# Atoms and Nuclei

## Question1

**If the radius of first Bohr orbit is $r$, then the radius of the second Bohr orbit will be**

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**Options:**

A. 8 r

B. $4r$

C. $2\sqrt{2}r$

D. $2r$

**Answer: B**

## Solution:

In the Bohr model the radius of the $n$th orbit is given by

$r_n = n^2 r_1$

where $r_1 = r$ is the radius of the first orbit.

For $n = 2$:

$r_2 = 2^2 r_1 = 4r$

Answer: 4 r (Option B)

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## Question2

Match the following types of nuclei with examples shown

| Column-I | Column-II |
|----------|-----------|
| A. Isotopes | i. $Li^7, Be^7$ |
| B. Isobars | ii. $_8O^{18}, _9F^{19}$ |
| C. Isotopes | iii. $_1H^1, _1H^2$ |

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**Options:**

A. A-ii, B-iii, C-i

B. A-i, B-iii, C-ii

C. A-iii, B-ii, C-i
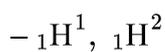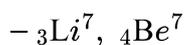
D. A-iii, B-i, C-ii

**Answer: D**

# Solution:

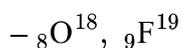Here's how the examples match up:

Isotopes (same Z, different A)

$- _1H^1, _1H^2$

$\rightarrow$ group iii

Isobars (same A, different Z)

$- _3Li^7, _4Be^7$

$\rightarrow$ group i

Isotones (same N, different Z)

$- _8O^{18}, _9F^{19}$

$\rightarrow$ group ii

So the correct matching is

A–iii, B–i, C–ii $\rightarrow$ Option D.

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# Question3

**Which of the following statements is incorrect with reference of 'Nuclear force'?**

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**Options:**

A. Nuclear force becomes attractive for nucleon distances larger than 0.8 fm

B. Nuclear force becomes repulsive for nucleon distances less then 0.8 fm

C. Nuclear force is always attractive

D. Potential energy is minimum, if the separation between the nucleons is 0.8 fm

**Answer: C**

## Solution:

The incorrect statement is Option C.

• At very short separations (r < 0.8 fm) the nuclear force is strongly repulsive (a "hard core").

• For distances r ≃ 0.8–3 fm it becomes attractive.

• The potential energy reaches its minimum (stable equilibrium) at roughly r = 0.8 fm.

Since the force is not always attractive (it's repulsive at r < 0.8 fm), saying "nuclear force is always attractive" is wrong.

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# Question4

**In alpha particle scattering experiment, if $v$ is the initial velocity of the particle, then the distance of closest approach is $d$. If the velocity is doubled, then the distance of closest approach becomes**

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**Options:**

A. $4d$

B. $2d$

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

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

**Answer: D**

**Solution:**

If $r_0$ be the distance of closest approach, then

$$(\text{KE})_\alpha = \frac{(Ze)(2e)}{4\pi\varepsilon_0 \cdot (r_0)_\alpha} \Rightarrow \frac{1}{2}mv_\alpha^2 = \frac{(Ze)(2e)}{4\pi\varepsilon_0 \cdot (r_0)_\alpha}$$

$$\Rightarrow \quad v_\alpha^2 \propto \frac{1}{(r_0)_\alpha} \Rightarrow (r_0)_\alpha \propto \frac{1}{v_\alpha^2}$$

$$\Rightarrow \quad \frac{(r_0)_{\alpha_i}}{(r_0)_{\alpha_f}} = \frac{v_{\alpha f}^2}{v_{\alpha i}^2} = \frac{(2v_{\alpha_i})^2}{v_{\alpha_i}^2} = 4$$

$$\therefore \quad (r_0)_{\alpha_f} = \frac{(r_0)\alpha_i}{4} = \frac{d}{4} \quad \left[\because (r_0)_{\alpha_i} = d\right]$$

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# Question5

**The ratio of area of first excited state to ground state of orbit of hydrogen atom is**

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**Options:**

A. 1 : 16

B. 1 : 4

C. 4 : 1

D. 16 : 1

**Answer: D**

## Solution:

Since, $r_n \propto n^2$

$\therefore$ Area, $A_n \propto r_n^2 \propto n^4$

$\Rightarrow \quad \dfrac{A_{n_1}}{A_{n_2}} = \left(\dfrac{n_1}{n_2}\right)^4 = \left(\dfrac{2n}{n}\right)^4 = 16$

$\therefore \quad A_{n_1} : A_{n_2} = 16 : 1$

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# Question6

**The ratio of volume of $\mathrm{Al}^{27}$ nucleus to its surface area is (Given, $R_0 = 1.2 \times 10^{-15}$ m)**

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**Options:**

A. $2.1 \times 10^{-15}$ m

B. $1.3 \times 10^{-15}$ m

C. $0.22 \times 10^{-15}$ m

D. $1.2 \times 10^{-15}$ m

**Answer: D**

## Solution:

$\dfrac{\text{Volume of } \mathrm{Al}^{27} \text{ nucleus}}{\text{Surface area}} = \dfrac{\frac{4}{3}\pi R^3}{4\pi R^2} = \dfrac{R}{3}$

$= \dfrac{1}{3}\left(R_0 A^{\frac{1}{3}}\right)$

$\left[\because R = R_0 A^{\frac{1}{3}}\right]$

$= \dfrac{1}{3} \times 1.2 \times 10^{-15}(27)^{\frac{1}{3}}$

$= 1.2 \times 10^{-15}$ m

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# Question7

**Consider the nuclear fission reaction**
$^{1}_{0}n + ^{235}_{92}U \longrightarrow ^{144}_{56}Ba + ^{89}_{36}Kr + 3^{1}_{0}n.$ **Assuming all the kinetic energy is carried away by the fast neutrons only and total binding energies of $^{235}_{92}U, ^{144}_{56}Ba$ and $^{89}_{36}Kr$ to be $1800MeV, 1200$ MeV and $780$ MeV respectively, the average kinetic energy carried by each fast neutron is (in MeV)**

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**Options:**

A. 200

B. 180

C. 67

D. 60

**Answer: D**

## Solution:

Binding energy $^{235}_{92}U, BE_1 = 1800$ MeV

Binding energy of $^{144}_{56}Ba, BE_2 = 1200$ MeV

Binding energy of $^{89}_{36}Kr, BE_3 = 780$ MeV

$\therefore$ Binding energy of reactants $= BE_1 = 1800MeV$

Binding energy of products $= BE_2 = BE_2 + BE_3$

$= 1200 + 780$
$= 1980MeV$

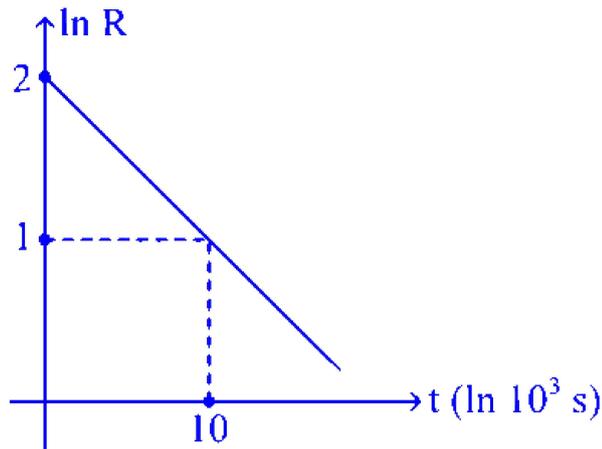$\therefore$ Average kinetic energy carried by each fast neutron

$= \dfrac{\text{Binding energy of products - Binding energy of reactants}}{3}$

$$= \frac{1980-1800}{3} = 60 \text{ MeV}$$

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# Question8

The natural logarithm of the activity $R$ of a radioactive sample varies with time $t$ as shown. At $t = 0$, there are $N_0$ undecayed nuclei. Then, $N_0$ is equal to [Take $e^2 = 7.5$ ]
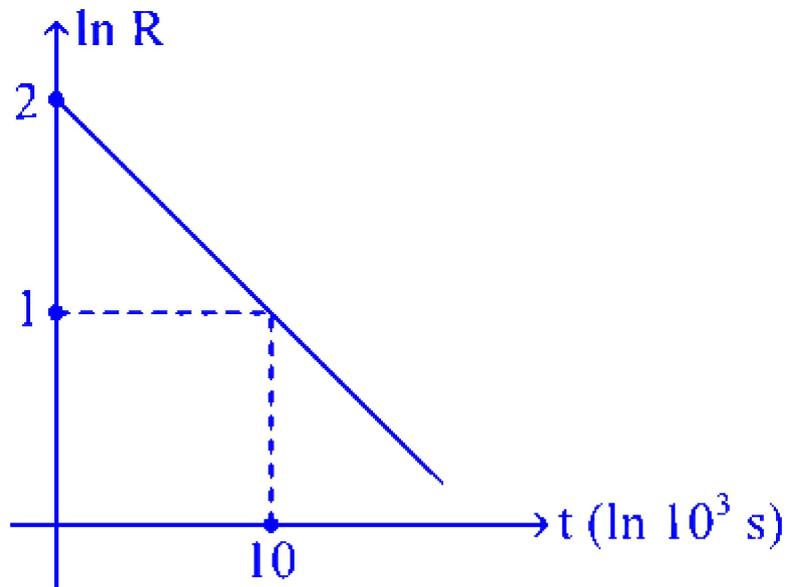


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**Options:**

A. 7500

B. 3500

C. 75000

D. 150000

**Answer: D**

## Solution:

From the diagram at $t = 0$

$\log_e R_0 = 2$

$\Rightarrow \qquad R_0 \quad = e^2 = 7.5$

Since, $\quad R_0 \quad = \lambda N_0 \quad$ .... (i)

Since, $\qquad \lambda \quad =$ Slope of graph

$\qquad\qquad\qquad = \frac{1}{10 \times 10^3} = 10^{-4} \text{ s}^{-1}$

$\therefore$ From Eq. (i), $N_0 = \frac{R_0}{\lambda} = \frac{7.5}{10^{-4}} = 75000$

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# Question9

**In the Rutherford's alpha scattering experiment, as the impact parameter increases, the scattering angle of the alpha particle**

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**Options:**

A. remains the same

B. is always $90°$

C. decreases

D. increases

**Answer: C**

# Solution:

In the Rutherford's $\alpha$-scattering experiment, impact parameter $(b)$ and scattering angle $\theta$ are related as,
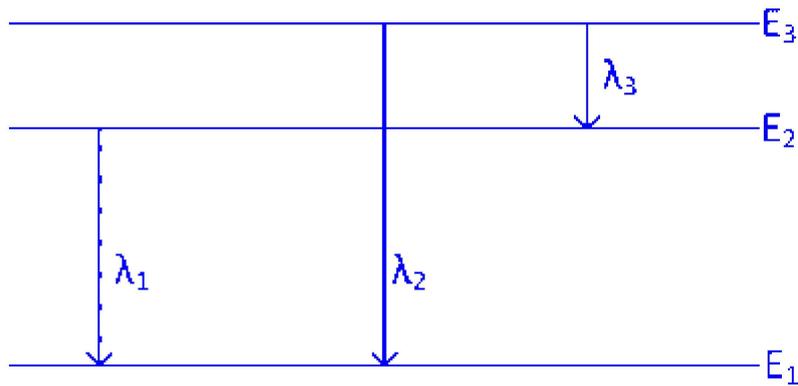
$$b = \frac{1}{4\pi\varepsilon_0} \cdot \frac{ze^2 \cot\frac{\theta}{2}}{\left(\frac{1}{2}mv^2\right)}$$

$$\Rightarrow \quad b \propto \cot\frac{\theta}{2}$$

Thus, with the increase of impact parameter $(b)$, $\cot\frac{\theta}{2}$ increases. It is possible only when $\theta$ will decrease.

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# Question10

**Three energy levels of hydrogen atom and the corresponding wavelength of the emitted radiation due to different electron transition are as shown. Then,**



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**Options:**

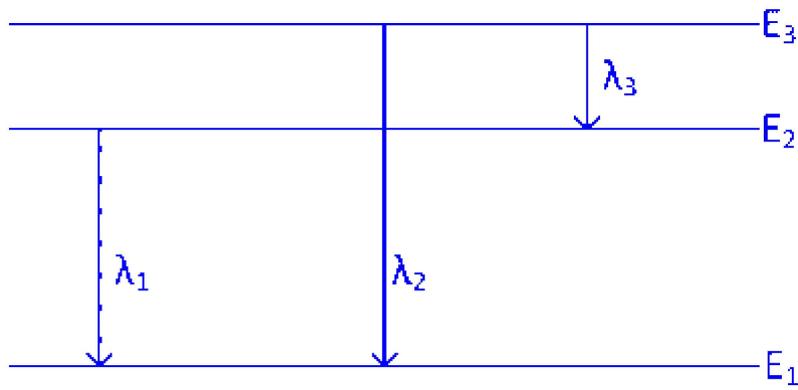A. $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$

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

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

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

**Answer: D**

## Solution:

From the given diagram,

$$E_2 - E_1 = \frac{hc}{\lambda_1} \quad \text{..... (i)}$$

$$E_3 - E_2 = \frac{hc}{\lambda_3} \quad \text{..... (ii)}$$

$$E_3 - E_1 = \frac{hc}{\lambda_2} \quad \text{..... (iii)}$$

Adding Eq. (i) and Eq. (ii), we get

$$E_3 - E_1 = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_3}$$

$$\Rightarrow \quad \frac{hc}{\lambda_2} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_3} \quad \text{[From Eq. (iii)]}$$

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

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

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# Question11

**A radioactive sample has half-life of 3 years. The time required for the activity of the sample to reduce to $\frac{1}{5}$th of its initial value is about**

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**Options:**

A. 10 years

B. 7 years

C. 15 years

D. 5 years

**Answer: B**

## Solution:

Given, $T_{1/2} = 3$ years

We know that

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

Here, $R = \frac{R_0}{5}$

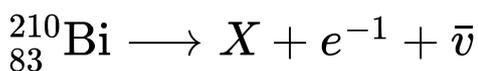$$\Rightarrow \quad \frac{R_0}{5} = R_0 e^{-\lambda t} \Rightarrow \frac{1}{5} = e^{-\lambda t}$$

$$\Rightarrow \ln(5)^{-1} = \ln\left(e^{-\lambda t}\right)$$

$$\Rightarrow \quad t = \frac{\ln 5}{\lambda} = \frac{\ln 5}{\frac{0.693}{t_{1/2}}} = \frac{\ln 5}{0.693} \times t_{1/2} = \frac{\ln 5}{0.693} \times 3$$

$$= 6.96 \simeq 7 \text{ years}$$

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# Question12

**In the following equation representing $\beta^-$ decay, the number of neutrons in the nucleus $X$ is**

$$_{83}^{210}\text{Bi} \longrightarrow X + e^{-1} + \bar{v}$$

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**Options:**

A. 126

B. 127

C. 125

D. 84

**Answer: A**

## Solution:

In $\beta^-$ decay, reaction is given as,

$$^{210}_{83}\text{Bi} \longrightarrow {}^{210}_{84}X + e^{-1} + \bar{v}$$
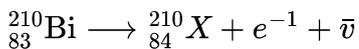
$\therefore$ Number of neutrons $= 210 - 84 = 126$

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# Question13

**A nucleus with mass number 220 initially at rest emits an alpha particle. If the $Q$ value of reaction is $5.5\ \text{MeV}$. Calculate the value of kinetic energy of alpha particle**

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### Options:

A. $6.5\ \text{MeV}$

B. $5.4\ \text{MeV}$

C. $7.4\ \text{MeV}$

D. $4.5\ \text{MeV}$

### Answer: B

## Solution:

Given, $Q = 5.5\ \text{MeV}$

Mass number of nucleus $= 220$

By conservation of linear momentum.

$$M_\alpha v_\alpha = M_y v_y$$

where, $M_\alpha, v_\alpha$ are mass and velocity of $\alpha$-particle, and $M_X v_X$ are mass and velocity of the daughter nuclei $X$.

Since, $Q = (\text{KE})_\alpha + (\text{KE})_X$ .... (i)

Let $Y$ be the nucleus with the mass number 220 and $X$ be the daughter nuclei produced.

Hence, we have $^{220}Y \longrightarrow {}^{216}X + {}^2_4\alpha$

Using conservation of linear momentum.

$$M_\alpha v_\alpha = M_X v_X$$

$$\Rightarrow \quad v_x = \frac{M_\alpha v_\alpha}{M_X}$$

$\therefore$ From Eq. (i), $Q = \dfrac{1}{2} M_\alpha v_\alpha^2 + \dfrac{1}{2} M_X v_X^2$

$$\Rightarrow \quad 5.5 = \frac{1}{2} M_\alpha v_\alpha^2 + \frac{1}{2} \frac{M_\alpha^2 v_\alpha^2}{M_x}$$

$$\Rightarrow \quad 5.5 = \frac{1}{2} M_\alpha v_\alpha^2 \left[ 1 + \frac{M_\alpha}{M_X} \right]$$

$$\Rightarrow \quad 5.5 = (\text{KE})_\alpha \left( 1 + \frac{4}{216} \right)$$

$$\Rightarrow \quad \text{KE}_\alpha = 5.4 \text{ MeV}$$

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# Question14

**The radius of hydrogen atom in the ground state is $0.53 \overset{o}{A}$. After collision with an electron, it is found to have a radius of $2.12 \overset{o}{A}$, the principal quantum number $n$ of the final state of the atom is**

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**Options:**

A. $n = 2$

B. $n = 3$

C. $n = 4$

D. $n = 1$

**Answer: A**

## Solution:

Given, radius of H-atom in the ground state $(n_1 = 1)$

$r_1 = 0.53 \overset{o}{A}$

Radius of excited state $(n_2)$

$r_1 = 2.12 \overset{o}{A}$

We know that, $r \propto n^2$

$\Rightarrow \quad \frac{r_1}{r_2} = \left(\frac{n_1}{n_2}\right)^2 \Rightarrow \frac{0.53}{212} = \left(\frac{1}{n_2}\right)^2 \quad [\because n_1 = 1]$

$\Rightarrow \quad \frac{1}{4} = \frac{1}{n_2^2} \Rightarrow \left(\frac{1}{2}\right)^2 = \frac{1}{n_2^2} \Rightarrow n_2 = 2$

i.e. $\quad n \simeq n = 2$

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# Question15

**In accordance with the Bohr's model, the quantum number that characterises the Earth's revolution around the Sun in an orbit of radius $1.5 \times 10^{11}$ m with orbital speed $3 \times 10^4$ ms$^{-1}$ is[given, mass of Earth $= 6 \times 10^{24}$ kg]**

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**Options:**

A. $2.57 \times 10^{38}$

B. $8.57 \times 10^{64}$

C. $2.57 \times 10^{74}$

D. $5.98 \times 10^{86}$

**Answer: C**

## Solution:

Given, $v = 3 \times 10^4$ m/s

$\quad\quad\quad r = 1.5 \times 10^{11}$ m

$\quad\quad\quad m_e = 6 \times 10^{24}$ kg

According Bohr's atomic model,

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

where, $h =$ Planck's constant $= 6.62 \times 10^{-34}$ J $-$ s

and. $n$ = quantum number

$$\therefore \quad n = \frac{2\pi (m_e vr)}{h}$$

$$= \frac{2 \times 314 \times 6 \times 10^{24} \times 3 \times 10^4 \times 1.5 \times 10^{11}}{6.62 \times 10^{-34}}$$

$$= 2.57 \times 10^{74}$$

Hence, the quantam number that characterises the Earth's revolution is $2.57 \times 10^{74}$.

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# Question16

**If an electron is revolving in its Bohr orbit having Bohr radius of $0.529\overset{o}{A}$, then the radius of third orbit is**

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**Options:**

A. $4496\overset{o}{A}$

B. $4.761\overset{o}{A}$

C. 5125 nm

D. 4234 nm

**Answer: B**

**Solution:**

Given, Bohr radius, $r_1 = 0.529\overset{o}{A}$

We know that, radius of revolving electron in $n$th orbit is given as

$r \propto n^2$

$$\Rightarrow \quad \frac{r_1}{r_2} = \left(\frac{n_1}{n_2}\right)^2$$

$$\Rightarrow \quad \frac{r_1}{r_2} = \left(\frac{1}{3}\right)^2 = \frac{1}{9} \quad [\because n_1 = 1 \text{ and } n_2 = 3]$$

$$\Rightarrow \quad r_2 = 9r_1 = 9 \times 0.529 = 4.761\overset{o}{A}$$

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# Question17

**Binding energy of a nitrogen nucleus $\left[{}^{14}_{7}\,\mathrm{N}\right]$, given $m\left[{}^{14}_{7}\,\mathrm{N}\right] = 14.00307\mathrm{u}$**

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**Options:**

A. 85 MeV

B. 206.5 MeV

C. 78 MeV

D. 104.7 MeV

**Answer: D**

## Solution:

Given, mass of nucleus of nitrogen,

$m\left[{}_{7}\,\mathrm{N}^{14}\right] = 14.00307\mathrm{u}$

Mass of proton, $m_p = 1.00783$ amu

Mass of neutron, $m_n = 1.0087$ amu

Mass defect, $\Delta m = (7m_p + 7m_n) - m\left({}_{7}\,\mathrm{N}^{14}\right)$

$= 7 \times 1.00783 + 7 \times 1.00807 - 14.00307$
$= 0.11243$ amu

$\therefore$ Binding energy of nitrogen nucleus

$= \Delta m \times 931 = 0.11243 \times 931$
$= 104.67 \simeq 104.7$ MeV

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# Question18

**Which of the following radiations is deflected by electric field?**

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**Options:**

A. Neutrons

B. $\gamma$-rays

C. $\alpha$-particles

D. X-rays

**Answer: C**

## Solution:

$\alpha$-particles are deflected in electric and magnetic field both because it has a charge of $+2e$. $\gamma$-rays and $X$-rays are electromagnetic waves which do not deflected in electric and magnetic field. Neutrons are neutral (chargeless) particles, hence it cannot deflect in electric and magnetic field.

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# Question19

**A nuclear reactor delivers a power of $10^9$ W, the amount of fuel consumed by the reactor in one hour is**

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**Options:**

A. 0.08 g

B. 0.72 g

C. 0.96 g

D. 0.04 g

**Solution:**

Given, power delivered by nuclear reactor,

$P = 10^9$ W
$c = 3 \times 10^8$ m/s
$t = 1$ h $= 60 \times 60$ s

Since, $\quad P = \dfrac{E}{t} = \dfrac{mc^2}{t} \quad \left[\because E = mc^2\right]$

$\Rightarrow \quad m = \dfrac{Pt}{c^2} = \dfrac{10^9 \times 60 \times 60}{\left(3 \times 10^8\right)^2}$

$\qquad = \dfrac{10^9 \times 3600}{9 \times 10^{16}} = 4 \times 10^{-5}$ kg

$\qquad = 0.04 \times 10^{-3}$ kg $= 0.04$ g

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# Question20

**Energy of an electron in the second orbit of hydrogen atom is $E_2$. The energy of electron in the third orbit of $\text{He}^+$ will be**

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**Options:**

A. $\dfrac{9}{16} E_2$

B. $\dfrac{16}{9} E_2$

C. $\dfrac{3}{16} E_2$

D. $\dfrac{16}{3} E_2$

**Solution:**

The energy of the electron in the $n$th orbit is given by

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

$E_n \propto \dfrac{Z^2}{n^2}$

For hydrogen atom, $Z = 1$

$E_n \propto \dfrac{1}{n^2}$

In second orbit, $n = 2$

$E_2 \propto \dfrac{1}{(2)^2}$

In case of $\text{He}^+$, $Z = 2$ and $n = 3$
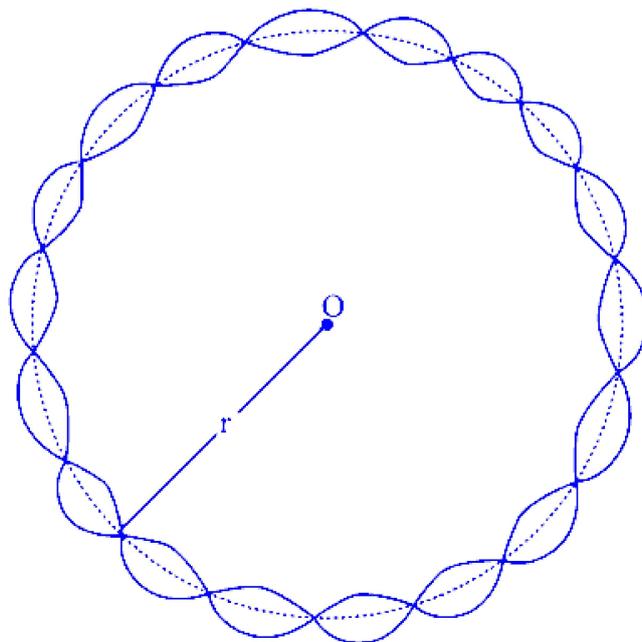
$E_3 \propto \dfrac{(2)^2}{(3)^2}$

$\therefore \quad \dfrac{E_2}{E_3} = \dfrac{1}{4} \times \dfrac{9}{4} = \dfrac{9}{16}$

$\Rightarrow \quad E_3 = \dfrac{16 E_2}{9}$

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# Question21

**The figure shows standing de-Broglie waves due to the revolution of electron in a certain orbit of hydrogen atom. Then, the expression for the orbit radius is (All notations have their usual meanings)**

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**Options:**

A. $\frac{h^2 \varepsilon_0}{\pi m e^2}$

B. $\frac{4 h^2 \varepsilon_0}{\pi m e^2}$

C. $\frac{9 h^2 \varepsilon_0}{\pi m e^2}$

D. $\frac{16 h^2 \varepsilon_0}{\pi m e^2}$

**Answer: A**

## Solution:

According to de-Broglie, the circumference of a stationary orbit must be an integral number of wavelengths.

$$n\lambda = 2\pi r_n$$

Also, angular momentum, $m v_n r_n = \frac{nh}{2\pi}$

$$\Rightarrow \quad m \frac{e^2}{2nh\varepsilon_0} r_n = \frac{nh}{2\pi} \quad \left[ \because v_n = \frac{e^2}{2nh\varepsilon_0} \right]$$

$$\Rightarrow \quad r_n = \frac{n^2 h^2 \varepsilon_0}{me^2 \pi} = \frac{n^2 h^2 \varepsilon_0}{\pi m e^2}$$

Here, number of standing waves, $n = 6$

$$\therefore \quad r_n = \frac{(6)^2 h^2 \varepsilon_0}{\pi m e^2} = \frac{36 h^2 \varepsilon_0}{\pi m e^2}$$

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# Question22

**An electron in an excited state of $\text{Li}^{2+}$ ion has angular momentum $\frac{3h}{2\pi}$. The de-Broglie wavelength of electron in this state is $p\pi a_0$ (where, $a_0 = $ Bohr radius). The value of $p$ is**

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**Options:**

A. 3

B. 2

C. 1

D. 4

**Answer: B**

## Solution:

According to de-Broglie hypothesis,

$$\Rightarrow \quad \begin{aligned} L &= \frac{nh}{2\pi} = \frac{3h}{2\pi} = mvr \\ n &= 3 \end{aligned}$$

As, wavelength, $\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{hr}{mvr}$

$$= \frac{hr}{\frac{3h}{2\pi}} = \frac{2}{3}\pi r$$

For $Li^{2+}$ atom, radius of orbit,

$$r = r_0 \frac{n^2}{Z} = a_0 \frac{3^2}{3} = 3a_0$$

$$\Rightarrow \quad \lambda = \frac{2}{3}\pi \times a_0 \times 3 = 2\pi a_0 = p\pi a_0 \text{ (given)}$$

$$\therefore \quad p = 2$$
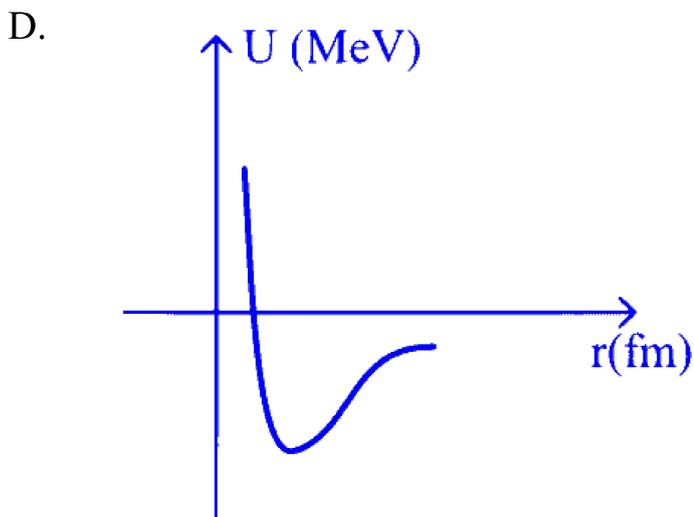
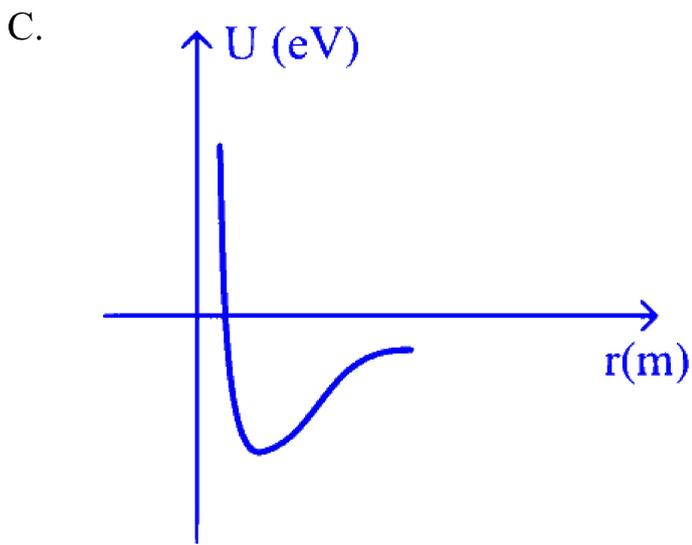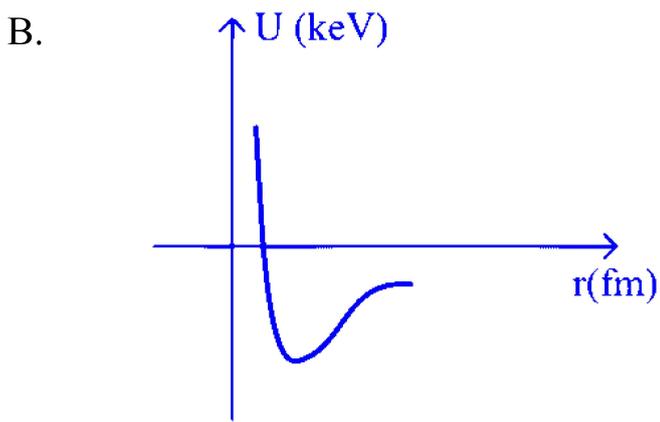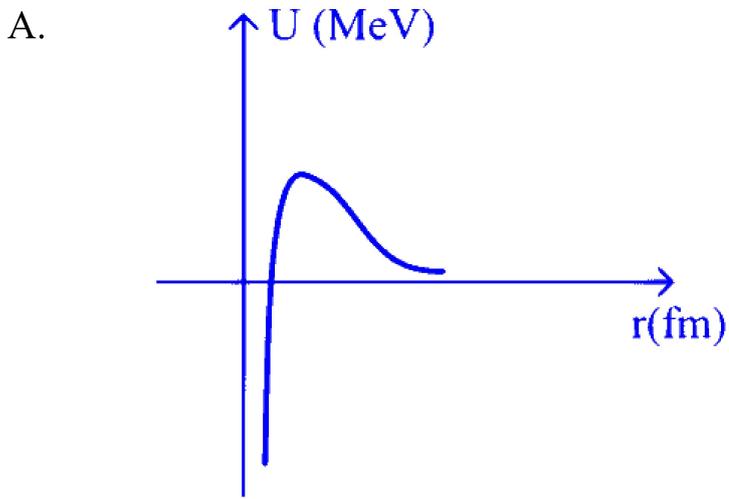---------------------------------------------------------------------------------------------------

# Question23

**Which graph in the following diagram correctly represents the potential energy of a pair of nucleons as a function of their separation?**
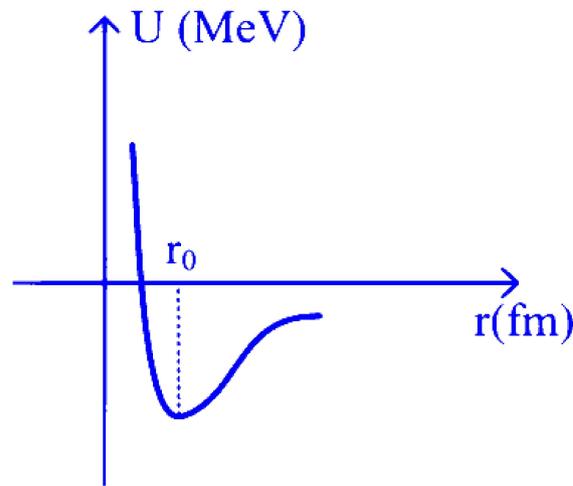
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**Options:**

A.



B.



C.



D.

## Solution:

The graph between potential energy of a pair of nucleons (in MeV) and their separation is shown below.



For, $r < r_0$, force is repulsive and force $r > r_0$, the force is attractive between nucleons.

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# Question24

**In a nuclear reactor heavy nuclei is not used as moderators because**

**KCET 2021**

**Options:**

A. they will break up

B. elastic collision of neutrons with heavy nuclei will not slow them down

C. the net weight of the reactor would be unbearably high

D. substance with heavy nuclei do not occur in liquid or gaseous state at room temperature

**Answer: B**

## Solution:

The moderator used in nuclear reactor, have light nuclei (like proton). When protons undergo perfectly elastic collision with the neutrons emitted, their velocities are exchanged i.e. neutrons. Heavy nuclei will not serve the purpose because elastic collision of neutrons with heavy nuclei will not slow them down.

# Question25

**The period of revolution of an electron revolving in nth orbit of H-atom is proportional to**

**KCET 2020**

**Options:**

A. $n^2$

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

C. $n^3$

D. independent of $n$

**Answer: C**

**Solution:**

The time period of revolution of an electron revolving in $n$th orbit of H-atom is given by

$$T_n = \frac{2\pi r_n}{v_n} = \left( \frac{4\varepsilon_0^2 h^2}{me^4} \right) \frac{n^3}{z^2}$$

$$\Rightarrow \quad T_n \propto n^3$$

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# Question26

**Angular momentum of an electron in hydrogen atom is $\frac{3h}{2\pi}$ ($h$ is the Planck's constant). The KE of the electron is**

**KCET 2020**

**Options:**

A. 4.35 eV

B. 1.51 eV

C. 3.4 eV

D. 6.8 eV

**Answer: B**

## Solution:

Given, angular momentum of electron in

H-atom $= \frac{3h}{2\pi}$   .... (i)

From Bohr's postulate,

Angular momentum $= \frac{nh}{2\pi}$   .... (ii)

Comparing Eqs. (i) and (ii), we get

$n = 3$

The kinetic energy of an electron in hydrogen is given by

$$
\begin{aligned}
\text{KE} &= \frac{13.6 \times Z^2}{n^2}\text{eV} \\
&= \frac{13.6 \times 1}{3^2} \quad \text{(for H, Z = 1)} \\
&= 1.51 \text{ eV}
\end{aligned}
$$

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# Question27

**A beam of fast moving alpha particles were directed towards a thin film of gold. The parts $A, B$ and $C$ of the transmitted and reflected beams corresponding to the incident parts $A, B$ and $C$ of the beam are shown in the adjoining diagram. The number of alpha particles in**
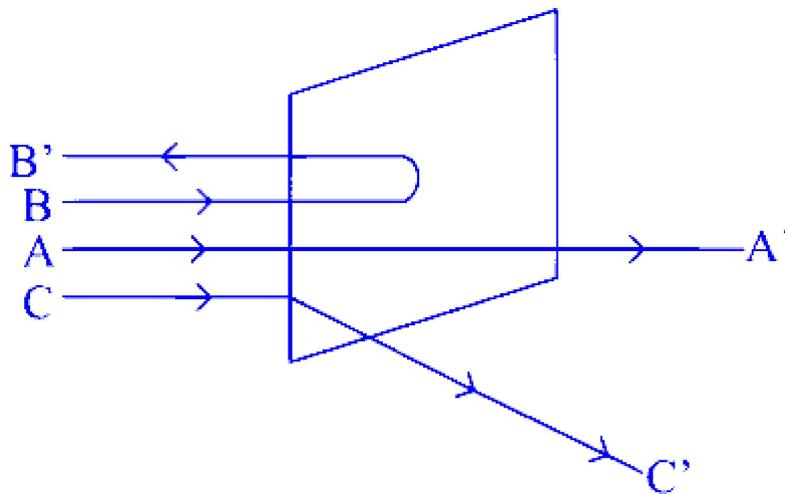
## KCET 2020

**Options:**

A. $B'$ will be minimum and in $C'$ maximum

B. $A'$ will be maximum and in $C'$ minimum

C. $A'$ will be minimum and in $B'$ maximum

D. $C'$ will be minimum and in $B'$ maximum

**Answer: A**

## Solution:

According to Rutherford's $\alpha$-particles scattering experiment, following observations are made

(i) Most of the $\alpha$-particles passed through the gold foil undeflected.

(ii) Only about 0.14% of the incident $\alpha$-particles scattered by an angle greater than $1°$.

(iii) About one $\alpha$-particle in every $8000\alpha$-particles deflects by angle more than $90°$.

So, from above observation, we can conclude about the number of $\alpha$-particle in given figure as,

$n_{A'} > n_{C'} > n_{B'}$

i.e., number of $\alpha$-particle will be maximum in $A'$ and minimum in $B'$.

No given option is correct.

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# Question28

**Two protons are kept at a separation of** $10$ **nm.** **Let** $F_n$ **and** $F_e$ **the nuclear force and the electromagnetic force between them**

**KCET 2020**

**Options:**

A. $F_e = F_n$

B. $F_e \gg F_n$

C. $F_e \ll F_n$

D. $F_e$ and $F_n$ differ only slightly

**Answer: B**

## Solution:

The nuclear forces are short range forces in range of few fm (ferrometre).

whereas, electromagnetic force are long range forces.

So, at a separation of 10 nm, the electromagnetic force is greater than the nuclear force between two protons, i.e.

$F_e \gg F_n$

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# Question29

**During a** $\beta^-$**-decay**

**KCET 2020**

**Options:**

A. an atomic electron is ejected

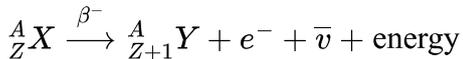B. an electron which is already present within the nucleus is ejected

C. a neutron in the nucleus decays emitting an electron

D. a proton in the nucleus decays emitting an electron

**Answer: C**

## Solution:

The process of $\beta^-$ decay is shown below

$$^A_Z X \xrightarrow{\beta^-} \, ^A_{Z+1}Y + e^- + \bar{v} + \text{energy}$$

Thus, in this decay a neutron inside the nucleus decays into a proton with the emission of an electron $e^-$ and a particle called anti-neutrino $(\bar{v})$.

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# Question30

**A radio-active elements has half-life of 15 years. What is the fraction that will decay in 30 years?**

**KCET 2020**

**Options:**

A. 0.25

B. 0.5

C. 0.75

D. 0.85

**Answer: C**

## Solution:

Given, half-life, $T_{1/2} = 15$ years

Time, $t = 30$ years

$\therefore$ Number of half-life, $n = \frac{t}{T} = \frac{30}{15} = 2$

The number of nuclei left undecayed in 30 years or 2 half-lives is

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

$\therefore$ Fraction of decayed element $= \left(1 - \frac{N}{N_0}\right) = 1 - \frac{1}{4}$

$= \frac{3}{4}$ or $0.75$

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# Question31

## Which one of the following nuclei has shorter mean life?
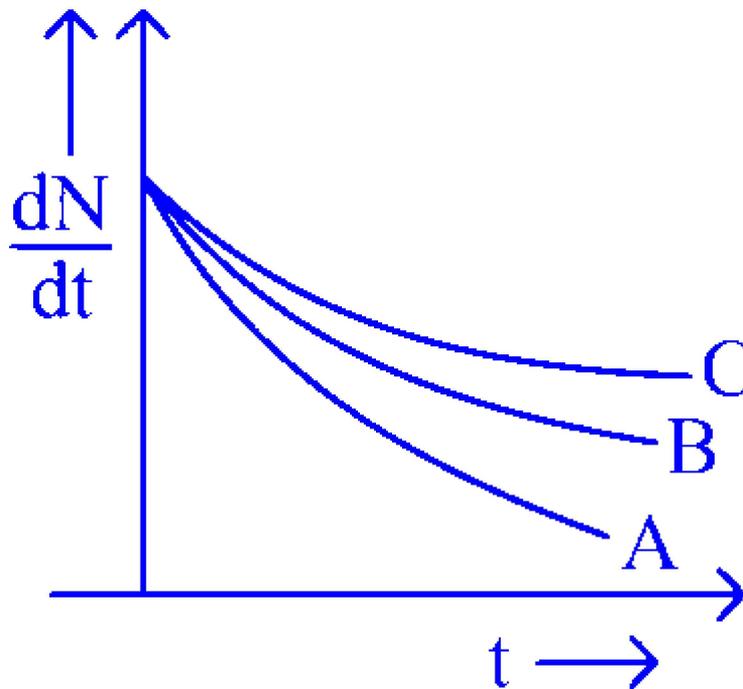


**KCET 2019**

**Options:**

A. A

B. B

C. C

D. Same for all

<span style="color:green">**Answer: A**</span>

## Solution:

According to radioactive decay law,

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

i.e. $\quad \frac{dN}{dt} = \frac{R_0}{e^{\lambda t}} \quad$ .... (i)

where, $\lambda =$ disintegration constant

If $\tau$ be the mean life time, then $\tau = \frac{1}{\lambda} \quad$ .... (ii)

From given curve, it is clear that when $\frac{dN}{dt}$ is minimum, then from Eq (i), $\lambda$ will be maximum and from Eq (ii), $\tau$ will be minimum. Hence, curve $A$ represents for the nuclei of shorter wavelength.

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# Question32

## In Rutherford experiment, for head-on collision of $\alpha$-particles with a gold nucleus, the impact parameter is

### KCET 2019

**Options:**

A. zero

B. of the order of $10^{-14}$ m

C. of the order of $10^{-10}$ m

D. of the order of $10^{-6}$ m

**Answer: A**

## Solution:

Impact parameter $b$ in Rutherford experiment is given by $b = \frac{1}{4\pi\varepsilon_0} \frac{Ze^2 \cot\frac{\theta}{2}}{\left(\frac{1}{2}mv^2\right)} \quad$ ..... (i)

For head on collision, $\alpha$-particle just collides at centre of the nucleus and reverse back along its original path.

$\therefore$ Scattering angle, $\theta = 180°$

$\therefore \quad \frac{\theta}{2} = 90°$

$\cot\frac{\theta}{2} = \cot 90° = 0$

From Eq (i),

$b = 0$

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# Question33

**Frequency of revolution of an electron revolving in $n$th orbit of H-atom is proportional to**

**KCET 2019**

**Options:**

A. $\frac{1}{n^2}$

B. $n$

C. $n$ independent of $n$

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

**Answer: D**

## Solution:

Time period of revolving electron in $n$th orbit of H-atom,

$$T_n = \frac{2\pi r_n}{v_n}$$

$T_n \propto \frac{r_n}{v_n}$  ... (i)

where, $r_n \to$ radius of $n$th orbit

$v_n \to$ yelocity of electron in $n$th orbit

$\therefore \quad v_n \propto \frac{1}{n}$ and $r_n \propto n^2$

$\therefore$ From Eq (i),

$T_n \propto \frac{n^2}{1/n} \Rightarrow T_n \propto n^3$

$\therefore$ Frequency of electron in $n$th orbit

$$f_n \propto \frac{1}{T_n}$$

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

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# Question34

**A hydrogen atom is ground state absorbs $10.2$ eV of energy. The orbital angular momentum of the electron is increased by**

**KCET 2019**

**Options:**

A. $1.05 \times 10^{-34}$ Js

B. $2.11 \times 10^{-34}$ Js

C. $3.16 \times 10^{-34}$ Js

D. $4.22 \times 10^{-34}$ Js

**Answer: A**

## Solution:

Energy absorb by hydrogen atom in ground state,

$E = 10.2 \text{ eV} = 10.2 \times 1.6 \times 10^{-19}$ J

Increasement of orbital angular momentum of electron

$$\Delta L = \frac{h}{2\pi} = \frac{6.6 \times 10^{-34}}{2 \times 314}$$
$$= 1.05 \times 10^{-34} \text{ Js}$$

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# Question35

**The end product of decay of $_{90}\text{Th}^{232}$ is $_{82}\text{Pb}^{208}$. The number of $\alpha$ and $\beta$ particles emitted are respectively**

**Options:**

A. $3, 3$

B. $6, 4$

C. $6, 0$

D. $4, 6$

**Answer: B**

## Solution:

In radioactive decay, end product $_{82}\text{Pb}^{208}$ is obtained from $_{90}\text{Th}^{232}$

Change in atomic mass $= 232 - 208 = 24$

Change in atomic mass by the emission of $\alpha$-particle $= 4$

Number of emitted $\alpha$-particle $= \frac{24}{4} = 6$

Change in atomic number

$= 90 - 82 = 8$

$\therefore$ On emission of $\alpha$-particle, atomic number decreases by 2 unit and on emission of $\beta$-particle, atomic mass increases by one unit.

On emission of $6\alpha$-particle, atomic number decreases by 12 units.

$\therefore$ number of emitted $\beta$-particle

$= 12 - 8 = 4$

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# Question36

**The energy equivalent to a substance of mass 1 g is**

**KCET 2018**

**Options:**

A. $18 \times 10^{13}$ J

B. $9 \times 10^{13}$ J

C. $18 \times 10^6$ J

D. $9 \times 10^6$ J

**Answer: B**

## Solution:

To determine the energy equivalent of a 1 g mass, we make use of Einstein's famous equation:

$E = mc^2$

Here's how to calculate it step by step:

**Convert Mass to Kilograms:**

Since 1 g = 0.001 kg, we have:

$m = 0.001 \, \text{kg}$

**Substitute the Value of the Speed of Light:**

The speed of light, $c$, is approximately $3 \times 10^8$ m/s. Substituting into the equation:

$E = 0.001 \times \left(3 \times 10^8\right)^2$

**Compute $c^2$:**

$\left(3 \times 10^8\right)^2 = 9 \times 10^{16}$

**Calculate the Energy:**

Multiply:

$E = 0.001 \times 9 \times 10^{16} = 9 \times 10^{13} \, \text{J}$

Thus, the energy equivalent to a mass of 1 g is $9 \times 10^{13}$ J.

This matches Option B.

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# Question37

**The half-life of tritium is 12.5 years. What mass of tritium of initial mass 64 mg will remain undecayed after 50 years?**

**KCET 2018**

**Options:**

A. 32 mg

B. 8 mg

C. 16 mg

D. 4 mg

**Answer: D**

## Solution:

To solve this problem, we use the half-life decay formula:

$$m = m_0 \left(\frac{1}{2}\right)^{\frac{t}{T_{1/2}}}$$

Where:

$m$ is the remaining mass,

$m_0$ is the initial mass,

$t$ is the elapsed time,

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

Here are the steps:

Given:

$m_0 = 64$ mg

$T_{1/2} = 12.5$ years

$t = 50$ years

Calculate the number of half-lives:

$$\frac{t}{T_{1/2}} = \frac{50}{12.5} = 4$$

Compute the remaining mass:

$$m = 64 \left(\frac{1}{2}\right)^4 = 64 \left(\frac{1}{16}\right) = 4 \text{ mg}$$

Thus, after 50 years, the mass of tritium that remains is 4 mg.

The correct answer is Option D.

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# Question38

**The total energy of an electron revolving in the second orbit of hydrogen atom is**

**KCET 2018**

**Options:**

A. -13.6 eV

B. -1.51 eV

C. -3.4 eV

D. zero

**Answer: C**

## Solution:

The energy levels in a hydrogen atom are given by the formula:

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

Here, $n$ represents the principal quantum number. For the second orbit, we have $n = 2$. Plugging that into the formula:

Calculate the denominator:

$n^2 = 2^2 = 4$

Compute the energy:

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

Thus, the total energy of an electron revolving in the second orbit of a hydrogen atom is $-3.4$ eV.

The correct answer is Option C.

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# Question39

**The period of revolution of an electron in the ground state of hydrogen atom is $T$. The period of revolution of the electron in the first excited state is**

**KCET 2018**

**Options:**

A. $2T$

B. $4T$

C. $6T$

D. $8T$

**Answer: D**

## Solution:

Let's analyze the problem using the Bohr model for the hydrogen atom.

In the Bohr model, the radius of the electron's circular orbit for the state with principal quantum number $n$ is given by:

$r_n = n^2 a_0,$

where $a_0$ is the Bohr radius.

The speed of the electron in the orbit is inversely proportional to $n$:

$v_n \propto \frac{1}{n}.$

The time period of revolution $T_n$ is the circumference of the orbit divided by the speed:

$T_n = \frac{2\pi r_n}{v_n}.$

Substituting the dependencies for $r_n$ and $v_n$, we get:

$T_n \propto \frac{2\pi (n^2 a_0)}{(v_1/n)} = 2\pi n^3 \frac{a_0}{v_1}.$

This shows that the period scales as $n^3$.

For the ground state ($n = 1$), the period is given as $T_1 = T$.

For the first excited state ($n = 2$):

$T_2 = 2^3 T = 8T.$

Thus, the period of revolution of the electron in the first excited state is $8T$.

The correct answer is Option D: $8T$.

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# Question40

# The particle emitted in the decay of $^{238}_{92}U$ to $^{234}_{92}U$

## KCET 2017

**Options:**

A. $2\alpha$ and $2\beta$

B. $1\alpha$ and $2\beta$

C. $1\alpha$ only
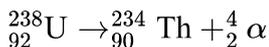
D. $1\alpha$ and $1\beta$

**Answer: B**

## Solution:

To understand the transformation from $^{238}_{92}U$ to $^{234}_{92}U$, let's break it down step by step:

**Alpha Decay:**

An alpha particle is the same as a helium nucleus, denoted by $^4_2\alpha$.

When $^{238}_{92}U$ emits an alpha particle, it loses 4 units from its mass number and 2 units from its atomic number.

This turns uranium into thorium:

$^{238}_{92}U \rightarrow\, ^{234}_{90}Th +\, ^4_2\alpha$

**Beta Decay:**

Beta decay (specifically, beta minus decay) converts a neutron into a proton while emitting an electron ($\beta^-$).

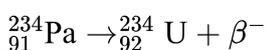The atomic number increases by 1, but the mass number remains unchanged.

Since $^{234}_{90}Th$ has an atomic number of 90 and we want to reach $^{234}_{92}U$, we need to increase the atomic number by 2.

This happens via two successive beta decays:

First beta decay:

$^{234}_{90}Th \rightarrow\, ^{234}_{91}Pa + \beta^-$

Second beta decay:

$^{234}_{91}Pa \rightarrow\, ^{234}_{92}U + \beta^-$
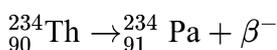
**Net Effect:**

The overall process involves the emission of:

1 alpha particle

2 beta particles

Therefore, the correct option is:

Option B: $1\alpha$ and $2\beta$.

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# Question41

**The mass defect of $_2^4\mathrm{He}$ is 0.03 u . The binding energy per nucleon of helium (in MeV) is**

**KCET 2017**

**Options:**

A. 6.9825

B. 27.93

C. 2.793

D. 69.825

**Answer: A**

## Solution:

The mass defect of $_2^4\mathrm{He}$ is 0.03 u. Given the mass number is 4, the binding energy is calculated using the formula:

Binding energy $= 0.03 \times 931 = 27.93\,\mathrm{MeV}$

The binding energy per nucleon is then determined by dividing the total binding energy by the number of nucleons:

Per nucleon binding energy $= \frac{27.93}{4} = 6.9825\,\mathrm{MeV}$

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# Question42

**The energy (in eV ) required to excite an electron from $n = 2$ to $n = 4$ state in hydrogen atom is**

**KCET 2017**

**Options:**

A. -0.85

B. +425

C. -3.4

D. +2.55

**Answer: D**

## Solution:

To determine the energy required to excite an electron from the $n = 2$ to the $n = 4$ state in a hydrogen atom, we use the formula for the energy of an electron at a specific energy level $n$:

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

We need to calculate the energy difference between the two states:

$E = E_2 - E_4$

Substituting the values:

$E_2 = \frac{13.6}{2^2} = \frac{13.6}{4}$

$E_4 = \frac{13.6}{4^2} = \frac{13.6}{16}$

Thus, the energy required, $E$, is:

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

Breaking it down further, we get:

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

$E = \frac{40.8}{16} = +2.55\,\text{eV}$

Thus, the energy required to excite the electron is $+2.55\,\text{eV}$.

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# Question43

**In a nuclear reactor, the function of the moderator is to decreases**

**KCET 2017**

**Options:**

A. number of neutrons

B. speed of neutrons

C. escape of neutrons

D. temperature of the reactor

**Answer: B**

# Solution:

In a nuclear reactor, the moderator's main function is to slow down the fast neutrons produced by fission. Here's a breakdown of the reasoning:

**Purpose of Moderators:**

When fission occurs, it releases fast neutrons.

These fast neutrons are less effective at causing further fission in fuel like uranium-235.

**Action of the Moderator:**

The moderator slows down these neutrons through collisions.

This reduction in their speed brings them to thermal energies (slow neutrons), making them far more likely to induce further fission.

**Clarifying Incorrect Options:**

**Option A (number of neutrons):** The moderator does not reduce the number of neutrons; rather, it improves the efficiency of the chain reaction by slowing them down.

**Option C (escape of neutrons):** The moderator is not designed to prevent neutrons from escaping the reactor core.

**Option D (temperature of the reactor):** Moderators do not directly control the reactor's temperature.

Thus, the correct answer is:

**Option B: speed of neutrons**

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# Question44

## The scientist who is credited with the discovery of 'nucleus' in an atom is

## KCET 2017

## Options:

A. Rutherford

B. Niels Bohr

C. Balmer

D. J.J Thomson

**Answer: A**

# Solution:

The correct answer is Option A: Rutherford.

Here's a brief explanation:

In 1911, Ernest Rutherford conducted his landmark gold foil experiment.

His experiment demonstrated that an atom has a small, dense, positively charged center, which he called the nucleus.

This led to the development of the nuclear model of the atom.

Niels Bohr later built upon Rutherford's work with his own model of atomic structure, while J.J. Thomson is best known for discovering the electron, and Balmer is known for his work on spectral lines.

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