \quad \frac{V_p}{V_n} = \frac{n}{p}$$

Question45

When a hydrogen atom is raised from the ground state to the excited state

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Options:

A. potential energy increases and K.E. decreases.

B. potential energy decreases and K.E. increases.

C. both K.E. and potential energy will increase.

D. both K.E. and potential energy decreases.

Answer: A

Solution:

In the (simplified) Bohr model of the hydrogen atom:

The **total energy** E_n in the n^{th} orbit is

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

The **kinetic energy** of the electron is

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

The **potential energy** of the electron is

$U_n = 2E_n = -\frac{27.2 \text{ eV}}{n^2}$.

When the atom is excited from $n = 1$ (ground state) to $n > 1$ (an excited state):

E_n becomes **less negative** (it increases toward 0).

K_n **decreases**, because $K_n = 13.6 \text{ eV}/n^2$ gets smaller for larger n.

U_n becomes **less negative**, which means U_n is effectively **increasing** (going from a larger negative value to a smaller negative value).

Therefore, when a hydrogen atom is raised from the ground state to an excited state,

the potential energy increases (less negative),

the kinetic energy decreases.

Hence the correct option is:

$\boxed{\text{(A) potential energy increases and K.E. decreases.}}$

Question46

In hydrogen atom, ratio of the shortest wavelength in the Balmer series to that in the Paschen series is

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Options:

A. 9 : 4

B. 3 : 1

C. 4 : 9

D. 1 : 3

Answer: C

Solution:

The shortest wavelength in Balmer series is given by

$\frac{1}{\lambda_1} = \mathrm{R}\left(\frac{1}{2^2} - \frac{1}{\infty}\right) = \frac{\mathrm{R}}{4}$ .... (i)

The shortest wavelength in the Paschen series given by

$\frac{1}{\lambda_2} = \mathrm{R}\left(\frac{1}{3^2} - \frac{1}{\infty}\right) = \frac{R}{9}$ .... (ii)

Dividing equation (ii) by equation (i),

$\frac{\lambda_1}{\lambda_2} = \frac{\mathrm{R}}{9} \times \frac{4}{\mathrm{R}} = \frac{4}{9}$

Question47

According to Bohr's theory of hydrogen atom, the ratio of the maximum and minimum wavelength of Lyman series will be

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Options:

A. 3 : 4

B. 4 : 3

C. 2 : 5

D. 5 : 2

Answer: B

Solution:

$$\frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{\mathrm{n}_1^2} - \frac{1}{\mathrm{n}_2^2}\right)$$

For Lyman series, $\mathrm{n}_1 = 1$

$$\frac{1}{\lambda_{\max}} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3}{4}R$$

$$\frac{1}{\lambda_{\min}} = R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R$$

$$\therefore \quad \frac{\lambda_{\max}}{\lambda_{\min}} = \frac{4}{3}$$

Question48

The ratio of minimum wavelengths of Lyman and Balmer series will be

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Options:

A. 1.25

B. 0.25

C. 5

D. 10

Answer: B

Solution:

Wavelength, $\frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{\mathrm{n}^2} - \frac{1}{\mathrm{m}^2}\right)$

For shortest wavelength in Lyman series:

$$n = 1, m = \infty$$
$$\frac{1}{\lambda_L} = R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R \quad \text{.... (i)}$$

For shortest wavelength in Balmer series:

$$\mathrm{n} = 2,\ \mathrm{m} = \infty$$
$$\frac{1}{\lambda_\mathrm{B}} = \mathrm{R}\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{\mathrm{R}}{4} \quad \text{.... (ii)}$$

Dividing equation (ii) by equation (i),

$\frac{\lambda_1}{\lambda_B} = \frac{\mathrm{R}/4}{\mathrm{R}} = \frac{1}{4} = 0.25$

Question49

Half-lives of two radioactive elements A and B are 30 minute and 60 minute respectively. Initially the samples have equal number of nuclei. After 120 minute the ratio of decayed numbers of nuclei of B to that of A will be

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Options:

A. 1 : 15

B. 1 : 4

C. 4 : 5

D. 5 : 4

Answer: C

Solution:

For radioactive decay, amount of sample remaining is given by,

$N = N_o\left(\frac{1}{2}\right)^{\lambda}$ .... (i)

N_o is initial sample and λ is decay constant.

Decay constant, $\lambda = \left(\frac{t}{t_{1/2}}\right) = \frac{120}{t_{1/2}}$ .... (given)

For element A,

$N_A = N_o\left(\frac{1}{2}\right)^{\frac{120}{30}} = \frac{N_o}{2^4}$ ...[From(i)]

Amount of sample A decayed, $N'_A = N_o - N_A = N_o - \frac{N_o}{2^4} = \frac{15}{16}N_O$ .... (ii)

For element B,

$N_B = N_0\left(\frac{1}{2}\right)^{\frac{120}{60}} = \frac{N_0}{2^2}$ ...[From(i)]

Amount of sample B decayed,

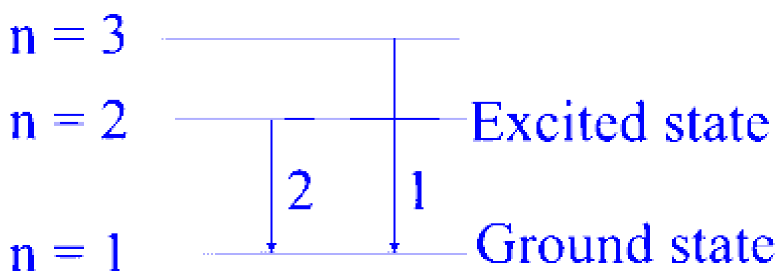
$N_B{}' = N_o - N_B = N_o - \frac{N_o}{2^2} = \frac{3}{4}N_o$

From (ii) and (iii),

$\frac{N_{A'}}{N_{B'}} = \frac{4}{5}$

Question50

For hydrogen atom, ' λ_1 ' and ' λ_2 ' are the wavelengths corresponding to the transitions 1 and 2 respectively as shown in figure. The ratio of ' λ_1 ' and ' λ_2 ' is $\frac{x}{32}$. The value of ' x ' is



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Options:

A. 3

B. 9

C. 27

D. 81

Answer: C

Solution:

Using Rydberg's formula

$\frac{1}{\lambda_1} = \mathrm{R}\left[\frac{1}{\mathrm{n}_1^2} - \frac{1}{\mathrm{n}_2^2}\right] = \mathrm{R}\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8}{9}\mathrm{R}$

Similarly, $\frac{1}{\lambda_2} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}R$

$\therefore \quad \frac{\frac{1}{\lambda_1}}{\frac{1}{\lambda_2}} = \frac{\frac{8}{9}\mathrm{R}}{\frac{3}{4}R}$

$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{27}{32}$

$\therefore \quad x = 27$

Question51

The ratio of the radius of the first Bohr orbit to that of the second Bohr orbit of the orbital electron is

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Options:

A. 4 : 1

B. 2 : 1

C. 1 : 4

D. 1 : 2

Answer: C

Solution:

The radius of the n-th Bohr orbit for an electron in a hydrogen atom is given by:

$r_n = n^2 \cdot r_1$

where r_1 is the radius of the first Bohr orbit (also known as the Bohr radius).

For the first orbit ($n = 1$):

$r_1 = 1^2 \cdot r_1 = r_1$

For the second orbit ($n = 2$):

$r_2 = 2^2 \cdot r_1 = 4r_1$

The ratio of the radius of the first Bohr orbit to that of the second Bohr orbit is:

$\frac{r_1}{r_2} = \frac{r_1}{4r_1} = \frac{1}{4}$

Thus, the correct answer is:

Option C

1 : 4

Question52

A diatomic molecule has moment of inertia ' I ', By applying Bohr's quantization condition, its rotational energy in the n^{th} level is

$[\mathrm{n} \geq 1]$ **[h= Planck's constant]**

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Options:

A. $\frac{1}{\mathrm{n}^2}\left(\frac{\mathrm{h}^2}{8 \pi^2 \mathrm{I}}\right)$

B. $\frac{1}{\mathrm{n}}\left(\frac{\mathrm{h}^2}{8 \pi^2 \mathrm{I}}\right)$

C. $n\left(\frac{h^2}{8 \pi^2 \mathrm{I}}\right)$

D. $\mathrm{n}^2\left(\frac{\mathrm{h}^2}{8 \pi^2 \mathrm{I}}\right)$

Answer: D

Solution:

Bohr's quantization condition for the rotational motion of a diatomic molecule states that the angular momentum is quantized and given by:

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

where n is the quantum number (an integer), and h is Planck's constant.

The rotational energy E of a diatomic molecule in the n-th level can be linked to its moment of inertia I and angular momentum L through the following expression:

$E=\frac{L^2}{2 I}.$

Substituting the quantized angular momentum into the expression for energy gives:

$E=\frac{\left(n \frac{h}{2 \pi}\right)^2}{2 I}=\frac{n^2 h^2}{8 \pi^2 I}.$

Thus, the rotational energy of a diatomic molecule in the n-th level is:

$\mathrm{n}^2\left(\frac{\mathrm{h}^2}{8 \pi^2 \mathrm{I}}\right).$

Therefore, the correct option is **Option D**.

Question53

In the uranium radioactive series, the initial nucleus is $_{92}^{238}\mathrm{U}$ and that the final nucleus is $_{82}^{206}\mathrm{Pb}$. When uranium nucleus decays into lead, the number of α-particles and β-particles emitted are

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Options:

A. $4\alpha, 5\beta$

B. $5\alpha, 3\beta$

C. $6\alpha, 7\beta$

D. $8\alpha, 6\beta$

Answer: D

Solution:

To determine the number of α-particles and β-particles emitted when uranium-238 ($_{92}^{238}\mathrm{U}$) decays into lead-206 ($_{82}^{206}\mathrm{Pb}$), we must first understand the changes in atomic and mass numbers during the decay process.

Calculation of α-particles

An α-particle is composed of 2 protons and 2 neutrons, equivalent to a helium nucleus ($_{2}^{4}\mathrm{He}$). Emitting one α-particle decreases the atomic number by 2 and the mass number by 4.

Initial nucleus: $_{92}^{238}\mathrm{U}$

Final nucleus: $_{82}^{206}\mathrm{Pb}$

Change in mass number:

$238 - 206 = 32$

Since each α-particle reduces the mass number by 4:

Number of α-particles $= \frac{32}{4} = 8$

Calculation of β-particles

A β-particle decay involves the conversion of a neutron into a proton, increasing the atomic number by 1, but leaving the mass number unchanged.

Change in atomic number:

$92 - 82 = 10$

To account for the 10-unit change in atomic number caused by the emission of 8 α-particles (which decrease the atomic number by 16), β-particles must be emitted to increase the atomic number by 6 units (since $16 - 10 = 6$).

Hence, the number of β-particles is 6.

Conclusion

The decay of uranium-238 to lead-206 involves the emission of:

8 α-particles

6 β-particles

Therefore, the correct answer is **Option D:** $8\alpha, 6\beta$.

Question54

If ' λ_1 ' and ' λ_2 ' are the wavelengths of the first line of the Lyman and Paschen series respectively, then $\lambda_2 : \lambda_1$ is

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Options:

A. $3 : 1$

B. $30 : 1$

C. $50 : 7$

D. $108 : 7$

Answer: D

Solution:

In the hydrogen atom spectrum, the Lyman and Paschen series are defined by the electron transition levels. The Lyman series involves transitions where the final energy level is $n_1 = 1$, while the Paschen series involves transitions to $n_1 = 3$.

The wavelength of light emitted during a transition between two energy levels in a hydrogen atom can be determined using the Rydberg formula:

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

where R_H is the Rydberg constant, n_1 is the lower energy level, and n_2 is the higher energy level.

For the first line of the series (the first transition):

Lyman series: $n_1 = 1, n_2 = 2$

Paschen series: $n_1 = 3, n_2 = 4$

Calculating the wavelength for the Lyman series:

$\frac{1}{\lambda_1} = R_H \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = R_H \left(1 - \frac{1}{4}\right) = R_H \cdot \frac{3}{4}$

Thus,

$\lambda_1 = \frac{4}{3R_H}$

Calculating the wavelength for the Paschen series:

$\frac{1}{\lambda_2} = R_H \left(\frac{1}{3^2} - \frac{1}{4^2}\right) = R_H \left(\frac{1}{9} - \frac{1}{16}\right)$

Simplifying the above expression:

$\frac{1}{\lambda_2} = R_H \left(\frac{16-9}{144}\right) = R_H \cdot \frac{7}{144}$

Thus,

$\lambda_2 = \frac{144}{7R_H}$

Finding the ratio $\frac{\lambda_2}{\lambda_1}$:

$\frac{\lambda_2}{\lambda_1} = \frac{\frac{144}{7R_H}}{\frac{4}{3R_H}} = \frac{144 \cdot 3}{7 \cdot 4} = \frac{432}{28} = \frac{108}{7}$

Therefore, the ratio $\lambda_2 : \lambda_1$ is

$108 : 7$

Thus, the correct answer is **Option D:** $108 : 7$.

Question55

An electron of stationary Hydrogen atom passes from fifth energy level to ground level. The velocity that the atom acquired as a result of photo emission is

($\mathrm{m} =$ mass of electron, $\mathrm{R} =$ Rydberg's constant)

($\mathrm{h} =$ Planck's constant)

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Options:

A. $\frac{24 \mathrm{Rh}}{25 \mathrm{~m}}$

B. $\frac{25 \mathrm{Rh}}{24 \mathrm{~m}}$

C. $\frac{25 \mathrm{~m}}{24 \mathrm{Rh}}$

D. $\frac{24 \mathrm{~m}}{25 \mathrm{Rh}}$

Answer: A

Solution:

$$\frac{1}{\lambda}=R\left(\frac{1}{\mathrm{n}_1^2}-\frac{1}{\mathrm{n}_2{}^2}\right)$$

In this case, $\mathrm{n}_1=1$ and $\mathrm{n}_2=5$

$$\therefore \quad \frac{1}{\lambda}=R\left(\frac{1}{1^2}-\frac{1}{5^2}\right)=\frac{24}{25} R \quad \text{... (i)}$$

Momentum of Photon,

$p=\frac{h}{\lambda}=h\left(\frac{24}{25} R\right)$ ...[From (i)]

By conservation of momentum,

Momentum of Photon = Momentum of atom

$$h\left(\frac{24}{25} R\right)=m v$$

$$\therefore \quad v=\frac{24 R h}{25 m}$$

Question56

Which of the following statements about the Bohr model of the hydrogen atom is false?

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Options:

A. Acceleration of electron in n $=2$ orbit is less than that in $n=1$ orbit.

B. Angular momentum of electron in n $=2$ orbit is more than that in $n=1$ orbit.

C. Kinetic energy of electron in n $=2$ orbit is less than that in n $=1$ orbit.

D. Potential energy of electron in n $=2$ orbit is less than that in $n=1$ orbit.

Answer: D

Solution:

Potential energy in n^{th} orbit is given by,

$$\therefore \quad P \cdot E=-\frac{m_e Z^2 e^4}{4 \varepsilon_o^2 n^2 h^2}$$

$$\therefore \quad P \cdot E \propto \frac{1}{n^2}$$

Question57

The radius of innermost orbit of hydrogen atom is 5.3×10^{-11} m . The radius of fourth allowed orbit of hydrogen atom is

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Options:

A. $8.48 \stackrel{o}{A}$

B. $2.12 \stackrel{o}{A}$

C. $4.77 \stackrel{o}{A}$

D. $0.53 \stackrel{o}{A}$

Answer: A

Solution:

The radius of the orbit in a hydrogen atom is determined by the formula for the Bohr model of the hydrogen atom. The radius of the n-th orbit is given by:

$r_n = n^2 \times r_1$

where r_1 is the radius of the innermost orbit (ground state, $n = 1$) and n is the principal quantum number.

Given:

The radius of the innermost orbit (ground state) is $r_1 = 5.3 \times 10^{-11}$ m.

For the fourth orbit ($n = 4$), the radius is calculated as follows:

$r_4 = 4^2 \times r_1 = 16 \times 5.3 \times 10^{-11}$ m

Calculate r_4:

$r_4 = 16 \times 5.3 \times 10^{-11} = 84.8 \times 10^{-11}$ m

Converting meters to ångströms (where $1 \text{Å} = 10^{-10}$ m):

$r_4 = 8.48 \text{Å}$

Therefore, the radius of the fourth allowed orbit of the hydrogen atom is:

Option A

$8.48 \overset{o}{A}$

Question58

In the third orbit of hydrogen atom the energy of an electron ' E '. In the fifth orbit of helium $(Z = 2)$ the energy of an electron will be

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Options:

A. $\frac{25E}{36}$

B. $\frac{36E}{25}$

C. $\frac{3E}{5}$

D. $\frac{5E}{3}$

Answer: B

Solution:

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

$$\therefore \quad \frac{E_H}{E_{Hc}} = \frac{(Z^2)_H}{(n)_H^2} \times \frac{(n)_{He}^2}{(Z^2)_{He}}$$

$$= \frac{1}{3^2} \times \frac{5^2}{2^2} = \frac{25}{36}$$

$$\therefore \quad E_{He} = \frac{36}{25} E_H = \frac{36}{25} E$$

Question59

Ratio of longest wavelength corresponding to Lyman and Balmer series in hydrogen spectrum is

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Options:

A. $\frac{7}{29}$

B. $\frac{9}{31}$

C. $\frac{5}{27}$

D. $\frac{3}{23}$

Answer: C

Solution:

Wavelength for Lyman series is,

$\frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{n^2}\right]$

For the longest wavelength, $\lambda = \lambda_{max}$ and $n = 2$

$\frac{1}{\lambda_{\max(\mathrm{L})}}=\mathrm{R}\left[\frac{1}{1^2}-\frac{1}{2^2}\right]=\frac{3}{4}$

Wavelength for Balmer series is,

$\frac{1}{\lambda}=R\left[\frac{1}{2^2}-\frac{1}{n^2}\right]$

For the longest wavelength, $\mathrm{n}=3$

$$\frac{1}{\lambda_{\max(\mathrm{B})}}=\mathrm{R}\left[\frac{1}{2^2}-\frac{1}{3^2}\right]=\frac{5}{36}$$
$$\frac{\lambda_{\max(\mathrm{L})}}{\lambda_{\max(\mathrm{B})}}=\frac{4}{3}\times\frac{5}{36}=\frac{5}{27}$$

Question60

Half life of radio-active element is 1600 years. The fraction of sample remains undecayed after 6400 years will be

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Options:

A. $\frac{1}{16}$

B. $\frac{1}{4}$

C. $\frac{1}{8}$

D. $\frac{1}{24}$

Answer: A

Solution:

The half-life of a radioactive substance is the time it takes for half of the substance to decay. The remaining fraction of the original substance after a certain number of half-lives can be calculated using the formula:

$N=N_0\left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$

Where:

N is the remaining quantity of the substance,

N_0 is the initial quantity of the substance,

t is the elapsed time,

$T_{1/2}$ is the half-life of the substance.

Given that the half-life $T_{1/2}$ is 1600 years, and we want to find the amount of substance left after 6400 years, we can use the above formula:

$\frac{t}{T_{1/2}} = \frac{6400}{1600} = 4$ half-lives

Therefore,

$N = N_0\left(\frac{1}{2}\right)^4$

$N = N_0\left(\frac{1}{2^4}\right)$

$N = N_0\left(\frac{1}{16}\right)$

The fraction of the original sample remaining undecayed after 6400 years is $\frac{1}{16}$.

Thus, the correct answer is:

Option A $\frac{1}{16}$

Question61

Frequency of the series limit of Balmer series of hydrogen atom in terms of Rydberg's constant (R) and velocity of light (c) is

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Options:

A. 4Rc

B. $\frac{4}{\mathrm{Rc}}$

C. Rc

D. $\frac{\mathrm{Rc}}{4}$

Answer: D

Solution:

Wavelength of Balmer series is given as, $\frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{\mathrm{n}_1^2} - \frac{1}{\mathrm{n}_2^2}\right)$ where $\mathrm{n}_1 = 2$

For series limit, $\mathrm{n}_2 = \infty$

$\therefore \quad \frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{4} - \frac{1}{\infty}\right) = \mathrm{R}\left(\frac{1}{4}\right)$

Now, $v = \frac{c}{\lambda}$

$\therefore \quad v = \frac{Rc}{4}$

Question62

If the radius of the first Bohr orbit is 'r' then the de-Broglie wavelength of the electron in the 4^{th} orbit will be

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Options:

A. $4\pi\mathrm{r}$

B. $6\pi\mathrm{r}$

C. $8\pi\mathrm{r}$

D. $\frac{\pi r}{4}$

Answer: C

Solution:

According to Bohr's second postulate,

$\frac{\mathrm{nh}}{2\pi} = \mathrm{mvr_n}$

$\therefore$ de-Broglie wavelength, $\lambda_n = \frac{h}{mv} = \frac{2\pi r_n}{n}$

Also, $\mathrm{r_n} \propto \mathrm{n}^2$

$\therefore \quad$ The de-Broglie wavelength of the electron in the 4^{th} orbit is:

$$\lambda_4 = \frac{2\pi r_4}{4} = \frac{2\pi \times (16r)}{4}$$
$$\therefore \quad \lambda_4 = 8\pi r$$

Question63

Magnetic field at the centre of the hydrogen atom due to motion of electron in n^{th} orbit is proportional to

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Options:

A. n^4

B. n^{-3}

C. n^3

D. n^{-5}

Answer: D

Solution:

The radius of the n^{th} Bohr orbit is, $r_n \propto n^2$.

The angular velocity of the electron, $\omega_{\mathrm{n}} \propto \frac{1}{\mathrm{n}^3}$

Also, current $I_n = \frac{q}{T_n} = \frac{q\omega_n}{2\pi}$

$\therefore \quad I_n \propto \omega_n \propto \frac{1}{n^3}$

Now, $B_n = \frac{\mu_0 I_n}{2r_n}$

$\therefore \quad B_n \propto \frac{1}{n^3} \times \frac{1}{n^2}$

$\therefore \quad B_n \propto \frac{1}{n^5}$

Question64

An excited hydrogen atom emits a photon of wavelength λ in returning to ground state. The quantum number n of the excited state is ($R =$ Rydberg's constant)

Options:

A. $\sqrt{\lambda R(\lambda R-1)}$

B. $\sqrt{\frac{\lambda R}{(\lambda R-1)}}$

C. $\sqrt{\frac{(\lambda R-1)}{\lambda R}}$

D. $\sqrt{\frac{1}{\lambda R(\lambda R-1)}}$

Answer: B

Solution:

The wave number of emitted photon when electron jumps from n_1 to n_2 is given by

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

Here, $n_1=1, n_2=n$

Put the value of n_1 and n_2 in Eq. (i), we get

$$\Rightarrow \quad \frac{1}{\lambda}=R\left[\frac{1}{1^2}-\frac{1}{n^2}\right]$$
$$\Rightarrow \quad \frac{1}{\lambda R}=\left[1-\frac{1}{n^2}\right] \Rightarrow \frac{1}{n^2}=1-\frac{1}{\lambda R}$$
$$\Rightarrow \quad \frac{1}{n^2}=\frac{(\lambda R-1)}{\lambda R} \Rightarrow n^2=\frac{\lambda R}{(\lambda R-1)}$$
$$\Rightarrow \quad n=\sqrt{\frac{\lambda R}{(\lambda R-1)}}$$

Question65

When an electron is excited from its 4 th orbit to 5 th stationary orbit, the change in the angular momentum of electron is approximately.

(Planck's constant $=h=6.63\times10^{-34}$ J $-$ s)

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Options:

A. 2×10^{-34} J − s

B. 6.63×10^{-34} J − s

C. 1×10^{-34} J − s

D. 3.14×10^{-34} J − s

Answer: C

Solution:

Charge in angular momentum is

$$\begin{aligned} & \Delta L = L_2 - L_1 = n_2 h - n_1 h \\ \Rightarrow\ & \Delta L = h\left(n_2 - n_1\right) \\ \Rightarrow\ & \Delta L = \frac{h}{2\pi}\left(n_2 - n_1\right) \\ \Rightarrow\ & \Delta L = \frac{6.6 \times 10^{-34}}{2 \times 3.14}(5-4) \\ \Rightarrow\ & \Delta L = 1 \times 10^{-34}\ \mathrm{J-s} \end{aligned}$$

Question66

A radioactive sample has half-life of 5 years. The percentage of fraction decayed in 10 years will be

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Options:

A. 25%

B. 50%

C. 75%

D. 100%

Answer: C

Solution:

Given:

Total time, $\mathrm{T} = 10$ years

Half life, $\mathrm{T}_{1/2} = 5$ years

$\therefore$ No. of half lives, $\mathrm{n} = \frac{10}{5} = 2$

From $\frac{\mathrm{N}}{\mathrm{N}_0} = \left(\frac{1}{2}\right)^{\mathrm{n}}$

$\therefore \quad \frac{\mathrm{N}}{\mathrm{N}_0} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$

$\therefore$ After 10 years, $\frac{1}{4}^{\text{th}}$ of the original substance will remain.

$\Rightarrow \left(1 - \frac{1}{4}\right) = \frac{3}{4} \times 100 = 75\%$ of the fraction would get decayed.

Question67

An isotope of the original nucleus can be formed in a radioactive decay, with the emission of following particles.

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Options:

A. one α and one β

B. one α and two β

C. one α and four β

D. four α and one β

Answer: B

Solution:

${}_{Z}X^{A} \xrightarrow{\alpha} {}_{Z-2}Y^{A-4} \xrightarrow{2\beta^{-}} {}_{Z}X^{A-4}$

Question68

Two different radioactive elements with half lives 'T_1' and 'T_2' have undecayed atoms 'N_1' and 'N_2' respectively present at a given instant. The ratio of their activities at that instant is

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Options:

A. $\frac{N_1 T_1}{N_2 T_2}$

B. $\frac{N_2 T_2}{N_1 T_1}$

C. $\frac{N_1 T_2}{N_2 T_1}$

D. $\frac{N_1 N_2}{T_1 T_2}$

Answer: C

Solution:

$\therefore$ Activity is given as:

$\therefore$ $A = \lambda N$

$$\lambda = \frac{\ln 2}{T}$$

$\therefore$ Ratio of two different radioactive elements will be:

$$\frac{A_1}{A_2} = \frac{\lambda_1 N_1}{\lambda_2 N_2}$$

$$\frac{A_1}{A_2} = \frac{\frac{\ln 2}{T_1} N_1}{\frac{\ln 2}{T_2} N_2}$$

$$\frac{A_1}{A_2} = \frac{N_1 T_2}{N_2 T_1}$$

Question69

In Balmer series, wavelength of the 2^{nd} line is 'λ_1' and for Paschen series, wavelength of the 1^{st} line is 'λ_2', then the ratio 'λ_1' to 'λ_2' is

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Options:

A. 5 : 128

B. 5 : 81

C. 7 : 27

D. 9 : 132

Answer: C

Solution:

For spectral series, $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For the Balmer series, $n_1 = 2$

The wavelength for 2^{nd} line of the Balmer series is

$$\frac{1}{\lambda_1} = RZ^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$
$$\frac{1}{\lambda_1} = RZ^2\left(\frac{1}{4} - \frac{1}{16}\right)$$
$$\frac{1}{\lambda_1} = RZ^2\left(\frac{3}{16}\right) \Rightarrow \lambda_1 = \left[\frac{16}{3}\right]$$

For the Paschen series, $n_1 = 3$

The wavelength for 1^{st} line of the Paschen series is

$$\frac{1}{\lambda_2} = RZ^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$
$$\frac{1}{\lambda_2} = RZ^2\left(\frac{1}{9} - \frac{1}{16}\right)$$
$$\lambda_2 = \frac{144}{7}$$
$$\frac{1}{\lambda_2} = RZ^2\left(\frac{7}{144}\right)$$
$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{16}{3} \times \frac{7}{144} = \frac{7}{27}$$

Question70

In Lyman series, series limit of wavelength is λ_1. The wavelength of first line of Lyman series is λ_2 and in Balmer series, the series limit of wavelength is λ_3. Then the relation between λ_1, λ_2 and λ_3 is

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Options:

A. $\lambda_1 = \lambda_2 + \lambda_3$

B. $\lambda_2 = \lambda_1 + \lambda_3$

C. $\frac{1}{\lambda_1} = \frac{1}{\lambda_2} - \frac{1}{\lambda_3}$

D. $\frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

Answer: D

Solution:

According to Rydberg's formula,

$\frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{\mathrm{n}^2} - \frac{1}{\mathrm{m}^2}\right)$

For series limit of Lyman series,

$$\mathrm{n} = 1,\ \mathrm{m} = \infty, \lambda = \lambda_1$$
$$\therefore \quad \frac{1}{\lambda_1} = \mathrm{R}$$

For 1st line of Lyman series,

$$n = 1,\ m = 2, \lambda = \lambda_2$$

$$\therefore \quad \frac{1}{\lambda_2} = \frac{3R}{4}$$

For series limit of Balmer series,

$$n = 2,\ m = \infty, \lambda = \lambda_3$$

$$\therefore \quad \frac{1}{\lambda_3} = \frac{R}{4}$$

Now, $\frac{1}{\lambda_1} - \frac{1}{\lambda_2} = R - \frac{3R}{4} = \frac{R}{4}$

$\therefore \quad \frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

Question71

The wavelength of radiation emitted is 'λ_0' when an electron jumps from the second excited state to the first excited state of hydrogen atom. If the electron jumps from the third excited state to the second orbit of the hydrogen atom, the wavelength of the radiation emitted will be $\frac{20}{x}\lambda_0$. The value of x is

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Options:

A. 3

B. 9

C. 13

D. 27

Answer: D

Solution:

According to Rydberg's formula,

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

When electron jumps from 2^{nd} exited state to first exited state,

$n_2 = 3, n_1 = 2, \lambda = \lambda_0$, we get

$\frac{1}{\lambda_0} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

When electron jumps from 3^{rd} exited state to 2^{nd} orbit,

$n_2 = 4, n_1 = 2$, we get

$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{2^2}\right)$

$$\therefore \quad \frac{\lambda}{\lambda_0} = \frac{R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)}{R\left(\frac{1}{2^2} - \frac{1}{4^2}\right)}$$

$$= \frac{5}{36} \times \frac{16}{3} = \frac{20}{27}$$

$$\therefore \quad \lambda = \frac{20}{27}\lambda_0$$

$$\Rightarrow x = 27$$

Question72

According to Bohr's theory of hydrogen atom, the total energy of the electron in the n^{th} stationary orbit is

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Options:

A. directly proportional to n

B. inversely proportional to n

C. directly proportional to n^2

D. inversely proportional to n^2

Answer: D

Solution:

According to Bohr's theory of hydrogen atom, the equation for total energy of the electron in the n^{th} stationary orbit is,

$$E_n = \frac{-mZ^2e^4}{8\varepsilon_0{}^2\, h^2n^2}$$

$$\therefore \quad E_n \propto \frac{1}{n^2}$$

Question73

Bohr model is applied to a particle of mass 'm' and charge 'q' moving in a plane under the influence of a transverse magnetic field 'B'. The energy of the charged particle in the n^{th} leve will be $[h =$ Planck's constant $]$

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Options:

A. $\frac{nhqB}{4\pi m}$

B. $\frac{nhqB}{2\pi m}$

C. $\frac{nhqB}{\pi m}$

D. $\frac{2nhqB}{\pi m}$

Answer: A

Solution:

We know,

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

$$\therefore \quad vr = \frac{nh}{2\pi m} \quad \text{.... (i)}$$

Also,

$$qvB = \frac{mv^2}{r}$$

$\therefore \quad mv = qBr \quad .... (ii)$

$mv^2 r = qBr \times \frac{nh}{2\pi m} \quad$ ....(Multiplying (i) with (ii))

$$E = \frac{1}{2} mv^2 = n\left[\frac{qBh}{4\pi m}\right]$$

Question74

The orbital magnetic moment associated with orbiting electron of charge 'e' is

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Options:

A. inversely proportional to angular momentum

B. directly proportional to mass of electron

C. directly proportional to angular momentum

D. inversely proportional to charge on electron

Answer: C

Solution:

$\therefore$ Orbital magnetic moment:

$M_0 = \frac{-e}{2m_e} L$

$\therefore$ The orbital magnetic moment is directly proportional to angular momentum L of the electron

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Question75

An electron in the hydrogen atom jumps from the first excited state to the ground state. What will be the percentage change in the speed of electron?

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Options:

A. 25%

B. 50%

C. 75%

D. 100%

Answer: B

Solution:

Velocity of electron in the n^{th} orbit is

$$v_n = \frac{e^2}{2\varepsilon_0 nh}$$
$$\Rightarrow v_n \propto \frac{1}{n}$$

Taking the ratio,

$$\therefore \quad \frac{v_2}{v_1} = \frac{n_1}{n_2} = \frac{1}{2} \Rightarrow v_2 = \frac{v_1}{2}$$

Change in velocity,

$$\Delta v = |v_2 - v_1|$$
$$= \left|\frac{v_1}{2} - v_1\right| = 0.5v_1$$

Therefore, change in percentage is 50%

Question76

In a radioactive disintegration, the ratio of initial number of atoms to the number of atoms present at time $t = \frac{1}{2\lambda}$ is [$\lambda =$ decay constant]

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Options:

A. $\frac{1}{e}$

B. $\sqrt{e}$

C. e

D. 2e

Answer: B

Solution:

According to radioactive disintegration law,

$$N = N_0 e^{-\lambda t}$$
$$\frac{N}{N_0} = e^{-\lambda t}$$
$$\frac{N}{N_0} = e^{-\lambda \times \frac{1}{2\lambda}} \quad \ldots \left(\because t = \frac{1}{2\lambda}\right)$$
$$\frac{N}{N_0} = e^{-\frac{1}{2}}$$
$$\frac{N_0}{N} = e^{\frac{1}{2}}$$
$$\frac{N_0}{N} = \sqrt{e}$$

Question77

The ratio of the velocity of the electron in the first Bohr orbit to that in the second Bohr orbit of hydrogen atom is

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Options:

A. 8 : 1

B. 2 : 1

C. 4 : 1

D. 1 : 4

Answer: B

Solution:

Velocity of electron in the n^{th} orbit $V_n = \frac{Ze^2}{2\varepsilon_0 nh}$

$\Rightarrow \quad v_n \propto \frac{1}{n}$

given $n_1 = 1$ and $n_2 = 2$,

$\therefore \quad \frac{v_1}{v_2} = \frac{n_2}{n_1} = \frac{2}{1}$

Question78

The shortest wavelength in the Balmer series of hydrogen atom is equal to the shortest wavelength in the Brackett series of a hydrogen like atom of atomic number z. The value of z is

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Options:

A. 2

B. 3

C. 4

D. 6

Answer: A

Solution:

Using Rydberg's formula,

$\frac{1}{\lambda} = R_H Z^2 \left[\frac{1}{n^2} - \frac{1}{m^2}\right]$

where R_H is the Rydberg's constant

For calculating the shortest wavelength in the Balmer series of hydrogen atom, $n = 2,\ m = \infty$ and $Z = 1$

$\therefore \quad \lambda_1 = \frac{4}{R_H}$

For hydrogen like atom, the shortest wavelength is given by,

In Brackett series

$$\begin{aligned} &\mathrm{n} = 4,\ \mathrm{m} = \infty \\ \therefore \quad &\frac{1}{\lambda_2} = R_H \cdot Z^2 \left(\frac{1}{16}\right) \end{aligned}$$

$$\therefore \quad \lambda_2 = \frac{16}{R_H \cdot Z^2}$$

Given: $\lambda_1 = \lambda_2$,

$$\therefore \quad \frac{4}{R_H} = \frac{16}{R_H \cdot Z^2} \Rightarrow Z^2 = 4$$

$$\therefore \quad Z = 2$$

Question79

The ratio of longest to shortest wavelength emitted in Paschen series of hydrogen atom is

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Options:

A. $\frac{144}{63}$

B. $\frac{25}{9}$

C. $\frac{9}{25}$

D. $\frac{63}{144}$

Answer: A

Solution:

For Paschen series, Longest wavelength corresponds to

$$\mathrm{n}_1 = 3, \mathrm{n}_2 = \mathrm{n}_1 + 1 = 4$$
$$\lambda_{\max} = \frac{144}{7R}$$

Shortest wavelength corresponds to $n_1 = 3, n_2 = \infty$

$$\lambda_{\min} = \frac{9}{R}$$

$$\therefore \quad \frac{\lambda_{\max}}{\lambda_{\min}} = \frac{\left(\frac{144}{7R}\right)}{\left(\frac{9}{R}\right)} = \frac{144}{63}$$

Question80

The force acting on the electron in hydrogen atom (Bohr' theory) is related to the principle quantum number 'n' as

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Options:

A. n^4

B. n^{-4}

C. n^2

D. n^{-2}

Answer: B

Solution:

The centripetal force of the rotating electron is given by $F = \frac{mv^2}{r}$

But, according to Bohr,

$v \propto \frac{1}{n}$ and $r \propto n^2$

i.e. $F \propto \frac{v^2}{r^2}$

$\Rightarrow F \propto \frac{1}{n^2 n^2}$

$F \propto \frac{1}{n^4}$

Question81

The wavelength of light for the least energetic photons emitted in the Lyman series of the hydrogen spectrum is nearly [Take $\mathrm{hc} = 1240\ \mathrm{eV}$ - nm, change in energy of the levels $= 10.2\ \mathrm{eV}$]

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Options:

A. 150 nm

B. 122 nm

C. 102 nm

D. 82 nm

Answer: B

Solution:

For least energetic photon emitted in Lyman series, $E = E_2 - E_1 = 10.2\ \mathrm{eV}$

$$\lambda = \frac{\mathrm{hc}}{\mathrm{E}} = \frac{1240}{10.2}\ \mathrm{nm}$$
$$= 121.57\ \mathrm{nm} \approx 122\ \mathrm{nm}$$

Question82

The ratio of wavelengths for transition of electrons from 2^{nd} orbit to 1^{st} orbit of Helium $\left(\mathrm{He}^{++}\right)$ and Lithium $\left(\mathrm{Li}^{++1}\right)$ is (Atomic number of Helium $= 2$, Atomic number of Lithium $= 3$)

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Options:

A. 9 : 4

B. 9 : 36

C. 4 : 9

D. 2 : 3

Answer: A

Solution:

To find the ratio of the wavelengths for the transition of electrons from the 2^{nd} orbit to the 1^{st} orbit for Helium ion He^{++} and Lithium ion Li^{+}, we can use the formula derived from the Rydberg equation for wavelengths of emitted photons during electron transitions in hydrogen-like atoms.

The Rydberg formula for the wavelength λ is given by:

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

where,

- R is the Rydberg constant for hydrogen,
- Z is the atomic number of the nucleus,
- n_1 is the lower energy level,
- n_2 is the higher energy level.

For a transition from the 2^{nd} orbit to the 1^{st} orbit ($n_2 = 2$ and $n_1 = 1$), the formula simplifies to:

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = RZ^2\left(\frac{3}{4}\right)$$

Therefore, $\lambda = \frac{4}{3RZ^2}$.

For Helium ion He^{++} ($Z = 2$):

$$\lambda_{\mathrm{He}} = \frac{4}{3R \cdot 2^2} = \frac{4}{12R} = \frac{1}{3R}$$

For Lithium ion Li^{+} ($Z = 3$):

$$\lambda_{\mathrm{Li}} = \frac{4}{3R \cdot 3^2} = \frac{4}{27R}$$

To find the ratio of the wavelengths ($\lambda_{\mathrm{He}} : \lambda_{\mathrm{Li}}$), we divide the expressions obtained for λ_{He} and λ_{Li}:

$$\frac{\lambda_{\mathrm{He}}}{\lambda_{\mathrm{Li}}} = \frac{\frac{1}{3R}}{\frac{4}{27R}} = \frac{27}{12} = \frac{9}{4}$$

Thus, the ratio of the wavelengths for the transition of electrons from the 2^{nd} orbit to the 1^{st} orbit of Helium ion (He^{++}) to Lithium ion (Li^{+}) is 9 : 4.

Therefore, the correct answer is **Option A:** 9 : 4.

Question83

For an electron moving in the n^{th} Bohr orbit the deBroglie wavelength of an electron is

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Options:

A. $\mathrm{n} \pi \mathrm{r}$

B. $\frac{\pi r}{\mathrm{n}}$

C. $\frac{\mathrm{nr}}{2 \pi}$

D. $\frac{2 \pi r}{\mathrm{n}}$

Answer: D

Solution:

From de Broglie's hypothesis,

$\lambda=\frac{\mathrm{h}}{\mathrm{p}_{\mathrm{n}}}=\frac{\mathrm{h}}{\mathrm{mv}} \quad \ldots .(\mathrm{i})$

and from Bohr's atomic model,

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

Also,

$\mathrm{L}=\mathrm{mvr}_{\mathrm{n}}$

Due to quantization of angular momentum, we can write,

$$\frac{\mathrm{nh}}{2 \pi}=\mathrm{mvr}_{\mathrm{n}}$$

$$\therefore \quad \mathrm{v}=\frac{\mathrm{nh}}{2 \pi \mathrm{mr}} \quad \ldots .(\mathrm{ii})$$

putting (ii) into (i), we get,

$\therefore \quad \lambda=\frac{\mathrm{h}}{\mathrm{m}(\mathrm{nh} / 2 \pi \mathrm{mr})}=\frac{2 \pi \mathrm{r}}{\mathrm{n}}$

Question84

If an electron in a hydrogen atom jumps from an orbit of level $n = 3$ to orbit of level $n = 2$, then the emitted radiation frequency is (where R = Rydberg's constant, C = Velocity of light)

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Options:

A. $\frac{3RC}{27}$

B. $\frac{RC}{25}$

C. $\frac{8RC}{9}$

D. $\frac{5RC}{36}$

Answer: D

Solution:

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\therefore \quad \frac{1}{\lambda} = \left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5}{36}R$$

$$\therefore \quad f = \frac{c}{\lambda} = \frac{5}{36}Rc$$

Question85

Using Bohr's model, the orbital period of electron in hydrogen atom in the n^{th} orbit is (ε_0 = permittivity of vacuum, h = Planck's constant, m = mass of electron, e = electronic charge)

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Options:

A. $\frac{4\varepsilon_0 nh^3}{me^2}$

B. $\frac{4\varepsilon_0 \mathrm{n}^2 \mathrm{~h}^2}{\mathrm{me}^2}$

C. $\frac{4\varepsilon_0^2 n^3 h^3}{m e^4}$

D. $\frac{4\varepsilon_0^2 \mathrm{n}^2 \mathrm{~h}^3}{m e^3}$

Answer: C

Solution:

The period of an electron in the n^{th} orbit of a hydrogen atom is given by

$$\mathrm{T}_{\mathrm{n}}=\frac{2\pi \mathrm{r}_{\mathrm{n}}}{\mathrm{v}_{\mathrm{n}}}$$

and $\mathrm{r}_{\mathrm{n}}=\frac{\varepsilon_0 \mathrm{n}^2 \mathrm{~h}^2}{\pi \mathrm{me}^2}$

and linear speed $\mathrm{v}_{\mathrm{n}}=\frac{\mathrm{e}^2}{2\varepsilon_0 \mathrm{nh}}$

$$\therefore \mathrm{T}_{\mathrm{n}}=\frac{2\pi \cdot \varepsilon_0 \mathrm{n}^2 \mathrm{~h}^2}{\pi \mathrm{me}^2} \times \frac{2\varepsilon_0 \mathrm{nh}}{\mathrm{e}^2}=\frac{4\varepsilon_0^2 \mathrm{n}^3 \mathrm{~h}^3}{\mathrm{me}^4}$$

Question86

The wave number of the last line of the Balmer series in hydrogen spectrum will be

(Rydberg's constant $=10^7 \mathrm{~m}^{-1}$)

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Options:

A. $250 \mathrm{~m}^{-1}$

B. $2.5 \times 10^6 \mathrm{~m}^{-1}$

C. $0.25 \times 10^9 \mathrm{~m}^{-1}$

D. $2.5 \times 10^5 \mathrm{~m}^{-1}$

Answer: B

Solution:

Wave number $= \frac{1}{\lambda} =$ Receiprocal of wavelength

For the last line of the Balmer series, $n = \infty$ and the transition is from $n = \infty$ to $n = 2$

$\therefore$ Wave number $\bar{v} = \frac{1}{\lambda} = \mathrm{R}\left[\frac{1}{2^2} - \frac{1}{\infty}\right] = \frac{\mathrm{R}}{4}$ and $\mathrm{R} = 10^7/\mathrm{m}$

$\therefore \bar{v} = \frac{R}{4} = \frac{10^7}{4} = \frac{10 \times 10^6}{4} = 2.5 \times 10^6\ \mathrm{m/s}$

Question87

The half life of a radioactive substance is 30 minute. The time taken between 40% decay and 85% decay of the same radioactive substance is

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Options:

A. 15 minute

B. 90 minute

C. 60 minute

D. 30 minute

Answer: C

Solution:

When 40% nuclei decay, 60% nuclei remain undecayed

Let this number be N_0

When 85% nuclei decay, 15% nuclei remain undecayed This number will be $\mathrm{N} = \frac{\mathrm{N}_0}{4}$

The number of nuclei will become one-fourth in two half lives i.e. 60 minutes.

Question88

The ratio of energies of photons produced due to transition of electron of hydrogen atom from its (i) second to first energy level and (ii) highest energy level to second energy level is

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Options:

A. 6 : 1

B. 3 : 1

C. 12 : 1

D. 8 : 1

Answer: B

Solution:

Let E_1 be the energy of the first energy level Then $E_2 = \frac{E_1}{4}$

Highest level $E_\infty = 0$

$$\therefore \quad E_2 - E_1 = \frac{E_1}{4} - E_1 = -\frac{3}{4}E_1$$

$$E_\infty - E_2 = 0 - \frac{E_1}{4} = -\frac{E_1}{4}$$

$$\therefore \quad \frac{E_2 - E_1}{E_\infty - E_2} = 3$$

Question89

An electron makes a transition from an excited state to the ground state of a hydrogen like atom. Out of the following statements which one is correct?

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Options:

A. Kinetic energy, potential energy and total energy decreases

B. Kinetic energy and total energy decreased but potential energy increases

C. Kinetic energy increases but potential energy and total energy decreases

D. Kinetic energy decreases, potential energy increases but total energy remains the same.

Answer: C

Solution:

Potential energy $= -\frac{1}{4\pi\varepsilon_0} \cdot \frac{\mathrm{ze}^2}{\mathrm{r}}$

Kinetic energy $= -\frac{1}{2}(\mathrm{P.E.}) = \frac{1}{8\pi\varepsilon_0} \cdot \frac{\mathrm{ze}^2}{\mathrm{r}}$

Total energy $= \frac{1}{2}(\mathrm{P.E.}) = -\frac{1}{8\pi\varepsilon_0} \frac{\mathrm{ze}^2}{\mathrm{r}}$

As r decreases K.E, increases

As r decreases P.E. and T.E. decreases (since they are negative).

Question90

The ratio of maximum to minimum wavelength in Balmer series of hydrogen atom is

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Options:

A. 36 : 5

B. 3 : 4

C. 9 : 5

D. 5 : 9

Answer: C

Solution:

Maximum wavelength of Balmer series is given by

$\frac{1}{\lambda} = \mathrm{R}\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5\mathrm{R}}{36}$ .... (1)

Maximum wavelength is given by

$\frac{1}{\lambda'} = \mathrm{R}\left(\frac{1}{4} - \frac{1}{\infty}\right) = \frac{\mathrm{R}}{4}$ .... (2)

Dividing Eq.(2) by Eq.(1)

$\frac{\lambda}{\lambda'} = \frac{9}{5}$

Question91

Energy of electron in the second orbit of hydrogen atom is E. The energy of electron 'E_3' in the third orbit of helium (He) atom will be

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Options:

A. $\mathrm{E}_3 = \frac{4\mathrm{E}}{9}$

B. $\mathrm{E}_3 = \frac{16\mathrm{E}}{3}$

C. $\mathrm{E}_3 = \frac{16\mathrm{E}}{9}$

D. $\mathrm{E}_3 = \frac{4\mathrm{E}}{3}$

Answer: A

Solution:

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

$$\therefore \frac{E_3}{E_2} = \frac{4}{9} \quad \therefore E_3 = \frac{4}{9} E_2$$

Question92

The shortest wavelength for Lyman series is 912 $\overset{o}{A}$. The longest wavelength in Paschen series is

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Options:

A. 1216 $\overset{o}{A}$

B. 3646 $\overset{o}{A}$

C. 18760 $\overset{o}{A}$

D. 8208 $\overset{o}{A}$

Answer: C

Solution:

Shortest wavelength in Lyman series is given by

$$\frac{1}{\lambda_L} = R\left[\frac{1}{1^2} - \frac{1}{\infty}\right] = R$$
$$\therefore \lambda_L = \frac{1}{R}$$

The longest wavelength in Paschen series is given by

$$\begin{aligned}\frac{1}{\lambda_p} &= \mathrm{R}\left[\frac{1}{(3)^2} - \frac{1}{(4)^2}\right] \\ &= \mathrm{R}\left[\frac{1}{9} - \frac{1}{16}\right] = \mathrm{R} \cdot \frac{7}{144} \\ \lambda_\mathrm{p} &= \frac{144}{7\mathrm{R}}\end{aligned}$$

$$\therefore \quad \frac{\lambda_p}{\lambda_L} = \frac{144}{7\mathrm{R}} \cdot \mathrm{R} = \frac{144}{7}$$

$$\therefore \quad \lambda_\mathrm{p} = \frac{144}{7\mathrm{R}} \cdot \lambda_L = \frac{144}{7} \times 912 = 18760\overset{o}{A}$$

Question93

In the Bohr model, an electron moves in a circular orbit around the nucleus. Considering an orbiting electron to be a circular current loop, the magnetic moment of the hydrogen atom, when the electron is in nth excited state, is

(e = electronic charge, m_e = mass of the electron, h = Planck's constant)

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Options:

A. $\left(\frac{e}{m_e}\right)\frac{nh}{2\pi}$

B. $\left(\frac{e}{m_e}\right)\frac{n^2h}{2\pi}$

C. $\left(\frac{e}{2m_e}\right)\frac{n^2h}{2\pi}$

D. $\left(\frac{e}{2\ m_e}\right)\frac{nh}{2\pi}$

Answer: D

Solution:

We need to determine the magnetic moment of the hydrogen atom when the electron is in the nth excited state using the Bohr model. In the Bohr model, an electron in the nth orbit has specific characteristics such as angular momentum and radius. These properties contribute to the overall magnetic moment of the atom.

The magnetic moment μ of a current loop is given by the product of the current I and the area A enclosed by the loop:

$\mu = I \cdot A$

For a circular loop with radius r, the area A is:

$A = \pi r^2$

In the case of an electron orbiting in a circle, the current I is the charge of the electron e divided by the orbital period T:

$I = \frac{e}{T}$

The orbital period T is the time it takes for the electron to complete one orbit, which is the circumference of the orbit divided by the orbital speed v:

$T = \frac{2\pi r}{v}$

Thus, the current I becomes:

$I = \frac{e}{T} = \frac{e}{\frac{2\pi r}{v}} = \frac{ev}{2\pi r}$

Substituting this into the equation for the magnetic moment μ, we get:

$\mu = \left(\frac{ev}{2\pi r}\right) \cdot \pi r^2 = \frac{evr}{2}$

Now, we use Bohr's quantization condition for angular momentum, which states that the angular momentum L is quantized and given by:

$m_e vr = n\frac{h}{2\pi}$

Solving for vr, we have:

$vr = \frac{nh}{2\pi m_e}$

Substituting this back into the expression for the magnetic moment, we obtain:

$\mu = \frac{e}{2m_e} \cdot \left(\frac{nh}{2\pi}\right) = \left(\frac{e}{2m_e}\right)\frac{nh}{2\pi}$

Therefore, the magnetic moment of the hydrogen atom in the nth excited state is:

$\left(\frac{e}{2m_e}\right)\frac{nh}{2\pi}$

This corresponds to option D:

$\left(\frac{e}{2m_e}\right)\frac{nh}{2\pi}$

Question94

The energy of an electron in the excited hydrogen atom is -3.4 eV. Then according to Bohr's theory, the angular momentum of the electron in that excited state is (h = Plank's constant)

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Options:

A. $\frac{2\pi}{h}$

B. $\frac{\mathrm{nh}}{2\pi}$

C. $\frac{\mathrm{h}}{\pi}$

D. $\frac{3\ \mathrm{h}}{2\pi}$

Answer: C

Solution:

According to Bohr's theory, the energy levels of an electron in a hydrogen atom are given by:

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

Given that the energy of the electron in the excited state is $-3.4\ \mathrm{eV}$, we can set up the following equation to find the principal quantum number n:

$-3.4 = -\frac{13.6}{n^2}$

Solving for n, we get:

$n^2 = \frac{13.6}{3.4} = 4$

So, $n = 2$. Now, according to Bohr's theory, the angular momentum L of the electron in the nth excited state is given by:

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

By substituting the value of $n = 2$, we get:

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

Therefore, the angular momentum of the electron in that excited state is:

Option C

$\frac{\mathrm{h}}{\pi}$

Question95

In n^{th} Bohr orbit, the ratio of the kinetic energy of an electron to the total energy of it, is

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Options:

A. 2 : 1

B. $1 : -1$

C. $+1 : 1$

D. $-1 : 2$

Answer: B

Solution:

To find the ratio of the kinetic energy (K.E.) to the total energy (E) of an electron in the n^{th} Bohr orbit, let's first recall the expressions for kinetic energy, potential energy, and total energy in a Bohr orbit.

The kinetic energy of an electron in the n^{th} orbit is given by:

$$K.E. = \frac{ke^2}{2r_n}$$

where k is Coulomb's constant, e is the charge of an electron, and r_n is the radius of the n^{th} orbit.

The potential energy (P.E.) of an electron in that orbit (due to the electrostatic force of attraction between the positively charged nucleus and the negatively charged electron) is:

$$P.E. = -\frac{ke^2}{r_n}$$

This expression is negative because the potential energy in an electrostatically bound system is considered zero at an infinite distance and negative within the system due to the attraction.

The total energy (E) of an electron in the n^{th} Bohr orbit is the sum of its kinetic energy and potential energy:

$$E = K.E. + P.E. = \frac{ke^2}{2r_n} - \frac{ke^2}{r_n}$$

$$E = -\frac{ke^2}{2r_n}$$

Notice that the total energy is $-\frac{1}{2}$ times the kinetic energy and also half of the potential energy in magnitude but with a negative sign, indicating that the electron is bound to the nucleus.

To find the ratio of kinetic energy to total energy:

$$\frac{K.E.}{E} = \frac{\frac{ke^2}{2rn}}{-\frac{ke^2}{2rn}}$$

This simplifies to:

$$\frac{K.E.}{E} = -1$$

Therefore, the correct answer is Option B), which represents the ratio of the kinetic energy of an electron to the total energy of it in the n^{th} Bohr orbit as $1 : -1$.

Question96

If 'E' and 'L' denote the magnitude of total energy and angular momentum of revolving electron in n^{th} Bohr orbit, then

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Options:

A. $\mathrm{E} \propto \mathrm{L}^{-1}$

B. $\mathrm{E} \propto \mathrm{L}$

C. $\mathrm{E} \propto \mathrm{L}^{-2}$

D. $\mathrm{E} \propto \mathrm{L}^{2}$

Answer: C

Solution:

Let's analyze the relationship between the energy (E) and angular momentum (L) of an electron in the n^{th} Bohr orbit according to Bohr's theory.

The energy of an electron in the n^{th} Bohr orbit is given by:

$$E=-\frac{k e^2}{2 r_n}$$

where k is a constant, e is the electronic charge, and r_n is the radius of the n^{th} orbit.

The angular momentum (L) of the electron in the n^{th} Bohr orbit is quantized and given by:

$$L=n \hbar$$

where $\hbar$ is the reduced Planck's constant, and n is the principal quantum number.

The radius of the n^{th} orbit (r_n) according to Bohr's model is given by:

$$r_n=n^2 \frac{\hbar^2}{k' m_e e^2}$$

where m_e is the mass of the electron and k' is another constant.

By substituting the expression for r_n in the equation for energy E, we get:

$$E=-\frac{k e^2}{2\left(n^2 \frac{\hbar^2}{k' m_e e^2}\right)}$$

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

Now, since $L = n\hbar$, it implies that $n \propto L$. Thus, the relationship between energy (E) and angular momentum (L) can be rewritten in terms of L:

$E \propto -\frac{1}{L^2}$

Therefore, among the provided options, the correct one is:

Option C: $\mathrm{E} \propto \mathrm{L}^{-2}$

Question97

Two radioactive materials X_1 and X_2 have decay constants '5λ' and 'λ' respectively. Initially, they have the same number of nuclei. After time 't', the ratio of number of nuclei of X_1 to that of X_2 is $\frac{1}{\mathrm{e}}$. Then t is equal to

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Options:

A. $\frac{\lambda}{2}$

B. $\frac{\mathrm{e}}{\lambda}$

C. λ

D. $\frac{1}{4\lambda}$

Answer: D

Solution:

To solve for time t based on the given conditions, let's apply the law of radioactive decay. The number of nuclei N remaining after time t from an initial amount N_0 for a substance with a decay constant λ is described by the equation:

$N = N_0 e^{-\lambda t}$

Given two radioactive materials X_1 and X_2 with decay constants 5λ and λ respectively, and the same initial number of nuclei, N_0, the number of remaining nuclei at time t for each can be described as follows:

For X_1:

$N_1 = N_0 e^{-5\lambda t}$

For X_2:

$N_2 = N_0 e^{-\lambda t}$

The given ratio of the number of nuclei of X_1 to X_2 after time t is $\frac{1}{e}$. Therefore, we can set up the equation:

$\frac{N_1}{N_2} = \frac{N_0 e^{-5\lambda t}}{N_0 e^{-\lambda t}} = \frac{1}{e}$

Simplifying the expression, we cancel out N_0:

$e^{\lambda t} = e^{5\lambda t} \cdot \frac{1}{e}$

taking natural logarithm on both side

$\implies \lambda t = 5\lambda t - 1$

Upon rearranging the equation, to solve for t, we find:

$-4\lambda t = -1$

Solving for t:

$t = \frac{1}{4\lambda}$

Thus, the correct option is D: $\frac{1}{4\lambda}$.

Question98

A nucleus breaks into two nuclear parts, which have their velocity ratio 2 : 1. The ratio of their nuclear radii will be

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Options:

A. $\sqrt{2}$

B. $\frac{1}{2}$

C. $\frac{1}{2^{1/3}}$

D. $\frac{1}{\sqrt{2}}$

Answer: C

Solution:

When a nucleus breaks into two parts, conservation of momentum applies. Let's denote the masses of the two nuclear parts as m_1 and m_2, and their velocities as v_1 and v_2 respectively. According to the conservation of momentum:

$$m_1 v_1 = m_2 v_2$$

Given that the velocity ratio is $v_1 : v_2 = 2 : 1$, we can write:

$$\frac{v_1}{v_2} = 2 \implies v_1 = 2v_2$$

Substituting this into the momentum equation:

$$m_1(2v_2) = m_2 v_2 \implies 2m_1 = m_2 \implies \frac{m_1}{m_2} = \frac{1}{2}$$

Now, the nuclear radius R is related to the mass number A (which corresponds to the mass) by the relation:

$$R \propto A^{1/3}$$

Thus, the ratio of the radii R_1 and R_2 of the two nuclear parts will be:

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{m_1}{m_2}\right)^{1/3} = \left(\frac{1}{2}\right)^{1/3} = \frac{1}{2^{1/3}}$$

Therefore, the correct answer is:

Option C

$$\frac{1}{2^{1/3}}$$

Question99

Ratio centripetal acceleration for an electron revolving in 3^{rd} and 5^{th} Bohr orbit of hydrogen atom is

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Options:

A. 425 : 18

B. 625 : 81

C. 125 : 27

D. 221 : 36

Answer: B

Solution:

Centripetal acceleration $a=\frac{v^2}{r}$

For hydrogen atom, $V \propto \frac{1}{\mathrm{n}}$ and $\mathrm{r} \propto \mathrm{n}^2$

$\therefore a \propto \frac{1}{n^4} \quad \therefore \frac{a_2}{a_5}=\left(\frac{5}{3}\right)^4=\frac{625}{81}$

Question100

When an electron in hydrogen atom jumps from third excited state to the ground state, the de-Broglie wavelength associated with the electron becomes

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Options:

A. $\left(\frac{1}{2}\right)^{\text{th}}$

B. $\left(\frac{1}{4}\right)^{\text{th}}$

C. $\left(\frac{1}{8}\right)^{\text{th}}$

D. $\left(\frac{1}{6}\right)^{\text{th}}$

Answer: B

Solution:

De-Broglie wavelength $\lambda \propto \frac{1}{p}$ where p is momentum

For an electron velocity $\mathrm{v} \propto \frac{1}{\mathrm{n}}$,

hence $\mathrm{p} \propto \frac{1}{\mathrm{n}}$

$\therefore \frac{\lambda_1}{\lambda_4}=\frac{1}{4}$

$\therefore \lambda_1 = \frac{\lambda_4}{4}$

Question101

'λ_1' is the wavelength of series limit of Lyman series, 'λ_2' is the wavelength of the first line line of Lyman series and 'λ_3' is the series limit of the Balmer series. Then the relation between λ_1, λ_2 and λ_3 is

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Options:

A. $\frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$

B. $\frac{1}{\lambda_1} = \frac{1}{\lambda_2} - \frac{1}{\lambda_3}$

C. $\lambda_2 = \lambda_1 + \lambda_3$

D. $\lambda_1 = \lambda_2 + \lambda_3$

Answer: A

Solution:

Series limit of Lyman series is given by

$\frac{1}{\lambda_1} = \mathrm{R}\left(\frac{1}{1} - \frac{1}{\infty}\right) = \mathrm{R}$

Series limit of Balmer series is given by

$\frac{1}{\lambda_3} = \mathrm{R}\left(\frac{1}{4} - \frac{1}{\infty}\right) = \frac{\mathrm{R}}{4}$

First line of Lyman series is given by

$$\frac{1}{\lambda_2} = \mathrm{R}\left(\frac{1}{1} - \frac{1}{4}\right) = \mathrm{R} - \frac{\mathrm{R}}{4} = \frac{1}{\lambda_1} - \frac{1}{\lambda_3}$$
$$\therefore \frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{1}{\lambda_3}$$

Question102

A sample of radioactive element contains 8×10^{16} active nuclei. The halt-life of the element is 15 days. The number of nuclei decayed after 60 days is

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Options:

A. 7.5×10^{16}

B. 2.0×10^{16}

C. 0.5×10^{16}

D. 4.0×10^{16}

Answer: A

Solution:

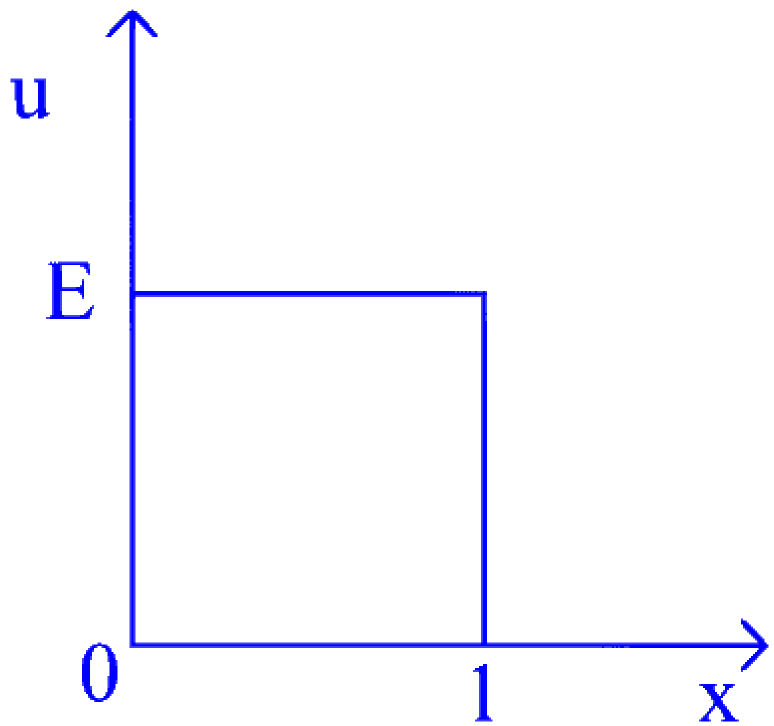
Half life, $T = 15$ days, time $t = 60$ days $= 4T$

The number of nuclei remaining is given by

$$\mathrm{N} = \mathrm{N}_0\left(\frac{1}{2}\right)^{\mathrm{n}} \quad = \mathrm{N}_0\left(\frac{1}{2}\right)^4 \quad \mathrm{n} = \text{ no. of half-lives}$$
$$= \frac{1}{16}\mathrm{N}_0 \quad = \frac{1}{16} \times 8 \times 10^{16}$$
$$= 0.5 \times 10^{16}$$
$$\therefore \text{ No. of nuclei decayed } = \mathrm{N}_0 - \mathrm{N}$$
$$= 8 \times 10^{16} - 0.5 \times 10^{16} = 7.5 \times 10^{16}$$

Question103

The P.E. 'U' of a moving particle of mass 'm' varies with 'x'-axis as shown in figure. The deBroglie wavelength or the particle in the regions $0 \leq x \leq 1$ and $x > 1$ are λ_1 and λ_2 respectively. II the total energy of the particle is 'nE', then the ratio λ_1/λ_2 is



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Options:

A. $\sqrt{\frac{n^2}{n-1}}$

B. $\sqrt{\frac{n-1}{n}}$

C. $\sqrt{\frac{\mathrm{n}}{\mathrm{n}-1}}$

D. $\sqrt{\frac{\mathrm{n}(\mathrm{n}-1)}{\mathrm{n}}}$

Answer: C

Solution:

In the region $0 \leq x \leq 1$, the potential energy of the particle is E.

Total energy is nE.

Hence, kinetic energy, $K = nE - E = (n-1)E$

Its momentum, $\mathrm{p}_1 = \sqrt{2\mathrm{mK}} = \sqrt{2\,\mathrm{m}(\mathrm{n}-1)\mathrm{E}}$

$\therefore \lambda_1 = \frac{h}{p_1} = \frac{h}{\sqrt{2\ m(n-1)E}}$

In the region $x > 1$, PE is zero.

Hence, total energy is kinetic energy.

$$\therefore K = nE$$
$$\therefore \lambda_2 = \frac{h}{p_2} = \frac{h}{\sqrt{2mK}}$$
$$\therefore \frac{\lambda_1}{\lambda_2} = \sqrt{\frac{n}{n-1}}$$

Question104

The gyromagnetic ratio of an electron in an hydrogen atom, according to Bohr model is

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Options:

A. decreases with the quantum number 'n'.

B. independent of which orbit it is in.

C. negative

D. positive

Answer: B

Solution:

Gyromagnetic ratio = $\frac{e}{2m}$

It is independent of the orbit of the electron.

Question105

The electron in hydrogen atom is initially in the third excited state. When it finally moves to ground state, the maximum

number of spectral lines emitted are

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Options:

A. 3

B. 4

C. 5

D. 6

Answer: D

Solution:

Initially the electron is in the third excited state i.e. n = 4. Hence we can have transitions :

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

$3 \rightarrow 2, 3 \rightarrow 1$

$2 \rightarrow 1$

Hence, six transitions are possible.

Question106

If the electron in a hydrogen atom moves from ground state orbit to 5^{th} orbit, then the potential energy of the electron

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Options:

A. is increased

B. is zero

C. is decreased

D. remains unchanged

Answer: A

Solution:

The potential energy of electron in hydrogen atom is given by

$U=-\frac{1}{4\pi\varepsilon_0}\cdot\frac{e^2}{r}$

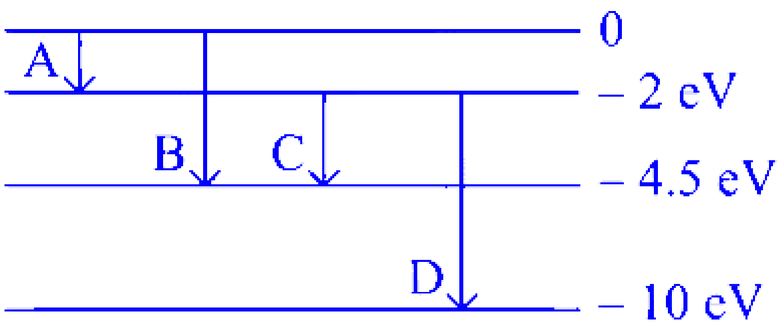
Hence, as r increases, potential energy will increase. (It will become less negative)

Alternatively, it is also given by

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

Question107

The energy levels with transitions for the atom are shown. The transitions corresponding to emission of radiation of maximum and minimum wavelength are respectively



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Options:

A. B, C

B. A, C

C. C, D

D. A, D

Answer: D

Solution:

As, we know that the difference of energy between two level is equal to the energy of photon.

$$\Delta E = hv = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E}$$

or $\quad \lambda \propto \frac{1}{\Delta E}$

The value of ΔE is minimum for A, so radiation corresponding to A have maximum wavelength and value of ΔE is maximum for D, so radiation corresponding to D have minimum wavelength.

Question108

Using Bohr's model, the orbital period of electron in hydrogen atom in nth orbit is ($\varepsilon_0 =$ permittivity of free space, $h =$ Planck's constant, $m =$ mass of electron and $\theta =$ electronic charge)

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Options:

A. $\frac{2\varepsilon_0^2 n^3 h^3}{me^4}$

B. $\frac{8\varepsilon_0^2 n^3 h^3}{me^4}$

C. $\frac{2\varepsilon_0 n^2 h^2}{me^4}$

D. $\frac{4\varepsilon_0^2 n^3 h^3}{me^4}$

Answer: D

Solution:

The orbital period of revolution of electron in nth orbit is

$T_n = \frac{2\pi r_n}{v_n}$

As, we know, $r_n = \left(\frac{h^2\varepsilon_0}{\pi m e^2}\right)\frac{n^2}{Z}$

and $v_n = \left(\frac{e^2}{2h\varepsilon_0}\right)\frac{z}{n}$

$\therefore \quad T_n = 2\pi\frac{h^2\varepsilon_0 n^2}{\pi m e^2 Z} \times \frac{2h\varepsilon_0 n}{e^2 Z}$

$= \frac{4\varepsilon_0^2 n^3 h^3}{m e^4 Z^2}$

For hydrogen atom, $Z = 1$

$\therefore \quad T_n = \frac{4\varepsilon_0^2 n^3 h^3}{m e^4}$

Question109

A radioactive nucleus emits 4α-particles and 7β-particles in succession. The ratio of number of neutrons of that of protons, is [$A =$ mass number, $Z =$ atomic number]

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Options:

A. $\frac{A-Z-13}{Z-2}$

B. $\frac{A-Z-15}{Z-1}$

C. $\frac{A-Z-13}{Z-1}$

D. $\frac{A-Z-11}{Z-2}$

Answer: B

Solution:

Let us assume, a particle X having atomic number Z and mass number A.

When an α-particle is emitted by a nucleus, then its atomic number decreases by 2 and mass number decreases by 4. So, for given case,

$z X^A \xrightarrow{4\alpha\text{-particle}} z - 8 Y^{A-16}$

When a β-particle is emitted by a nucleus its atomic number increases by one and mass number remains unchanged. So, for given case,

$$Z - 8^{Y^{A-16}} \xrightarrow{7\beta\text{-particle}} Z - 1^{Z^{A-16}}$$

$$\therefore \frac{\text{Number of neutrons}}{\text{Number of protons}} = \frac{(A-16)-(Z-1)}{(Z-1)}$$
$$= \frac{A-Z-15}{(Z-1)}$$

Question110

The ratio of energies of photons produced due to transition of electron of hydrogen atom from its (i) second to first energy level and (ii) highest energy level to second level is respectively

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Options:

A. 2.5 : 1

B. 3 : 1

C. 2 : 1

D. 4 : 1

Answer: B

Solution:

The energy of photons is given by

$$E = Rhc\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where, R is Rydberg constant, h is Planck's constant and c is the speed of light.

(i) Energy of photon produced from second to first energy level,

$$E_1 = Rhc\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$E_1 = \frac{3}{4}Rhc$$

(ii) Energy of photon produced from highest energy level (i.e., ∞) to second level,

$$E_2 = Rhc\left(\frac{1}{2^2} - \frac{1}{\infty}\right) = \frac{1}{4}Rhc$$

$$\therefore \quad \frac{E_1}{E_2} = \frac{\frac{3}{4}Rhc}{\frac{1}{4}Rhc} = \frac{3}{1} \text{ or } 3:1$$

Question111

Using Bohr's quantisation condition, what is the rotational energy in the second orbit for a diatomic molecule? ($I =$ moment of inertia of diatomic molecule and, $h =$ Planck's constant)

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Options:

A. $\frac{h}{2I\pi^2}$

B. $\frac{h^2}{2I\pi^2}$

C. $\frac{h^2}{2I^2\pi^2}$

D. $\frac{h}{2I^2\pi}$

Answer: B

Solution:

The angular momentum of diatomic molecules,

$L = I\omega = \frac{nh}{2\pi}$

For second orbit, $L = \frac{2h}{2\pi} = \frac{h}{\pi}$

Rotational energy

$= \frac{1}{2}I\omega^2 = \frac{(I\omega)^2}{2I} = \frac{L^2}{2I} = \left(\frac{h}{\pi}\right)^2 \times \frac{1}{2I} = \frac{h^2}{2h\pi^2}$

Question112

The ratio of speed of an electron in the ground state in the Bohr's first orbit of hydrogen atom to velocity of light (c) is ($h =$ Planck's constant, $\varepsilon_0 =$ permittivity of free space, $e =$ charge on electron)

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Options:

A. $\frac{2\theta^2\varepsilon_0}{hc}$

B. $\frac{e^3}{2\varepsilon_0 hc}$

C. $\frac{e^2}{2\varepsilon_0 hc}$

D. $\frac{2\varepsilon_0 hc}{e^2}$

Answer: C

Solution:

The velocity of an electron in the first orbit of a hydrogen atom according to Bohr's model can be derived from the quantization of angular momentum and the electrostatic force balance with centripetal force. The velocity v_n of an electron in the nth orbit is given by:

$v_n = \frac{e^2}{2\varepsilon_0 h} \cdot \frac{1}{n}$

For the ground state (first orbit, $n = 1$), the velocity v_1 is:

$v_1 = \frac{e^2}{2\varepsilon_0 h}$

To find the ratio of this velocity to the speed of light c, we divide the expression for v_1 by c:

$\frac{v_1}{c} = \frac{\frac{e^2}{2\varepsilon_0 h}}{c}$

$= \frac{e^2}{2\varepsilon_0 hc}$

Therefore, the correct option is:

Option C: $\frac{e^2}{2\varepsilon_0 hc}$

Question113

The force acting on the electrons in hydrogen atom (Bohr's theory) is related to the principle quantum number n as

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Options:

A. n^{-4}

B. n^{4}

C. n^{-2}

D. n^{2}

Answer: A

Solution:

In Bohr's theory of the hydrogen atom, the force acting on the electrons is the electrical force between the positively charged nucleus (proton) and the negatively charged electron. This force is given by Coulomb's law, which states that the force between two charged particles is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

The relevant formula from Coulomb's law is

$F = k\frac{e^2}{r^2}$

where F is the force between the electron and the nucleus, k is Coulomb's constant, e is the charge of the electron (the same magnitude for the proton), and r is the distance between the nucleus and the electron.

In Bohr's model, the radius of the nth orbit (where n is the principal quantum number) is directly proportional to n^2. This relation is given by the formula for the radius of the nth orbit as,

$r_n = n^2 \cdot a_0$

where a_0 is the Bohr radius, the radius of the electron's orbit in its ground state (when $n = 1$).

Substituting the expression for r_n into the formula for F, we get

$F = k\frac{e^2}{(n^2 a_0)^2} = k\frac{e^2}{n^4 a_0^2}$

This shows that the force F is inversely proportional to n^4, indicating that as the principal quantum number n increases, the force acting on the electrons decreases. Thus, the force acting on the electrons in a hydrogen atom, according to Bohr's theory, is related to the principal quantum number n as n^{-4}.

Therefore, the correct option is:

Option A: n^{-4}

Question114

If the speed of an electron of hydrogen atom in the ground state is $2.2 \times 10^6 \mathrm{~m/s}$, then its speed in the third excited state will be

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Options:

A. $5.5 \times 10^6 \mathrm{~m/s}$

B. $5.5 \times 10^5 \mathrm{~m/s}$

C. $8.8 \times 10^5 \mathrm{~m/s}$

D. $6.8 \times 10^6 \mathrm{~m/s}$

Answer: B

Solution:

Speed of electron of hydrogen atom in ground state,

$v_1 = 22 \times 10^6 \mathrm{~m/s}$

Since, $\quad v \propto \frac{1}{n}$

$\therefore \quad \frac{v_1}{v_2} = \frac{n_2}{n_1} = \frac{2.2 \times 10^6}{v_2}$

[for third excited state, $n_2 = 4$]

$\Rightarrow \quad v_2 = \frac{2.2 \times 10^6}{4} = 0.55 \times 10^6 \mathrm{~m/s}$

$= 5.5 \times 10^5 \mathrm{~m/s}$

Question115

In hydrogen emission spectrum, for any series, the principal quantum number is n. Corresponding maximum wavelength λ is ($R =$ Rydberg's constant)

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Options:

A. $\frac{R(2n+1)}{n^2(n+1)}$

B. $\frac{n^2(n+1)^2}{R(2n+1)}$

C. $\frac{n^2(n+1)}{R(2n+1)}$

D. $\frac{R(2n+1)}{n^2(n+1)^2}$

Answer: B

Solution:

In hydrogen emission spectrum, wavelength is given by

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

For maximum wavelength of any principal quantum number n,

$$
\begin{aligned}
& n_1 = n \text{ and } n_2 = n+1 \\
\therefore \quad & \frac{1}{\lambda_{\max}} = R\left[\frac{1}{n^2} - \frac{1}{(n+1)^2}\right] \\
& = R\left[\frac{(n+1)^2 - n^2}{n^2(n+1)^2}\right] \\
& = R\frac{\left(n^2 + 2n + 1 - n^2\right)}{n^2(n+1)^2} \\
& \frac{1}{\lambda_{\max}} = \frac{R^2(2n+1)}{n^2(n+1)^2} \\
& \therefore \quad \lambda_{\max} = \frac{n^2(n+1)^2}{R(2n+1)}
\end{aligned}
$$

Question116

When the electron in hydrogen atom jumps from fourth Bohr orbit to second Bohr orbit, one gets the

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Options:

A. second line of Balmer series

B. first line of Balmer series

C. first line of Pfund series

D. second line of Paschen series

Answer: A

Solution:

The wavelength of line in case of Balmer series is given by

$\frac{1}{\lambda}=R\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$, where $n=3,4,5,\ldots$

and $R=$ Rydberg constant.

So, for Balmer series, the transition takes from third orbit to second for first line spectrum, fourth orbit to second for second line spectrum and so on. Hence, given transition represents second line of Balmer series.

Question117

In Balmer series, wavelength of first line is ' λ_1 ' and in Brackett series wavelength of first line is ' λ_2 ' then $\frac{\lambda_1}{\lambda_2}$ is

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Options:

A. 0.162

B. 0.124

C. 0.138

D. 0.188

Answer: A

Solution:

The wavelength of a line in Balmer series is given by

$\frac{1}{\lambda}=R\left(\frac{1}{2^2}-\frac{1}{n^2}\right)$ [for $n=3,4,5,\ldots$]

where, $R=$ Rydberg constant.

For first line, $n=3$

$\Rightarrow \quad \frac{1}{\lambda_1}=R\left(\frac{1}{4}-\frac{1}{9}\right) \Rightarrow \lambda_1=\frac{36}{5R}$ .... (i)

The wavelength of a line in Brackett series is given by

$\frac{1}{\lambda}=R\left(\frac{1}{4^2}-\frac{1}{n^2}\right)$ for $n=5,6,7\ldots$

For first line, $n=5$

$\Rightarrow \quad \frac{1}{\lambda_2}=R\left(\frac{1}{16}-\frac{1}{25}\right) \Rightarrow \lambda_2=\frac{400}{9R}$ .... (ii)

Dividing Eq. (i) by Eq. (ii), we get

$\frac{\lambda_1}{\lambda_2}=\frac{36}{5R} \times \frac{9R}{400}=\frac{81}{500}=0.162$

Question118

Bohr model is applied to a particle of mass ' m ' and charge ' q ' is moving in a plane under the influence of a transverse magnetic field ' B '. The energy of the charged particle in the nth level will be ($h=$ Planck's constant)

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Options:

A. $2nhqB/\pi\mathrm{m}$

B. $nhqB/2\pi$ m

C. $nhqB/4\pi$ m

D. $nhqB/\pi\mathrm{m}$

Answer: C

Solution:

For a particle moving in a magnetic field, then applied two forces are equal.

centripetal force (F_c) = magnetic force (F_m)

$$\Rightarrow \quad \frac{mv^2}{r} = qvB$$
$$\Rightarrow \quad mv^2 = qB(vr) \quad \text{.... (i)}$$

Also, from Bohr's model,

$$mvr = \frac{nh}{2\pi}$$
$$\therefore \quad vr = \frac{nh}{2\pi m} \quad \text{.... (ii)}$$

From Eq. (i) and (ii), we get

$mv^2 = \frac{nh}{2\pi m} \cdot qB$ ... (iii)

Energy of the electron moving in nth orbit,

$$E = \frac{1}{2} \cdot mv^2 = \frac{1}{2} \cdot \frac{nhqB}{2\pi m} \quad \text{(using Eq. (iii)}$$
$$\Rightarrow \quad E = \frac{nhqB}{4\pi m}$$

Hence, the energy of the charged particle in the nth level will be $\frac{nhqB}{4\pi m}$.

Question119

The angle made by orbital angular momentum of electron with the direction of the orbital magnetic moment is

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Options:

A. 120°

B. 60°

C. 180°

D. 90°

Answer: C

Solution:

The relation between electron's angular momentum L and magnetic moment μ given, $\mu = -\frac{e}{2m_e}L$, where e and m_e are the charges and mass of the electron.

Here, negative sign shows that the angular momentum and magentic moment are in opposite direction to each other i.e., if L in $+z$-direction then μ in-z-direction

So, the angle between L and μ is 180°.

Question120

The wavelength of the first line in Balmer series in the hydrogen spectrum is ' λ '. What is the wavelength of the second line in the same series?

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Options:

A. $\frac{20}{27}\lambda$

B. $\frac{3}{16}\lambda$

C. $\frac{5}{36}\lambda$

D. $\frac{3}{4}\lambda$

Answer: A

Solution:

Wavelength in Balmer series of hydrogen spectrum is given by relation,

$\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$ where, $n = 3, 4, 5$

So, wavelength of first line,

$$\begin{aligned} \frac{1}{\lambda_1} &= R\left[\frac{1}{4} - \frac{1}{3^2}\right] \\ &= \frac{5R}{36} \\ \Rightarrow \quad R &= \frac{36}{5\lambda} \qquad (\because \lambda_1 = \lambda, \text{ given}) \text{ ..... (i)}) \end{aligned}$$

Similarly wavelength of second line,

$$\frac{1}{\lambda_2} = R\left[\frac{1}{4} - \frac{1}{4^2}\right] = \frac{3R}{16}$$

$$\Rightarrow \quad \lambda_2 = \frac{16}{3R} \quad \text{.... (ii)}$$

From Eqs. (i) and (ii), we get

$\lambda_2 = \frac{20}{27}\lambda.$

Hence, the wavelength of the second line in the same series is $\frac{20}{27}\lambda$.
