Atoms and Nuclei

Question1

If the half-life of a radioactive material is 10 years, then the percentage of the material decayed in 30 years is

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Options:

A.

87.5

B.

78.5

C.

58.7

D.

85.7

Answer: A

Solution:

$t = 30$ years, $T_{1/2} = 10$ years

$\therefore$ number of half lives, $n = \frac{t}{T_{1/2}} = \frac{30}{10} = 3$

$\therefore N = N_0\left(\frac{1}{2}\right)^n \Rightarrow N = N_0\left(\frac{1}{2}\right)^3 \Rightarrow N = \frac{N_0}{8}$

Percentage of material decayed

$$= \frac{N_0 - N}{N_0} \times 100\%$$
$$= \frac{N_0 - \frac{N_0}{8}}{N_0} \times 100\%$$
$$= \frac{7}{8} \times 100\% = 87.5\%$$

Question2

The ratio of the time periods of the revolution of the electrons in the second and third excited states of hydrogen atom is

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Options:

A.

9 : 16

B.

27 : 64

C.

4 : 9

D.

8 : 27

Answer: B

Solution:

$T \propto n^3$

$\frac{T_2}{T_3} = \left(\frac{n_2}{n_3}\right)^3$

For the second excited state, $n_2 = 3$

For the third excited state, $n_3 = 4$

$\therefore \quad \frac{T_2}{T_3} = \left(\frac{3}{4}\right)^3 = \frac{27}{64}$
$\Rightarrow \quad T_2 : T_3 = 27 : 64$

Question3

If the surface areas of two nucleii are in the ratio $9 : 47$, then the ratio of their mass number is

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Options:

A.

$27 : 343$

B.

$9 : 49$

C.

$3 : 7$

D.

$49 : 81$

Answer: A

Solution:

$$\frac{a_1}{a_2} = \frac{9}{49}$$
$$\Rightarrow \frac{4\pi R_1^2}{4\pi R_2^2} = \frac{9}{49} \Rightarrow \left(\frac{R_1}{R_2}\right)^2 = \left(\frac{3}{7}\right)^2$$
$$\Rightarrow \frac{R_1}{R_2} = \frac{3}{7}$$

Since, $R \propto A^{\frac{1}{3}}$

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{\frac{1}{3}}$$
$$\left(\frac{R_1}{R_2}\right)^3 = \frac{A_1}{A_2}$$
$$\Rightarrow \frac{A_1}{A_2} = \left(\frac{R_1}{R_2}\right)^3 = \left(\frac{3}{7}\right)^3 = \frac{27}{343}$$
$$\therefore A_1 : A_2 = 27 : 343$$

Question4

The ratio of energies of photons produced due to transition of an electron in hydrogen atom from second energy level to first energy level and fifth energy level to second energy level is

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Options:

A.

$2 : 1$

B.

$1 : 4$

C.

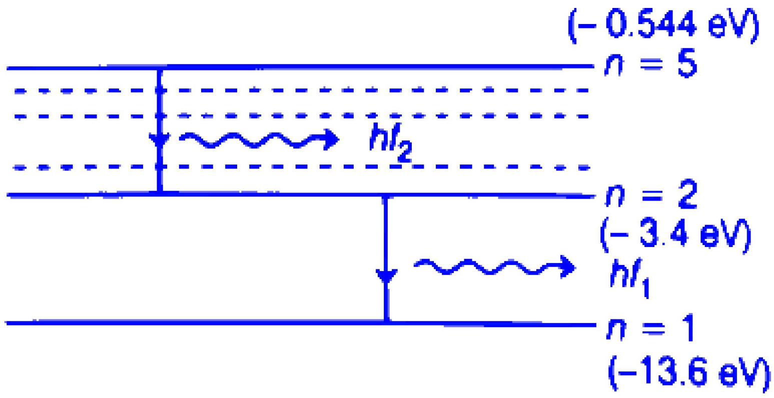
$3 : 2$

D.

$25 : 7$

Answer: D

Solution:



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

Energy of photon in transition $n = 2$ to $n = 1$

$$= \Delta E_1 = E_2 - E_1$$
$$= (-3.4) - (-13.6) = 10.2\text{eV}$$

Energy of photon in transition $n = 5$ to $n = 2$

$$= \Delta E_2 = E_5 - E_2 = -0.544 - (-3.4)$$
$$= 2.856\text{eV}$$

Ratio $\frac{\Delta E_1}{\Delta E_2} = \frac{10.2}{2.8} = \frac{102}{28} = \frac{25.5}{7} \approx \frac{25}{7}$

Question5

The half life of a radioactive substance is 10 minutes. If n_1 and n_2 are the number of atoms decayed in 20 and 30 minutes respectively, then $n_1 : n_2 =$

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Options:

A.

7 : 8

B.

1 : 2

C.

6 : 7

D.

3 : 4

Answer: C

Solution:

Decay occurs are

$$N_0 \xrightarrow{T_{1/2}=10 \text{ min}} \frac{N_0}{2} \xrightarrow{T_{1/2}=10 \text{ min}} \frac{N_0}{4} \xrightarrow{T_{1/2}=10 \text{ min}} \frac{N_0}{8}$$

$\therefore$ Number of atoms decayed in 20 min

$n_1 = N_0 - \frac{N_0}{4} = \frac{3}{4} N_0.$

Number of atoms decayed in 30 min

$n_2 = N_0 - \frac{N_0}{8} = \frac{7}{8} N_0$

Ratio $\frac{n_1}{n_2} = \frac{3}{4} \times \frac{8}{7} = \frac{6}{7}.$

Question6

The ratio of the wavelengths of the spectral lines emitted due to transitions $3 \rightarrow 2$ and $2 \rightarrow 1$ orbits in the hydrogen atom is

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Options:

A.

3 : 1

B.

9 : 17

C.

27 : 5

D.

25 : 9

Answer: C

Solution:

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

$$\frac{1}{\lambda_{3\to2}} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\frac{1}{\lambda_{3\to2}} = \frac{5R}{36} \Rightarrow \lambda_{3\to2} = \frac{36}{5R}$$

$$\text{and } \frac{1}{\lambda_{2\to1}} = R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3R}{4}$$

$$\Rightarrow \quad \lambda_{2\to1} = \frac{4}{3R}$$

$$\therefore \quad \frac{\lambda_{3\to2}}{\lambda_{2\to1}} = \frac{\frac{36}{5R}}{\frac{4}{3R}}$$

$$= \frac{36 \times 3R}{5R \times 4} = \frac{27}{5}$$

Question7

The density (in kgm^{-3}) of nuclear matter is of the order of

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Options:

A.

10^{21}

B.

10^{17}

C.

10^{12}

D.

10^{8}

Answer: B

Solution:

Step 1: Typical nuclear parameters

A nucleus has:

- Radius $R = R_0 A^{1/3}$,

  where $R_0 \approx 1.2 \times 10^{-15}\,\text{m}$
- Each nucleon (proton or neutron) has a mass $m_n \approx 1.67 \times 10^{-27}\,\text{kg}$

Step 2: Estimate the number of nucleons per unit volume

For nuclear matter, the **volume per nucleon** is roughly the volume of a sphere of radius R_0:

$$V_{\text{per nucleon}} \approx \frac{4}{3}\pi R_0^3$$

$$V_{\text{per nucleon}} \approx \frac{4}{3}\pi(1.2 \times 10^{-15})^3 \approx 7.2 \times 10^{-45}\,\text{m}^3$$

Hence, **number density of nucleons**:

$$n = \frac{1}{V_{\text{per nucleon}}} \approx \frac{1}{7.2\times10^{-45}} \approx 1.4 \times 10^{44}\,\text{m}^{-3}$$

Step 3: Compute the mass density

$$\rho = n \times m_n = (1.4 \times 10^{44})(1.67 \times 10^{-27}) \approx 2.3 \times 10^{17}\,\text{kg}\,\text{m}^{-3}$$

✅ **Answer:**

$$\boxed{\text{Density of nuclear matter } \sim 10^{17}\,\text{kg}\,\text{m}^{-3}}$$

Correct option: B (10^{17}).

Question8

Of the following, Bohr's atomic model is applicable to

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Options:

A.

explain relative intensities of spectral lines emitted by hydrogen atoms

B.

helium atom

C.

lithium atom

D.

hydrogenic atoms

Answer: D

Solution:

Bohr's atomic model is applicable to only hydrogenic atoms.

Question9

The ratio of the orders of the spacings of nuclear energy levels and atomic energy levels is

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Options:

A.

10^3

B.

10^6

C.

10^9

D.

10^{12}

Answer: B

Solution:

Step 1. Typical energy scale of atomic levels

Atomic energy levels (like in the hydrogen atom) are of the order of **electron volts (eV)**.

$E_{\text{atomic}} \sim 1\,\text{eV}$

Step 2. Typical energy scale of nuclear levels

Nuclear energy level spacings are typically in the range of **MeV (mega electron volts)**:

$E_{\text{nuclear}} \sim 1\,\text{MeV} = 10^6\,\text{eV}$

Step 3. Ratio of orders

$\frac{E_{\text{nuclear}}}{E_{\text{atomic}}} \sim \frac{10^6\text{ eV}}{1\text{ eV}} = 10^6$

✅ **Final Answer:**

$\boxed{10^6}$

Correct Option: (B) 10^6

Question10

The ratio of the wavelengths of the first Lyman line and the second Balmer line of hydrogen atom is

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Options:

A.

3 : 4

B.

1 : 4

C.

2 : 3

D.

1 : 3

Answer: B

Solution:

The formula for wavelength is:

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

First Line of Lyman Series:

For Lyman series, $n_1 = 1$. The first line means $n_2 = 2$.

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

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

Second Line of Balmer Series:

For Balmer series, $n_1 = 2$. The second line means $n_2 = 4$.

$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = R\left(\frac{1}{4} - \frac{1}{16}\right) = R\left(\frac{3}{16}\right) = \frac{3R}{16}$

So, $\lambda_B = \frac{16}{3R}$

Find the Ratio:

Now, find $\frac{\lambda_L}{\lambda_B}$:

$\frac{\lambda_L}{\lambda_B} = \frac{\frac{4}{3R}}{\frac{16}{3R}} = \frac{4}{16} = \frac{1}{4}$

This means $\lambda_L : \lambda_B = 1 : 4$

Question11

Each nuclear fission of ^{235}U releases 200 MeV of energy. If a reactor generates 1 MW power, then the rate of fission in the reactor is

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Options:

A.

3.125×10^6

B.

3.125×10^8

C.

3.125×10^{10}

D.

3.125×10^{16}

Answer: D

Solution:

Energy per fission $= 200 \mathrm{MeV}$

$$= 200 \times 1.6 \times 10^{-13} \text{ Joule}$$
$$E = 3.2 \times 10^{11} \text{ J}$$

Power of reactor

$P = 1 \mathrm{MW}$

So, Number of fissions in time t

$N = \frac{Pt}{E}$

So, number of fissions per second

$$\frac{N}{t} = \frac{P}{E} = \frac{10^6}{3.2 \times 10^{11}}$$
$$\simeq 3.125 \times 10^{16}$$

Rate of fission $= 3.125 \times 10^6$ per second

Question12

The difference between the frequencies of second and first Paschen lines of hydrogen atom is ($R =$ Rydberg constant and $c =$ speed of light in vacuum)

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Options:

A.

$\frac{9Rc}{16}$

B.

$\frac{16Rc}{25}$

C.

$\frac{9Rc}{400}$

D.

$\frac{3Rc}{200}$

Answer: C

Solution:

Frequency of a spectral line in the hydrogen atom,

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

For the first line of Paschen series,

$$n_1 = 3 \text{ and } n_2 = 4$$
$$\therefore \quad v_1 = Rc\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$
$$\Rightarrow \quad v_1 = \frac{7Rc}{144}$$

For the second line of Paschen series,

$$n_1 = 3 \text{ and } n_2 = 5$$
$$\therefore \quad v_2 = Rc\left(\frac{1}{3^2} - \frac{1}{5^2}\right) \Rightarrow v_2 = \frac{16Rc}{225}$$
$$\because \quad v_2 - v_1 = \frac{16Rc}{225} - \frac{7Rc}{144}$$
$$= \frac{81Rc}{3600} = \frac{9Rc}{400}$$

Question13

If the time taken for a radioactive substance to decay 8% to 77% is 12 minutes, then the half life of the substance in minutes is

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Options:

A.

24

B.

18

C.

12

D.

6

Answer: D

Solution:

When 8% of nuclei decays, then remaining nuclei are 92% from

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

Here, $N = 0.92 N_0$

So, $0.92 N_0 = N_0 e^{-\lambda t_1}$ $\quad\quad \ldots (i)$

When, 77% nuclei decay remaining number of nuclei are 23%.

So, $\quad N = 0.23 N_0$

$0.23 N_0 = N_0 e^{-\lambda t_2}$ $\quad\quad \ldots (ii)$

By dividing in equation (i) by equation (ii)

$\frac{0.92}{0.23} = \frac{e^{-\lambda t_1}}{e^{-\lambda t_2}} = e^{\lambda(t_2 - t_1)}$

So, $e^{\lambda(t_2 - t_1)} = 4$

By taking natural log of both sides

$$\lambda(t_2 - t_1) = \ln 4$$
$$\text{and } t_2 - t_1 = 12 \text{ minutes}$$
$$12\lambda = 2\ln 2$$
$$\lambda = \frac{\ln 2}{6}$$

and relation between half life and decay constant is

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

So, $\frac{\ln 2}{6} = \frac{\ln 2}{t_{1/2}}$

and $t_{1/2} = 6$ minutes

Question14

For an observer on the Earth, if a spectral line of wavelength $6600\overset{\circ}{\mathrm{A}}$ emitted by a star is found to be red shifted by $22\overset{\circ}{\mathrm{A}}$, then the star is

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Options:

A.

receding away from Earth with a speed of $9 \times 10^5 \text{ ms}^{-1}$

B.

receding away from Earth with a speed of $10 \times 10^5 \text{ ms}^{-1}$

C.

moving towards Earth with a speed of $9 \times 10^5 \text{ ms}^{-1}$

D.

moving towards Earth with a speed of $10 \times 10^5 \text{ ms}^{-1}$

Answer: B

Solution:

Given data

- Wavelength emitted by the star (rest wavelength):

  $\lambda_0 = 6600\ \text{Å}$

- Observed redshift (increase in wavelength):

  $\Delta\lambda = 22\ \text{Å}$

The redshift implies that the star is **moving away** from the Earth.

Formula (for non-relativistic Doppler shift)

For light at non-relativistic speeds:

$\frac{\Delta\lambda}{\lambda_0} = \frac{v}{c}$

where

v = radial speed of the source relative to the observer,

$c = 3 \times 10^8\ \text{m s}^{-1}$.

Substituting values

$\frac{22}{6600} = \frac{v}{3\times10^8}$

$v = 3 \times 10^8 \times \frac{22}{6600}$

$v = 3 \times 10^8 \times 3.33 \times 10^{-3}$

$v = 1.0 \times 10^6\ \text{m s}^{-1}$

$v = 10^6\ \text{m s}^{-1} = 10 \times 10^5\ \text{m s}^{-1}$

Direction

Since the wavelength is **red shifted**, the star is **receding** from Earth.

✅ **Answer:**

Option B

$\boxed{\text{Receding away from Earth with a speed of } 10 \times 10^5\ \text{m/s}}$

Question15

The difference between the frequencies of the first and second Lyman lines of hydrogen atom is ($R =$ Rydberg constant and $c =$ speed of light in vacuum)

Options:

A.

$\frac{9Rc}{28}$

B.

$\frac{7Rc}{12}$

C.

$\frac{3Rc}{8}$

D.

$\frac{5Rc}{36}$

Answer: D

Solution:

Frequency of spectral line of hydrogen atom

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

For the first line of Lyman series

$n_1 = 1$ and $n_2 = 2$

$$\therefore v_1 = Rc\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{3Rc}{4}$$

For the second line of Lyman series,

$n_1 = 1$ and $n_2 = 3$

$$v_2 = Rc\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = \frac{8}{9}Rc$$

Thus, $v_2 - v_1 = \frac{8}{9}Rc - \frac{3}{4}Rc = \frac{5}{36}Rc$

Question16

If the half-life of a radioactive element is 12.5 hours, then the time taken to disintegrate 256 g of the substance into 1 g is (in hours)

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Options:

A.

12.5

B.

2.5

C.

37.5

D.

100

Answer: D

Solution:

$T_{1/2} = 12.5$ hours

$\therefore N_0 = 256$ g, $N = 1$ g

Since, $N = N_0 \left(\frac{1}{2}\right)^n$

$$1 = 256\left(\frac{1}{2}\right)^n$$

$$\Rightarrow \left(\frac{1}{2}\right)^n = \frac{1}{256}$$

$$\Rightarrow \left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^8$$

$$\Rightarrow n = 8$$

$$\Rightarrow \frac{t}{T_{1/2}} = 8$$

$$\Rightarrow t = 8 \times T_{1/2} = 8 \times 12.5$$

$$= 100 \text{ hours}$$

Question17

An element X of a half-life of 1.4×10^9 years decays to form another stable element Y. A sample is taken from a rock that contains both X and Y in the ratio $1 : 7$. If at the time of formation of the rock Y was not present in the sample, then the age of the rock in years is

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Options:

A.

4.2×10^9

B.

1.4×10^9

C.

0.35×10^9

D.

2.8×10^9

Answer: A

Solution:

$$\frac{N_t}{N_0} = \left(\frac{1}{2}\right)^n$$

$$\Rightarrow \frac{1}{8} = \left(\frac{1}{2}\right)^n \Rightarrow n = 3$$

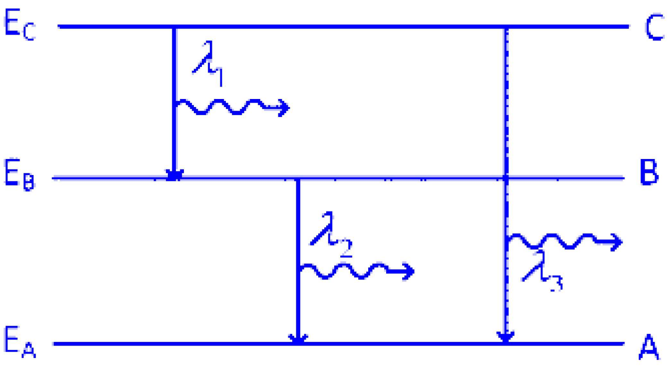
$$\frac{t}{T_{1/2}} = 3$$

$$\Rightarrow \quad t = 3 \times T_{1/2} = 3 \times 1.4 \times 10^9$$

$$= 4.2 \times 10^9 \text{ years}$$

Question18

Energy levels A, B and C of a certain atom corresponding to increasing values of energy i.e $E_A < E_B < E_C$. If λ_1, λ_2 and λ_3 are the wavelengths of a photon corresponding to the transitions shown then.



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Options:

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

B. $\lambda_3 = \frac{(\lambda_1 + \lambda_2)}{\lambda_1 \lambda_2}$

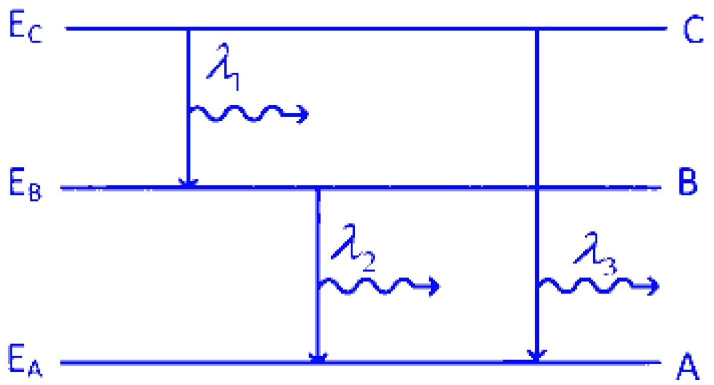
C. $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

D. $\lambda_3 = \frac{\lambda_1 \lambda_2}{(\lambda_1 + \lambda_2)}$

Answer: D

Solution:

From the given condition,
$E_C - E_A = (E_C - E_B) + (E_B - E_A)$



$$\Rightarrow \quad \frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \Rightarrow \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_1}$$

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

Question19

In a nuclear reactor, the fuel is consumed at the rate of $1 \times 10^{-3} \mathrm{gs}^{-1}$. The power generated in kW is

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Options:

A. 9×10^{14}

B. 9×10^{7}

C. 9×10^{8}

D. 9×10^{12}

Answer: B

Solution:

In a nuclear reactor, the fuel consumption rate is given as 1×10^{-3} g/s.

The speed of light is $c = 3 \times 10^{8}$ m/s.

For a nuclear reaction, the power generated P is given by the formula:

$P = \frac{E}{t} = \frac{mc^2}{t}$

Substituting the given values, we have:

$P=\frac{1\times10^{-3}\text{ g }\times(3\times10^{8}\text{ m/s })^{2}}{1\text{ s}}$

Converting grams to kilograms (since $1\text{ g}=10^{-3}\text{ kg}$):

$P=1\times10^{-6}\times3\times10^{8}\times3\times10^{8}$

This simplifies to:

$P=9\times10^{10}\text{ W}$

Converting watts to kilowatts (since $1\text{ W}=10^{-3}\text{ kW}$):

$P=9\times10^{7}\text{ kW}$

Question20

The principle quantum number n corresponding to the exited state of He^{+}ion. If on transition to the ground state two photons in succession with wavelength $1026\overset{\circ}{\mathrm{A}}$ and $304\overset{\circ}{\mathrm{A}}$ are emitted $\left(R=1.097\times10^{-7}\text{ m}^{-1}\right)$

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Options:

A. 2

B. 3

C. 6

D. 4

Answer: C

Solution:

Given:

$\lambda_1=1026\ \mathring{A}$

$\lambda_2=304\ \mathring{A}$

$R = 1.097 \times 10^7 \, \mathrm{m}^{-1}$

The excited state of He^+ is denoted as n_2. The electron transitions from the n_2 state to the ground state via an intermediate state n_1, emitting two photons successively.

For the first transition:

$$\frac{1}{\lambda_1} = RZ^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For the second transition:

$$\frac{1}{\lambda_2} = RZ^2 \left[\frac{1}{1} - \frac{1}{n_1^2}\right]$$

Adding the above two equations:

$$\left[\frac{1}{\lambda_1} + \frac{1}{\lambda_2}\right] = RZ^2 \left[1 - \frac{1}{n_2^2}\right]$$

Substitute the given values:

$$\left[\frac{1}{1026 \times 10^{-10}} + \frac{1}{304 \times 10^{-10}}\right] = 1.097 \times 10^7 \times 4 \left[1 - \frac{1}{n_2^2}\right]$$

Calculate:

$$\left[0.974 \times 10^7 + 3.289 \times 10^7\right] = 1.097 \times 4 \times 10^7 \left[1 - \frac{1}{n_2^2}\right]$$

$$\frac{4.263}{4.388} = 1 - \frac{1}{n_2^2}$$

From the above,

$$\frac{1}{n_2^2} = 0.0284 \quad \Rightarrow \quad n_2^2 = 35.21$$

Thus,

$$n_2 = \sqrt{35.21} \approx 6$$

According to the calculations, the principal quantum number $n_2 = 6$.

Question21

Which physical quantity is measured in barn?

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Options:

A. Radius of the nuclei

B. Pressure in a liquid drop

C. Scattering cross-section

D. Rate of flow of liquid

Answer: C

Solution:

The physical quantity measured in barns is the scattering cross-section.

In nuclear physics, a barn (symbol : b) is a unit of area used to quantity the likelihood of interaction between particles, such as the collision between a neutron and a nucleus. One barn is equal to 10^{-28} square metres.

Question22

The ratio of minimum wavelength of Balmer series to maximum wavelength in Brackett series in hydrogen spectrum is

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Options:

A. 25 : 16

B. 4 : 36

C. 9 : 100

D. 100 : 9

Answer: C

Solution:

To determine the ratio of the minimum wavelength in the Balmer series to the maximum wavelength in the Brackett series of the hydrogen spectrum, we start with the following calculations:

Maximum Wavelength of the Brackett Series:

The formula for the maximum wavelength in the Brackett series is given by:

$\frac{1}{\lambda_{\max}} = R\left[\frac{1}{4^2} - \frac{1}{5^2}\right]$

Simplifying this, we have:

$\frac{1}{\lambda_{\max}} = R\left[\frac{1}{16} - \frac{1}{25}\right] = \frac{9R}{25\times16}$

Minimum Wavelength of the Balmer Series:

For the Balmer series, the formula for the minimum wavelength is:

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

Ratio of Wavelengths:

We can now find the ratio of the minimum wavelength in the Balmer series to the maximum wavelength in the Brackett series:

$\frac{\text{Minimum wavelength of Balmer series}}{\text{Maximum wavelength of Brackett series}} = \frac{9R}{25\times16} \times \frac{4}{R} = \frac{9}{100}$

Therefore, the ratio is:

9 : 100

Question23

The half-life period of a radioactive element A is 62 years. It decays into another stable element B. An archaeologist found a sample in which A and B are in 1:15 ratio. The age of the sample is

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Options:

A. 248 years

B. 186 years

C. 124 years

D. 310 years

Answer: A

Solution:

To find the age of the sample where the radioactive element A and the stable element B are present in a 1:15 ratio, we start by using the information given:

The ratio of A (denoted as N_X) to B (denoted as N_Y) is $\frac{1}{15}$.

From this ratio:

$\frac{N_X}{N_Y} = \frac{1}{15}$

The total presence of elements A and B can be written as:

$N_X + N_Y = 16N_X$

We deduce that:

$\frac{N_X}{N_X+N_Y} = \frac{1}{16}$

Rearranging, we have:

$N_X = \frac{1}{16}(N_X + N_Y)$

Which implies:

$N_X = \frac{1}{2^4}(N_X + N_Y)$

This result indicates that only $\frac{1}{16}$ of the original A remains. It is now a problem of calculating how many half-lives this corresponds to. Using the relationship that each half-life divides the remaining sample by 2:

After 1 half-life, the remaining amount is $\frac{1}{2}$.

After 2 half-lives, the remaining amount is $\frac{1}{4}$.

After 3 half-lives, the remaining amount is $\frac{1}{8}$.

After 4 half-lives, the remaining amount is $\frac{1}{16}$.

Thus, 4 half-lives have passed. With a half-life period of 62 years for element A:

The age of the sample is:

$4 \times 62 = 248$ years

Question24

The electrostatic potential energy of the electron in an orbit of hydrogen is -6.8 eV . The speed of the electron in this orbit is (c is speed of light in vacuum)

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Options:

A. $\frac{c}{137}$

B. $\frac{c}{274}$

C. $\frac{2c}{137}$

D. $\frac{3c}{137}$

Answer: B

Solution:

Given:

Potential energy, $\text{PE} = -6.8 \text{ eV}$

According to Bohr's postulate, the relationship between total energy E and kinetic energy K is:

$E = K + \text{PE}$

We also know from Bohr's postulate:

$E = \frac{\text{PE}}{2}$

Substituting the given potential energy:

$E = \frac{-6.8 \text{ eV}}{2} = -3.4 \text{ eV}$

Using Bohr's relationship between kinetic and total energy:

$-E = K$

Thus:

$K = 3.4 \text{ eV}$

Given in equation form, where m_e is the mass of the electron and v_e is the speed of the electron:

$K = \frac{1}{2} m_e v_e^2$

Converting to joules:

$3.4 \times 1.6 \times 10^{-19} = \frac{1}{2} \times 9.1 \times 10^{-31} \times v_e^2$

Solving for v_e:

$v_e = 1.093 \times 10^6 \text{ m/s}$

Expressing this speed in terms of the speed of light, c:

$v_e = \frac{c}{274}$

After calculating:

$\frac{c}{274} = \frac{3 \times 10^8}{274} = 1.093 \times 10^6 \text{ m/s}$

Question25

The surface areas of two nuclei are in the ratio $9 : 25$. The mass number of the nuclei are in the ratio

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Options:

A. $27 : 125$

B. $9 : 25$

C. $3 : 5$

D. $1 : 1$

Answer: A

Solution:

Given:

The surface areas of two nuclei are in the ratio 9 : 25.

This can be expressed mathematically as:

$\frac{A_1}{A_2} = \frac{4\pi r_1^2}{4\pi r_2^2} = \frac{9}{25}$

Simplifying, we get:

$\frac{r_1^2}{r_2^2} = \frac{9}{25}$

Taking the square root of both sides, we find the ratio of the radii:

$\frac{r_1}{r_2} = \frac{3}{5}$

Assuming the density of the nuclei is ρ, the ratio of their masses can be calculated using their volumes:

$\frac{m_1}{m_2} = \frac{V_1 \cdot \rho}{V_2 \cdot \rho} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3}$

Substituting the radius ratio:

$\frac{m_1}{m_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{3}{5}\right)^3 = \frac{27}{125}$

Thus, the mass number ratio of the nuclei is:

$m_1 : m_2 = 27 : 125$

Question26

The ground state energy of hydrogen atom is -13.6 eV . The potential energy of the electron in this state is

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Options:

A. 27.2 eV

B. -27.2 eV

C. -13.6 eV

D. 13.6 eV

Answer: B

Solution:

Given that the ground state energy of a hydrogen atom is -13.6 eV, this represents the total energy of the atom.

The kinetic energy (KE) of the electron in this state is equal to the negative of the total energy:

$\mathrm{KE} = -E = -(-13.6) = 13.6 \mathrm{~eV}$

The potential energy (PE) is calculated as the negative of two times the kinetic energy:

$$\begin{aligned} \mathrm{PE} & = -2 \times \mathrm{KE} \\ & = -2 \times 13.6 \\ & = -27.2 \mathrm{~eV} \end{aligned}$$

Question27

If the energy released per fission of a ${}_{92}^{235}\mathrm{U}$ nucleus is 200 MeV . The energy released in the fission of 0.1 kg d ${}_{92}^{235}\mathrm{U}$ in kilowatt - hour is

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Options:

A. 22.8×10^5

B. 22.8×10^7

C. 11.4×10^5

D. 820×10^{10}

Answer: A

Solution:

To determine the energy released in the fission of 0.1 kg of U_{92}^{235}, we start by calculating the number of atoms in this amount. The number of atoms in 235 g of uranium is 6.023×10^{23}.

Calculate the number of atoms in 100 g of uranium:

Number of atoms $= \frac{6.023 \times 10^{23}}{235} \times 100$

Given that the energy released per fission is 200 MeV, the total energy released is:

$E_T = \frac{6.023 \times 10^{23} \times 200 \times 100}{235}$ MeV

Convert energy from MeV to Joules (since 1 MeV $= 1.6 \times 10^{-13}$ J):

$E_T = \frac{6.023 \times 10^{23} \times 200 \times 1.6 \times 10^{-13} \times 100}{235}$ J

Convert energy from Joules to kilowatt-hours (since 1 kWh $= 3.6 \times 10^6$ J):

$E_T = \frac{6.023 \times 10^{23} \times 200 \times 1.6 \times 10^{-13} \times 100}{235 \times 3.6 \times 10^6}$ kWh

Simplify the calculation:

$E_T = 0.02278 \times 10^6 \times 10^2$

The final energy released in kilowatt-hours is:

$E_T = 22.8 \times 10^5$ kWh

Question28

Inner shell electrons in atoms moving from one energy level to another lower energy level produce

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Options:

A. gamma rays

B. microwaves

C. radio waves

D. ultraviolet rays

Answer: D

Solution:

Ultraviolet rays are produced when inner shell electrons in atoms move from one energy level to a lower level.

Question29

The speed of the electron in a hydrogen atom in the $n=3$ level is

(Planck's constant $= 6.6 \times 10^{-34} \mathrm{Js}$)

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Options:

A. $62 \times 10^5 \mathrm{~ms}^{-1}$

B. $3.7 \times 10^5 \mathrm{~ms}^{-1}$

C. $7.3 \times 10^5 \mathrm{~ms}^{-1}$

D. $1.6 \times 10^5 \mathrm{~ms}^{-1}$

Answer: C

Solution:

To calculate the speed of the electron in a hydrogen atom when it is in the $n=3$ energy level, we use the formula:

$v_n=\frac{e^2}{2 \varepsilon_0 h n}$

where:

$e = 1.6 \times 10^{-19}$C is the charge of the electron,

$\varepsilon_0 = 8.85 \times 10^{-12}$F/m is the permittivity of free space,

$h = 6.64 \times 10^{-34}$Js is Planck's constant, and

$n = 3$ is the principal quantum number for the energy level.

Substituting these values into the formula, we calculate:

$v_3 = \frac{(1.6 \times 10^{-19})^2}{2 \times 8.85 \times 10^{-12} \times 6.64 \times 10^{-34} \times 3}$

Simplifying this, we find:

$v_3 \approx 0.0073 \times 10^8 \text{ m/s}$

Thus, the speed of the electron in the $n = 3$ level is:

$v_3 = 7.3 \times 10^5 \text{ m/s}$

Question30

One mole of radium has an activity of $\frac{1}{3.7}$ kilo curie. Its decay constant is

(Avagadro number $= 6 \times 10^{23} \text{ mol}^{-1}$)

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Options:

A. $\frac{1}{6} \times 10^{-10} \text{ s}^{-1}$

B. 10^{-10} s^{-1}

C. 10^{-11} s^{-1}

D. 10^{-8} s^{-1}

Answer: A

Solution:

To determine the decay constant for one mole of radium, we start with its given activity:

Activity (A) equation:

$A = \frac{1}{3.7} \times 10^3$ curie

Key constants:

1 Curie = 3.7×10^{10} decays per second

Avogadro's Number, $N_A = 6 \times 10^{23}$ atoms/mol

Calculate Decay Constant (λ):

The decay constant λ can be found using the formula:

$\lambda = \frac{A}{N_A}$

Substitute the values:

$A = \frac{1}{3.7} \times 10^3 \times 3.7 \times 10^{10}$ decays/s

Therefore:

$\lambda = \frac{\frac{1}{3.7} \times 10^3 \times 3.7 \times 10^{10}}{6 \times 10^{23}}$

Solving this gives:

$\lambda = \frac{1}{6} \times 10^{-10}\ \text{s}^{-1}$

Hence, the decay constant of radium is calculated to be $\frac{1}{6} \times 10^{-10}\ \text{s}^{-1}$.

Question31

μ-meson of charge e, mass $208 m_e$ moves in a circular orbit around a heavy nucleus having charge $+3e$. The quantum state n for which the radius of the orbit is same as that of the first Bohr orbit for hydrogen atom is (approximately]

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Options:

A. $n = 20$

B. $n = 25$

C. $n = 28$

D. $n = 29$

Answer: B

Solution:

The Bohr radius r_n for the n-th orbit in a hydrogen atom is defined as

$r_n = n^2 \frac{\hbar^2}{m_e e^2}$

For the first Bohr orbit ($n = 1$), the formula simplifies to:

$r_1 = \frac{\hbar^2}{m_e e^2}$

Here, $\hbar$ is the reduced Planck's constant.

Now, consider the Bohr radius for the μ-meson system:

$r'_n = n^2 \frac{\hbar^2}{m_\mu Z e^2}$

Given that $m_\mu = 208 m_e$ and $Z = 3$, we want to find the value of n such that the μ-meson's orbit r'_n is approximately equal to the radius of the first Bohr orbit r_1 of hydrogen:

$$\begin{aligned} r'_n &= r_1 \\ n^2 \frac{\hbar^2}{208 m_e 3 e^2} &= \frac{\hbar^2}{m_e e^2} \\ n^2 \frac{1}{208 \times 3} &= 1 \\ n^2 &= 208 \times 3 = 624 \\ n &= \sqrt{624} \approx 25 \end{aligned}$$

Hence, the quantum state n is approximately 25.

Question32

A nucleus with atomic mass number A produces another nucleus by loosing 2 alpha particles. The volume of the new nucleus is 60 times that of the alpha particle. The atomic mass number A of the original nucleus is

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Options:

A. 228

B. 238

C. 248

D. 244

Answer: C

Solution:

An alpha particle has an atomic mass number of 4. Let's assume the original nucleus has an atomic mass number A. After losing 2 alpha particles, the new nucleus will have an atomic mass number $A' = A - 2 \times 4 = A - 8$.

The volume of a nucleus is proportional to its atomic mass number A, i.e., $V \propto A$.

Given that the volume of the new nucleus is 60 times that of an alpha particle, we write:

$V_{\text{new}} = 60 \times V_{\text{alpha}}$

Thus,

$A' = 60 \times 4 = 240$

Since,

$A' = A - 8$

We equate:

$A - 8 = 240$

Solving for A:

$A = 240 + 8 = 248$

Therefore, the atomic mass number A of the original nucleus is 248.

Question33

A hydrogen atom falls from nth higher energy orbit to first energy orbit $(n = 1)$. The energy released is equal to 12.75 eV . The nth orbit is

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Options:

A. $n = 4$

B. $n = 3$

C. $n = 6$

D. $n=5$

Answer: A

Solution:

To determine the initial energy level n of a hydrogen atom that releases 12.75 eV when transitioning to the first energy level, follow these steps:

The change in energy (ΔE) for an electron falling from the n-th level to the first level is given by:

$\Delta E=-\frac{13.6}{n^2}-\left(-\frac{13.6}{1^2}\right)=12.75$

Simplify the equation:

$-\frac{13.6}{n^2}+13.6=12.75$

Isolate the energy term:

$-\frac{13.6}{n^2}=12.75-13.6$

Calculate the energy difference:

$-\frac{13.6}{n^2}=-0.85$

Rearrange to solve for n^2:

$n^2=\frac{13.6}{0.85}$

Calculate n^2:

$n^2=16$

Finally, find n:

$n=4$

Therefore, the n-th orbit from which the electron falls is $n=4$.

Question34

The decrease in each day in the uranium mass of the material in a uranium reactor operating at a power of 12 MW is (Energy released in one ${}_{92}U^{235}$ fission is about 200 MeV)

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Options:

A. 12.64×10^{-2} kg

B. 11.50×10^{-2} g

C. 12.64 kg

D. 12.64 g

Answer: D

Solution:

To determine the daily decrease in uranium mass in a reactor operating at a power of 12 MW, we start by calculating the total energy produced in one day.

Total Energy Per Day:

The power output of the reactor is 12 MW. Since power is energy per unit time, the energy output over one day is calculated as follows:

$\text{Total energy per day} = 12 \times 10^6 \text{ J/s} \times 24 \times 3600 \text{ s}$

Energy Released Per Fission:

For each fission event of ${}_{92}U^{235}$, approximately 200 MeV of energy is released. To convert this energy to joules:

$200 \text{ MeV} = 200 \times 1.6 \times 10^{-13} \text{ J} = 3.2 \times 10^{-11} \text{ J}$

Calculating Fissions Per Day:

Using the relationship between power, energy per fission, and the number of fissions, we get:

$\text{Power} = \frac{\text{Number of Fissions} \quad \times \text{Energy per Fission}}{\text{Time}}$

Solving for the number of fissions (n):

$12 \times 10^6 = \frac{n \times 3.2 \times 10^{-11}}{24 \times 3600}$

$n = \frac{12 \times 10^6 \times 24 \times 3600}{3.2 \times 10^{-11}} = 3.2 \times 10^{22}$

Calculating Mass of Uranium Consumed:

To find how much uranium is consumed, we first determine the number of moles:

$\text{Number of moles} = \frac{3.2 \times 10^{22}}{6.023 \times 10^{23}} = 0.053$

The mass of uranium consumed is then:

$\text{Mass of uranium} = 0.0531 \times 235 \approx 12.64 \text{ g}$

Thus, the daily decrease in uranium mass in the reactor is approximately 12.64 grams.

Question35

If the binding energy of the electron in a hydrogen atom is 13.6 eV . Then, energy required to remove electron from first excited state of Li^{2+} is

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Options:

A. 122.4 eV

B. 3.4 eV

C. 13.6 eV

D. 30.6 eV

Answer: D

Solution:

Given:

The binding energy for a hydrogen atom is 13.6 eV.

We know:

The energy of an electron in the n-th state is given by:

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

For Li^{2+}, the atomic number $Z = 3$.

To find the energy required to remove the electron from the first excited state ($n = 2$):

Substitute into the equation:

$$E_2 = -13.6 \times \frac{3^2}{2^2} = -13.6 \times \frac{9}{4}$$
$$E_2 = -30.6 \, \text{eV}$$

Since $E_2 + E = 0$, we have:

$-30.6 + E = 0$

Thus, solving for E:

$E = +30.6 \, \text{eV}$

Therefore, the energy required to remove the electron from the first excited state of Li^{2+} is 30.6 eV.

Question36

A mixture consists of two radioactive materials A_1 and A_2 with half lives of 20 s and 10 s respectively. Initially, the mixture has 40 g of A_1 and 160 g of A_2. The amount of the two in the mixture will become equal after

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Options:

A. 60 s

B. 80 B

C. 20 s

D. 40 s

Answer: D

Solution:

Given:

Initial amount of $A_1 = 40\,\text{g}$

Initial amount of $A_2 = 160\,\text{g}$

Half-life of $A_1, T_{A_1} = 20\,\text{s}$

Half-life of $A_2, T_{A_2} = 10\,\text{s}$

To determine when the amounts of A_1 and A_2 will be equal, we use the decay formula:

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

For A_1, the remaining amount is:

$N_{A_1} = 40\left(\frac{1}{2}\right)^{t/20}$

For A_2, the remaining amount is:

$N_{A_2} = 160\left(\frac{1}{2}\right)^{t/10}$

To find the time when these amounts are equal, set $N_{A_1} = N_{A_2}$:

$$40\left(\frac{1}{2}\right)^{t/20} = 160\left(\frac{1}{2}\right)^{t/10}$$
$$2^{t/10} = 4 \cdot 2^{t/20} \Rightarrow 2^{\frac{t}{10}-\frac{t}{20}} = 4$$
$$2^{t/20} = 2^2 \Rightarrow \frac{t}{20} = 2$$
$$t = 40\ \mathrm{s}$$

Therefore, the amounts of A_1 and A_2 in the mixture will become equal after 40 seconds.

Question37

An electron in the hydrogen atom excites from 2nd orbit to 4th orbit then the change in angular momentum of the electron is (Planck's constant $h = 6.64 \times 10^{-34}\ \mathrm{J-s}$)

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Options:

A. $2.11 \times 10^{-34}\ \mathrm{J-s}$

B. $1.05 \times 10^{-34}\ \mathrm{J-s}$

C. $0.57 \times 10^{-34}\ \mathrm{J-s}$

D. $422 \times 10^{-34}\ \mathrm{J-s}$

Answer: A

Solution:

Change in angular momentum of the electron in H-atom when it is excited from 2nd orbit to 4th orbit is given as

$\Delta L = L_2 - L_I$

Where, L_2 is angular momentum of 4th excited state $(n = 5)$ and L_1 is angular moment of 2nd excited state $(n = 3)$.

$$\begin{aligned}\therefore \Delta L &= \frac{n_2 h}{2\pi} - \frac{n_1 h}{2\pi} \\ &= \frac{h}{2\pi}[n_2 - n_1] = \frac{6.64 \times 10^{-34}}{2 \times 314}[5-4] \\ &= 2.11 \times 10^{-34}\ \mathrm{J-s}\end{aligned}$$

Question38

Choose the correct statement of the following

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Options:

A. The nuclear density in general, is independent of mass number A.

B. The radius of nucleus is directly proportional to the mass number of A of the nucleus.

C. The binding energy of a nucleus is inversely proportional to its mass defect.

D. Energy is observed when heavy nuclei undergo transmutation into light nuclei.

Answer: A

Solution:

We know that, the radius (R) of nucleus is given as

$R=R_0 A^{1/3}$ or $R \propto A^{1/3}$

Where,

$$\begin{aligned} R_0 &= \text{ constant} \\ A &= \text{ mass number} \end{aligned}$$

$\therefore$ Nuclear density, $\rho=\frac{\text{mass}}{\text{volume}}=\frac{mA}{\frac{4}{3}\pi R^3}$

(here, m is mass of each nucleon)

$$\begin{aligned} \Rightarrow \quad \rho &= \frac{mA}{\frac{4}{3}\pi\left(R_0 A^{1/3}\right)^3}=\frac{mA}{\frac{4}{3}\pi R_0^3 A} \\ \rho &= \frac{3m}{4\pi R_0^3} \end{aligned}$$

Hence, it is clear from above formula, nuclear density is independent of mass number A.

The binding energy, $E=\Delta mc^2$

i. e $E \propto \Delta m$

Where, Δm = mass defect

Energy is released when heavy nuclei undergo transmutation into light nuclei.

Question39

A ancient discovery found a sample, where 75% of the original carbon (C^{14}) remains. Then the age of the sample is

$$\left(\begin{array}{ll} T_{\frac{1}{2}}(C^{14})=5730 \text{ years}, & \ln 0.5=-0.7 \\ \ln(0.75)=-0.3 & \end{array}\right)$$

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Options:

A. 2300 years

B. 2456 years

C. 2546 years

D. 3456 years

Answer: B

Solution:

For a carbon sample (C^{14}),

$T_{1/2} = 5730$ year

Decay constant,

$$K = \frac{0.693}{T_{1/2}}$$
$$= \frac{0.693}{5730}$$
$$= 1.209 \times 10^{-4} / \text{ year}$$

The rate of counts is proportional to the number of C^{14} atom in the sample

$N_0 = 100, N = 75$

The age of the sample is given as,

$$
\begin{aligned}
t &= \frac{2.303}{K}\log\frac{N_0}{N} = \frac{2.303}{K}\log\frac{1}{0.75} \\
&= \frac{2303}{1.209\times10^{-4}}\log\frac{100}{75} \\
&= 2456\times10^{3}\text{ years} \\
&= 2456\text{ years}
\end{aligned}
$$

Question40

A hydrogen atom at the ground level absorbs a photon and is excited n = 4 level. The potential energy of the electron in the excited state is

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Options:

A. -0.85 eV

B. $+0.85$ eV

C. -1.7 eV

D. $+1.7$ eV

Answer: C

Solution:

Energy of hydrogen atom in ground state,

$E_0 = -13.6$ eV

Energy of electron in excited state $(n=4)$,

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

$$= \frac{-13.6}{4^2} = \frac{-13.6}{16} = -0.85\text{eV}$$

Potential energy of the electron in the excited state $(n=4)$,

$$
\begin{aligned}
U &= 2E' \\
&= 2\times(-0.85\text{eV}) \\
&= -1\cdot7\text{eV}
\end{aligned}
$$

Question41

The radius of an atomic nucleus of mass number 64 is 4.8 fermi. Then the mass number of another atomic nucleus of radius 6 fermi is

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Options:

A. 64

B. 81

C. 100

D. 125

Answer: D

Solution:

We know that, radius (R) of atomic nucleus and mass number (A) are related as

$$R = R_0 A^{1/3}$$
$$\Rightarrow \quad R \propto A^{1/3}$$
$$\Rightarrow \quad \frac{R_2}{R_1} = \left(\frac{A_2}{A_1}\right)^{1/3}$$
$$\Rightarrow \quad \frac{A_2}{A_1} = \left(\frac{R_2}{R_1}\right)^3$$

Given, $A_1 = 64$, $R_1 = 4.8$ fermi, $R_2 = 6$ fermi

Putting these values in above equation, we get

$$\frac{A_2}{64} = \left(\frac{6}{4.8}\right)^3 = \left(\frac{5}{4}\right)^3$$
$$\Rightarrow \quad \frac{A_2}{64} = \frac{125}{64}$$
$$\Rightarrow \quad A_2' = 125$$

Question42

Energy of a stationary electron in the hydrogen atom is $E = \frac{13.6}{n^2}$ eV, then the energies required to excite the electron in hydrogen atom to (a) its second excited state and (b) ionised state, respectively.

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Options:

A. (a) $\sim$ 10 eV (b) 13.6 eV

B. (a) $\sim$ 12 eV, (b) 13.6 eV

C. (a) $\sim$ 12 eV, (b) 10.6 eV

D. (a) $\sim$ 8 eV, (b) 13.6 eV

Answer: B

Solution:

Energy of electron in nth orbit of hydrogen atom,

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

energy of electron in ground state ($n = 1$),

$E_0 = \frac{-13.6}{1^2} = -13.6$ eV

for second excited state, $n = 3$

$\therefore$ energy of electron in H -atom in second excited state

$E' = \frac{-13.6}{3^2} = -1.51$ eV

Energy required to excite the electron in hydrogen atom to second excited state

$= E' - E_0$

$= -1.51 - (-13.6) = 1209\text{eV}$
$\simeq 12$ eV

Energy of ionised electron of $(n = \infty)$H - atom.

$E'' = \frac{-13.6}{\infty} = 0$ eV

energy required to ionise the electron

$= E'' - E_0 = 0 - (-13.6) = 13.6 \text{ eV}$

Question43

The graph of $\ln\left(\frac{R}{R_0}\right)$ versus $\ln A$ is where R is radius of a nucleus, A is its mass number, and R_0 is constant

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Options:

A. A straight line

B. A circle of radius R

C. A parabola

D. An ellipse

Answer: A

Solution:

Radius of nucleus (R) having mass number (A) is given as,

$R = R_0 A^{1/3}$

where, R_0 is constant.

Taking log both side, we have

$$\ln R = \ln R_0 A^{1/3}$$
$$\Rightarrow \ln R = \ln R_0 + \ln A^{1/3}$$
$$\Rightarrow \ln R = \ln R_0 + \frac{1}{3}\ln A$$
$$\Rightarrow \ln R = \frac{1}{3}\ln A + \ln R_0$$

this is in the form of equation of straight line

$y = mx + c$

where, $y = \ln R$

$m = \frac{1}{3}, x = \ln A$

and $\quad c=\ln R_0$

Question44

The shortest wavelength of X-rays emitted from an X-ray tube depends upon ....

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Options:

A. nature of the gas in the tube

B. voltage applied to tube

C. current in the tube

D. nature of target of the tube

Answer: B

Solution:

As we know that,

By using de-Broglie wavelength,

$\lambda=\frac{h}{p}=\frac{h}{\sqrt{2mE}}=\frac{h}{\sqrt{2meV}}$

where, λ is wavelength of X-ray,h is Planck's constant i.e. 6.63×10^{-34} J $-$ s, p is, momentum, m is mass, E is energy, e is charge and V is electric potential.

$\therefore \quad \lambda\propto\frac{1}{\sqrt{V}}$

Question45

The wavelength of the first spectral line ofthe Lyman series of hydrogen spectrum is

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Options:

A. 912 $\overset{o}{A}$

B. 1215 $\overset{o}{A}$

C. 1512 $\overset{o}{A}$

D. 6563 $\overset{o}{A}$

Answer: B

Solution:

By using Rydberg's formula

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

For Lyman series,

$$\begin{aligned} n_1 & =1 \text{ and } n_2=2 \\ \therefore \quad \frac{1}{\lambda} & =R\left(\frac{1}{1^2}-\frac{1}{2^2}\right)=R\left(\frac{1}{1}-\frac{1}{4}\right)=R\left(\frac{3}{4}\right) \\ \Rightarrow \quad \lambda & =4/3R=1215 \times 10^{-10} \text{ m} \\ & =\frac{4}{3 \times 1.097 \times 10^7}=1215 \overset{o}{A} \end{aligned}$$

Question46

Which of the following nuclear reactions ispossible?

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Options:

A. ${}_5\mathrm{B}^{10}+{}_2\mathrm{He}^4 \longrightarrow {}_7\mathrm{N}^{13}+{}_1\mathrm{H}^1$

B. ${}_{11}\mathrm{Na}^{24}+{}_{1}\mathrm{H}^{1}\longrightarrow{}_{10}\mathrm{Ne}^{20}+{}_{2}\mathrm{He}^{4}$

C. ${}_{93}\ \mathrm{Np}^{239}\longrightarrow{}_{94}\mathrm{Pu}^{239}+\beta^{-}+\gamma^{-}$

D. ${}_{7}\ \mathrm{N}^{11}+{}_{1}\mathrm{H}^{1}\longrightarrow{}_{6}\mathrm{C}^{12}+\beta^{-}+\gamma^{-}$

Answer: C

Solution:

As we know that,

In case of $(-\beta)$ - decay we get $+e_{1}^{0}$ positron, so atomic number of reactant increases get by 1

and in case of γ-decay we get only gamma-ray and no change in atomic number as well as mass.

$\therefore\ \mathrm{Np}_{93}^{239}\longrightarrow\mathrm{Pu}_{94}^{239}+\beta^{-}+\gamma^{-}$ is possiblewhereas (a), (b) and (d) are not possible.

Question47

The angular momentum of the orbitalelectron is integral multiple of

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Options:

A. h

B. $2\pi h$

C. $\frac{h}{2\pi}$

D. $3\pi h$

Answer: C

Solution:

As we know that, angular momentum of electron, $L=nh/2\pi$.

$\therefore$ L is integral multiple of $h/2\pi$.

Question48

Which of the following values is the correct order of nuclear density?

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Options:

A. $5 \times 10^5 \text{ kgm}^{-3}$

B. $9 \times 10^{10} \text{ kgm}^{-3}$

C. $3 \times 10^{21} \text{ kgm}^{-3}$

D. $2 \times 10^{17} \text{ kgm}^{-3}$

Answer: D

Solution:

As we know that, nuclear density of any atom $= 2 \times 10^{17} \text{ kg/m}^3$

$\therefore$ Option (d) is correct.

Question49

The ionisation potential of hydrogen atom is13.6 V. How much energy need to besupplied to ionise the hydrogen atom in thefirst excited state?

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Options:

A. 13.6 eV

B. 27.2 eV

C. 3.4 eV

D. 6.8 eV

Answer: C

Solution:

Ionisation potential of hydrogen $= 13.6$ V

Let energy E is required to excite electron to 1st excited state $n = 2$

Since, $E = \frac{13.6}{n^2} Z^2$ eV

$\Rightarrow \quad E = \frac{13.6}{2^2} = \frac{13.6}{4} = 3.4$ eV

Question50

Which of the following statement is correct?

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Options:

A. The rest mass of the stable nucleus is less than the sum of the rest masses of its separated nucleons.

B. The rest mass of the stable nucleus is greater than the sum of the rest masses of its separated nucleons.

C. In nuclear fission energy is released by fusion of two nuclei of medium mass (approximate 100 amu).

D. In nuclear fission energy is released by fragmentation of very low atomic mass nucleus.

Answer: A

Solution:

As we know that in case of fussion reactionenergy released is proportional to mass.

$\therefore$ When separated nucleons combine some mass gets converted to energy.

Hence, mass of stable nuclei will always be lessthan separated nucleons.

Question51

Potential energy between a proton and an electron is given by $U=\frac{K e^2}{3 R^3}$, then radius of Bohr's orbit can be given by

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Options:

A. $\frac{K e^2 m}{h^2}$

B. $\frac{6 \pi^3 K e^2 m}{n^3 h^2}$

C. $\frac{2 \pi}{n} \frac{K e^2 m}{h^2}$

D. $\frac{4 \pi^2 K e^2 m}{n^3 h^2}$

Answer: A

Solution:

Given, potential energy between proton and electron,

$U=\frac{K e^2}{3 R^3}$

As we know that,

Force, $F=\frac{-d U}{d R}$

$\therefore \quad F=-\frac{K e^2}{3} \frac{d}{d R} R^{-3} \Rightarrow \frac{m v^2}{R}=-\frac{K e^2}{3} \cdot(-3) R^{-4}$

where, m is mass,

v is speed and R is radius.

$\therefore \quad \frac{m v^2}{R}=\frac{K e^2}{R^4}$

$\Rightarrow \quad R^3=\frac{K e^2}{m v^2}$ ...... (i)

From uncertainty principle,

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

$$\Rightarrow \quad v = \frac{nh}{2\pi mR}$$

Substituting the value in Eq. (i), we get

$$R^3 = \frac{Ke^2}{m \cdot \frac{n^2h^2}{4\pi^2m^2R^2}}$$

$$\therefore \quad R^3 = \frac{Ke^2 \cdot 4\pi^2m^2R^2}{mn^2h^2}$$

$$\therefore \quad R = \frac{4\pi^2 \cdot Ke^2 \cdot m}{n^2h^2}$$
