

# Atoms and Nuclei

## Question1

**Bose-Einstein statistics is applicable to particles with**

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**Options:**

A.

even integral spin particles only

B.

integral spin particles

C.

half odd integral spin particles

D.

odd integral spin particles only

**Answer: B**

**Solution:**

Bose-Einstein statistics describes the behaviour of a system of identical, indistinguishable particles with integer spin, known as bosons.

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## Question2

**The ratio of the kinetic energies of the electrons in the third and fourth excited states of hydrogen atom is**



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Options:

A.

4 : 3

B.

16 : 9

C.

25 : 16

D.

5 : 4

**Answer: C**

**Solution:**

The kinetic energy (KE) of an electron in a hydrogen atom depends on the energy level ( $n$ ) it is in.

Here is the formula for kinetic energy at level  $n$ :

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

**Step 1: Identify the energy levels**

The "third excited state" means  $n = 4$ , and the "fourth excited state" means  $n = 5$ .

**Step 2: Calculate the kinetic energy for  $n = 4$**

$$KE_3 = \frac{13.6}{4^2} = \frac{13.6}{16} \text{ eV}$$

**Step 3: Calculate the kinetic energy for  $n = 5$**

$$KE_4 = \frac{13.6}{5^2} = \frac{13.6}{25} \text{ eV}$$

**Step 4: Find the ratio of kinetic energies**

$$\frac{KE_3}{KE_4} = \frac{\frac{13.6}{16}}{\frac{13.6}{25}} = \frac{25}{16}$$

So, the ratio of kinetic energies is 25 : 16.

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## Question3

In  $\beta^-$  decay, a neutron transforms into a proton within the nucleus according to the equation :



In this equation the particle represented by '  $x$  ' is

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**Options:**

A.

Neutrino

B.

Anti neutrino

C.

Positron

D.

Meson

**Answer: B**

**Solution:**

In  $\beta^-$ -decay, a neutron transforms into a proton, an electron (which is the  $\beta^-$  particle) and an antineutrino ( $\bar{\nu}$ )

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## Question4

Two radioactive substances  $A$  and  $B$  have same number of initial nuclei. If the half lives of  $A$  and  $B$  are 1.5 days and 4.5 days respectively, then the ratio of the number of nuclei remaining in  $A$  and  $B$  after 9 days is



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## Options:

A.

1 : 16

B.

1 : 1

C.

1 : 4

D.

1 : 8

**Answer: A**

## Solution:

### Step 1: Formula for Remaining Nuclei

We use the formula  $N = N_0 \left(\frac{1}{2}\right)^n$ , where:

- $N$  = number of nuclei left
- $N_0$  = starting number of nuclei
- $n$  = number of half-lives passed

### Step 2: Setting Up the Ratio

The question asks for the ratio of nuclei left in  $A$  and  $B$ , so:  $\frac{N_A}{N_B} = \frac{\left(\frac{1}{2}\right)^{n_A}}{\left(\frac{1}{2}\right)^{n_B}}$

### Step 3: Simplifying the Ratio

This simplifies to:  $\frac{N_A}{N_B} = \left(\frac{1}{2}\right)^{n_A - n_B}$

### Step 4: Finding Number of Half-lives for Each Substance

The number of half-lives  $n$  is found by dividing total time by half-life:

- For  $A$ :  $n_A = \frac{9}{1.5} = 6$
- For  $B$ :  $n_B = \frac{9}{4.5} = 2$

### Step 5: Plugging In the Values

$$\frac{N_A}{N_B} = \left(\frac{1}{2}\right)^{6-2} = \left(\frac{1}{2}\right)^4$$



• **Step 6: Final Answer**

$\left(\frac{1}{2}\right)^4 = \frac{1}{16}$  So, the ratio of the remaining nuclei in  $A$  and  $B$  after 9 days is  $\frac{1}{16}$ .

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## Question 5

If the difference in the frequencies of the first and second lines of Lyman series of hydrogen atom is  $f$ , then the difference in frequencies of the first and second lines of Balmer series of hydrogen atom is

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**Options:**

A.

$$\frac{3f}{4}$$

B.

$$f$$

C.

$$\frac{7f}{20}$$

D.

$$\frac{9f}{16}$$

**Answer: C**

**Solution:**

The frequency for hydrogen spectral lines is found using:

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

**Lyman Series** (moving to  $n_1 = 1$ ):

**First line:** Electron goes from  $n_2 = 2$  to  $n_1 = 1$



$$f_1^{(L)} = RC \left(1 - \frac{1}{4}\right) = RC \frac{3}{4}$$

**Second line:** Electron goes from  $n_2 = 3$  to  $n_1 = 1$

$$f_2^{(L)} = RC \left(1 - \frac{1}{9}\right) = RC \frac{8}{9}$$

**Difference between the two Lyman frequencies:**

$$\begin{aligned} f &= f_2^{(L)} - f_1^{(L)} \\ &= RC \left(\frac{8}{9} - \frac{3}{4}\right) \\ &= RC \left(\frac{32 - 27}{36}\right) = RC \frac{5}{36} \end{aligned}$$

**Balmer Series** (moving to  $n_1 = 2$ ):

**First line:** Electron goes from  $n_2 = 3$  to  $n_1 = 2$

$$f_1^{(B)} = RC \left(\frac{1}{4} - \frac{1}{9}\right) = RC \frac{5}{36}$$

**Second line:** Electron goes from  $n_2 = 4$  to  $n_1 = 2$

$$f_2^{(B)} = RC \left(\frac{1}{4} - \frac{1}{16}\right) = RC \frac{3}{16}$$

**Difference between the two Balmer frequencies:**

$$\begin{aligned} f' &= f_2^{(B)} - f_1^{(B)} \\ &= RC \left(\frac{3}{16} - \frac{5}{36}\right) \\ &= RC \left(\frac{27 - 20}{144}\right) \\ &= RC \left(\frac{7}{144}\right) \end{aligned}$$

**Relationship between differences:**

$$\begin{aligned} \frac{f'}{f} &= \frac{\left(\frac{7}{144}\right)}{\left(\frac{5}{36}\right)} = \frac{7}{144} \times \frac{36}{5} = \frac{252}{720} = \frac{7}{20} \\ f' &= \frac{7}{20} f \end{aligned}$$

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## Question 6

The average energy of a neutron produced in the fission of  ${}_{92}^{235}\text{U}$  is

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• **Options:**

A.

$$160 \times 10^{-13} \text{ J}$$

B.

$$320 \times 10^{-15} \text{ J}$$

C.

$$320 \times 10^{-13} \text{ J}$$

D.

$$160 \times 10^{-15} \text{ J}$$

**Answer: B**

**Solution:**

Average energy of a neutron emitted in  ${}_{92}^{235}\text{U}$  fission is 2 MeV

$$\begin{aligned} \therefore \epsilon &= 2\text{MeV} \\ &= 2 \times 10^6 \times 1.6 \times 10^{-19} \text{ J} \\ &= 3.2 \times 10^{-13} \text{ J} = 320 \times 10^{-15} \text{ J} \end{aligned}$$

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## Question7

**If 96.875% of a radioactive substance decays in 10 days, then the half life of the substance is (in days)**

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**Options:**

A.

10

B.

5



C.

4

D.

2

**Answer: D**

### **Solution:**

We use this formula to find how much of the substance is left after a certain time:

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

It is said that 96.875% of the substance has decayed after 10 days.

This means that only 3.125% of the substance is left, because  $100\% - 96.875\% = 3.125\%$ .

We can also write 3.125% as a fraction:  $3.125\% = \frac{1}{32}$ .

So,  $\frac{N}{N_0} = \frac{1}{32}$ . We set up the formula:

$$\left(\frac{1}{2}\right)^{t/T_{1/2}} = \frac{1}{32}$$

Now,  $\frac{1}{32} = \left(\frac{1}{2}\right)^5$ , so  $t/T_{1/2} = 5$ .

So,  $t = 5 \times T_{1/2}$ .

We know  $t = 10$  days. So,

$$T_{1/2} = \frac{10}{5} = 2 \text{ days}$$

The half-life of the substance is 2 days.

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### **Question8**

**In hydrogen atom, the frequency of the photon emitted when an electron jumps from second orbit to first orbit is  $f$ . The frequency of the photon emitted when an electron jumps from third excited state to first excited state is**

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**Options:**

A.  $\frac{f}{2}$

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



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

D.  $f$

**Answer: B**

### Solution:

In a hydrogen atom, the energy levels are given by

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

where,  $n$  = principal quantum number Energy difference between two energy levels,

$$\Delta E = E_i - E_f$$

$$h\nu = E_i - E_f$$

where,  $E_i$  and  $E_f$  are the initial and final energy levels.

For the transition from second orbit to first orbit.

$$\Delta E = E_2 - E_1$$

$$h\nu = \frac{-13.6}{(2)^2} - \left( -\frac{13.6}{(1)^2} \right)$$

$$h\nu = -13.6 \left[ \frac{1}{1} - \frac{1}{4} \right] = -13.6 \times \frac{3}{4} \text{eV}$$

$$\nu = \frac{-10.2}{h} \text{eV}$$

Given,  $\nu = f$ , then

$$f = \frac{-10.2}{h} \text{eV}$$

For the transition third excited states ( $n = 4$ ) to first excited state ( $n = 2$ ).

$$\Delta E' = E_4 - E_2$$

$$hf' = \frac{-13.6}{4^2} + \frac{13.6}{4} = -13.6 \left[ \frac{1}{4} - \frac{1}{16} \right]$$

$$f' = \frac{-2.55}{h} \text{eV}$$

On comparing Eq. (i) and Eq. (ii), we get

$$f' = \frac{f}{4}$$

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## Question9

If the ratio of the radii of nuclei  ${}_{52}X^A$  and  ${}_{13}Al^{27}$  is 5 : 3, then the number of neutrons in the nucleus  $X$  is

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Options:

A. 52

B. 63

C. 27

D. 73

**Answer: D**

**Solution:**

Given,

$$\frac{R_1}{R_2} = \frac{5}{3} \text{ and } A_2 = 27, A_1 = A$$

The radius  $R$  of a nucleus is related to its mass number  $A$  by the formula

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

Using Eq. (i),

$$\frac{R_1}{R_2} = \left( \frac{A_1}{A_2} \right)^{\frac{1}{3}}$$

$$\frac{5}{3} = \left( \frac{A}{27} \right)^{\frac{1}{3}} \Rightarrow \frac{5}{3} = \frac{(A)^{\frac{1}{3}}}{3}$$

$$A = 5^3$$

$$A = 125$$

So, the mass number  $A$  of nucleus  ${}_{52}X^{125}$  is 125 .

Given that the nucleus  ${}_{52}X^{125}$  has 52 protons, the number of neutrons  $N$  in the nucleus is

$$N = A - \text{number of protons}$$

$$N = 125 - 52$$

$$N = 73$$



## Question10

Half-life periods of two nuclei  $A$  and  $B$  are  $T$  and  $2T$  respectively. Initially  $A$  and  $B$  have same number of nuclei. After a time of  $4T$ , the ratio of the remaining number of nuclei of  $A$  and  $B$  is

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Options:

A. 1 : 16

B. 1 : 4

C. 1 : 1

D. 1 : 2

**Answer: B**

**Solution:**

Given,

Half-life of  $A$ ,  $T_A = T$

Half-life of  $B$ ,  $T_B = 2T$

Initial number of nuclei is same for  $A$  and  $B$ , it means  $N_A = N_B = N_0$ .

The number of remaining nuclei  $N(t)$  after time  $t$  is given by the exponential decay formula,

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

where,  $N_0$  = Initial number of nuclei,  $T_{1/2}$  = Half-life After a time  $t = 4T$

$$\frac{N_A(4T)}{N_B(4T)} = \frac{N_0 \left(\frac{1}{2}\right)^{\frac{4T}{T}}}{N_0 \left(\frac{1}{2}\right)^{\frac{4T}{2T}}} = \frac{\left(\frac{1}{2}\right)^4}{\left(\frac{1}{2}\right)^2} = \left(\frac{1}{2}\right)^2 = \frac{1}{4}$$

Therefore, the ratio of the remaining number of nuclei of  $A$  and  $B$  is 1 : 4.

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## Question11

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

## TG EAPCET 2024 (Online) 10th May Evening Shift

Options:

- A. -6.8 eV
- B. -3.4 eV
- C. -13.6 eV
- D. -272 eV

**Answer: A**

**Solution:**

The ground state energy of a hydrogen atom is given as  $-13.6$  eV. The total energy is equivalent to the kinetic energy, while the potential energy is twice the kinetic energy.

Therefore, the potential energy of the hydrogen atom in its ground state is:

$$PE = 2 \times (-13.6 \text{ eV}) = -27.2 \text{ eV}$$

For the first excited state of the hydrogen atom, the energy can be calculated using the formula:

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

When  $n = 2$ :

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

Thus, the potential energy, when  $n = 2$ , is:

$$(PE)_{n=2} = 2 \times (-3.4 \text{ eV}) = -6.8 \text{ eV}$$

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## Question12

After the decay of a single  $\beta$ -particle, the parent and daughter nuclei are

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Options:

- A. isotopes



- B. isobars
- C. isomers
- D. isotones

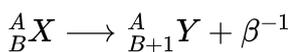
**Answer: B**

### **Solution:**

During a beta ( $\beta$ ) decay process, the transformation of the parent nucleus can be represented as follows:

Let the parent nucleus be  ${}^A_Z X$ .

After a beta ( $\beta$ ) decay, the transformation is:



Here,  ${}^A_{Z+1} Y$  represents the daughter nucleus.

In beta decay, the atomic number (denoted by  $Z$ ) increases by 1, but the mass number (denoted by  $A$ ) remains unchanged. This means that the parent and daughter nuclei have the same mass number but different atomic numbers. Such nuclei are known as isobars.

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## **Question13**

**${}_{92}\text{U}^{238}$  nucleus decays to a  ${}_{82}\text{Pb}^{214}$  nucleus. The number of  $\alpha$  and  $\beta^-$  particles emitted are**

**TG EAPCET 2024 (Online) 10th May Evening Shift**

**Options:**

- A. 6 and 2
- B. 3 and 3
- C. 2 and 6
- D. 3 and 4

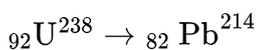
**Answer: A**

### **Solution:**



The decay of a  ${}_{92}\text{U}^{238}$  nucleus into a  ${}_{82}\text{Pb}^{214}$  nucleus involves emitting alpha and beta particles. Let's break down this process:

### Decay Reaction:



### Mass Number Change:

Initial mass number: 238

Final mass number: 214

Difference in mass number:  $238 - 214 = 24$

Each alpha particle reduces the mass number by 4 (since an alpha particle is  $\text{He}_2^4$ ). Therefore, the number of alpha particles is:

$$\frac{24}{4} = 6$$

### Atomic Number Change:

Initial atomic number: 92

Final atomic number: 82

Difference in atomic number:  $92 - 82 = 10$

### Alpha Particle Contribution:

Every alpha particle emission decreases the atomic number by 2.

With 6 alpha particles emitted, the atomic number reduces by:

$$6 \times 2 = 12$$

This brings the atomic number to  $92 - 12 = 80$ .

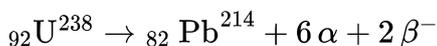
### Beta Particle Emission:

To adjust back from atomic number 80 to 82, beta particles are necessary.

Each beta particle ( $\beta^-$ ) increases the atomic number by 1.

Therefore, 2 beta particles are emitted to increase the atomic number from 80 to 82.

In conclusion, in the decay process of  ${}_{92}\text{U}^{238}$  to  ${}_{82}\text{Pb}^{214}$ , 6 alpha particles and 2 beta particles are emitted:



Thus, the numbers of alpha and beta particles emitted are 6 and 2, respectively.

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## Question 14

The ratio of the centripetal accelerations of the electron in two successive orbits of hydrogen is 81 : 16. Due to <sup>3</sup> transition between these two states, the angular momentum of the electron changes by ( $h = \text{Planck's constant}$ )

TG EAPCET 2024 (Online) 10th May Morning Shift

Options:

A.  $\frac{h}{3\pi}$

B.  $\frac{3h}{\pi}$

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

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

**Answer: C**

**Solution:**

According to Bohr's postulate, the angular momentum is,

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

We have been asked for change in angular momentum in two consecutive orbit.

Let  $n_1 = n$  and  $n_2 = n + 1$

$$L_1 = \frac{nh}{2\pi} \text{ and } L_2 = \frac{(n+1)h}{2\pi}$$

$$\Delta L = L_2 - L_1$$

$$= \frac{(n+1)h}{2\pi} - \frac{nh}{2\pi}$$

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

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## Question 15

The operation of a nuclear reactor is said to be critical when the value of neutron multiplication factor  $K$  is



## TG EAPCET 2024 (Online) 10th May Morning Shift

Options:

A.

$$K = 0$$

B.

$$K = 1$$

C.

$$K > 1$$

D.

0

**Answer: C**

**Solution:**

$K$ , known as multiplication factor is the ratio of number of neutron present at beginning generation to the number present at beginning of next generation. It is a measure of the growth rate of the neutrons in the reactor.

For  $K = 1$ , the operation of reactor is said to be critical.

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## Question16

An  $\alpha$ -particle of energy  $E$  is liberated during the decay of a nucleus of mass number 236. The total energy released in this process is

## TG EAPCET 2024 (Online) 10th May Morning Shift

Options:

A.  $58 E$

B.  $59E$

C.  $\frac{58E}{59}$



D.  $\frac{59E}{58}$

**Answer: D**

**Solution:**

Disintegration energy is given by

$$Q = K_{\alpha} \left[ 1 + \frac{M_{\alpha}}{M_D} \right]$$

where,  $K_{\alpha}$  = energ of  $\alpha$ -particle =  $E$

$$M_{\alpha} = 4$$

$$M_D = 236 - 4 = 232$$

$$Q = E \left[ 1 + \frac{4}{232} \right] = E \left[ \frac{236}{232} \right]$$

$$Q = \frac{59}{58} E$$

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## Question17

**The related effort to derive the properties of a bigger, more complex system from the properties and interactions of its constituent simpler parts is**

**TG EAPCET 2024 (Online) 9th May Evening Shift**

**Options:**

A. unification

B. reductionism

C. classical approach

D. quantum approach

**Answer: B**

**Solution:**

Reductionism and unification are two main approaches in physics that aim to explain physical phenomena.

Reductionism : It breaks down a complex system into its simplest parts, so that laws of physics can be applied on these systems.



Unification : It explains physical phenomena using new concepts and laws, or to correlate and unite universal laws and basic phenomena of nature.

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## Question18

The ratio of the wavelengths of radiation emitted when an electron in the hydrogen atom jumps from 4th orbit to 2 nd orbit and from 3rd orbit to 2 nd orbit is

**TG EAPCET 2024 (Online) 9th May Evening Shift**

Options:

A. 27 : 25

B. 20 : 25

C. 20 : 27

D. 25 : 27

**Answer: C**

**Solution:**

From Rydberg's formula, we have

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

According to question;

$$\frac{1}{\lambda_1} = v_1 = R \left( \frac{1}{2^2} - \frac{1}{4^2} \right) = R \left( \frac{1}{4} - \frac{1}{16} \right) = \frac{3R}{16}$$

$$\text{and } v_2 = \frac{1}{\lambda_2} = R \left( \frac{1}{2^2} - \frac{1}{3^2} \right) = R \left( \frac{1}{4} - \frac{1}{9} \right)$$

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

$$\therefore \frac{\lambda_1}{\lambda_2} = \frac{16}{3R} \times \frac{5R}{36} = \frac{20}{27}$$

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## Question19

The half lives of two radioactive material  $A$  and  $B$  are respectively  $T$  and  $2T$ . If the ratio of the initial masses of the materials  $A$  and  $B$  is  $8 : 1$ . Then, the time after which the ratio of the masses of the materials  $A$  and  $B$  becomes  $4 : 1$  is

**TG EAPCET 2024 (Online) 9th May Evening Shift**

**Options:**

A.  $2T$

B.  $T$

C.  $4T$

D.  $8T$

**Answer: A**

**Solution:**

Given, half-life of  $A, T_{t/2} = T$

half-life of  $B, T_{\frac{1}{2}} = 2T$

$$\therefore \lambda_A = \frac{0.693}{T} \text{ and } \lambda_B = \frac{0.693}{2T}$$

From law of radioactive decay,

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

$$\text{According to question; } \frac{N_A}{N_B} = \frac{N_{0A} e^{-\lambda_A t}}{N_{0B} e^{-\lambda_B t}}$$

$$\text{Given, } \frac{N_A}{N_B} = \frac{4}{1} \text{ and } \frac{N_{0A}}{N_{0B}} = \frac{8}{1}$$

$$\therefore \frac{4}{1} = \frac{8}{1} \frac{e^{-\lambda_A t}}{e^{-\lambda_B t}}$$

$$\Rightarrow \frac{1}{2} = \frac{e^{-\lambda_A t}}{e^{-\lambda_B t}} = e^{-\ln 2} \left( \frac{t}{2} \right)$$

$$\Rightarrow -\ln 2 = -\frac{\ln 2}{T} \left( \frac{t}{2} \right) \Rightarrow t = 2T$$



## Question20

The energy released by the fission of one uranium nucleus is 200 MeV . The number of fissions per second required to produce 128 W power is

TG EAPCET 2024 (Online) 9th May Evening Shift

Options:

A.  $6 \times 10^{12}$

B.  $8 \times 10^{12}$

C.  $2 \times 10^{12}$

D.  $4 \times 10^{12}$ .

**Answer: D**

**Solution:**

Given, energy released by uranium nucleus.

$$E = 200\text{MeV}$$

$$\text{Power} = 128 \text{ W}$$

$$\begin{aligned}\therefore E = 200\text{MeV} &= 200 \times 10^6 \times 1.6 \times 10^{-19} \text{ J} \\ &= 3.2 \times 10^{-11} \text{ J}\end{aligned}$$

$$\text{We know that power} = \frac{\text{Energy}}{\text{Time}}$$

$\therefore$  Number of fission required per second

$$= \frac{128 \text{ J}}{3.2 \times 10^{-11} \text{ J}}$$

$$n = 4 \times 10^{12}$$

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## Question21

At room temperature, gaseous hydrogen is bombarded with a beam of electrons of 13.6 eV energy. The series to which the emitted spectral line belongs to

TG EAPCET 2024 (Online) 9th May Morning Shift

Options:



- A. Lyman series
- B. Balmer series
- C. Paschen series
- D. Ptund series

**Answer: A**

## Solution:

The energy level of hydrogen is quantized, and the electrons in a hydrogen atom transition between these quantized energy levels. Each series of spectral lines corresponds to transitions that end at a specific level.

The energy levels ( $n$ ) for a hydrogen atom are given by the formula:

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

When a hydrogen atom is bombarded with 13.6 eV electrons, the electrons are excited from the ground state ( $n = 1$ ) to higher energy levels. When these electrons return to lower energy levels, they emit photons corresponding to specific spectral series:

**Lyman Series:** Transitions to  $n = 1$  (ultraviolet region).

**Balmer Series:** Transitions to  $n = 2$  (visible region).

**Paschen Series:** Transitions to  $n = 3$  (infrared region).

**Brackett Series:** Transitions to  $n = 4$  (infrared region).

**Pfund Series:** Transitions to  $n = 5$  (infrared region).

Since the excited electrons started from the ground state with an energy of 13.6 eV, they returned to the ground state by releasing energy, corresponding to the Lyman series.

Thus, the emitted spectral line belongs to the **Lyman series**. Therefore, the correct option is:

**Option A: Lyman series.**

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## Question22

**The half-life of a radioactive substance is 12 min . The time gap between 28% decay and 82% decay of the radioactive substance is**

**TG EAPCET 2024 (Online) 9th May Morning Shift**

**Options:**

A. 6 min

B. 18 min

C. 12 min

D. 24 min

**Answer: D**

### Solution:

As we know,

$$n = \frac{\log(\text{remaining fraction})}{\log(0.5)}$$

For 28% decay ( 72% remaining)

$$n_{28} = \frac{\log(0.72)}{\log(0.5)} \approx 0.473$$

For 82% decay ( 18% remaining)

$$n_{82} = \frac{\log(0.18)}{\log(0.5)} \approx 2.473$$

Time gap between 28% and 82% decay is the difference in the number of half lives,

$$\begin{aligned} \text{Time gap} &= (n_{82} - n_{28}) \times 12 \text{ min} \\ &= (2.473 - 0.473) \times 12 \\ &= 2 \times 12 = 24 \text{ min} \end{aligned}$$

Therefore, time gap between 28% decay and 82% of radioactive substance is approximately 24 min .

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## Question23

**An element consists of a mixture of three isotopes  $A$ ,  $B$  and  $C$  of masses  $m_1$ ,  $m_2$  and  $m_3$ , respectively. If the relative abundances of the three isotopes  $A$ ,  $B$  and  $C$  are in the ratio 2 : 3 : 5, the average mass of the element is**

**TG EAPCET 2024 (Online) 9th May Morning Shift**

**Options:**

A.  $0.2m_1 + 0.3m_2 + 0.5m_3$

B.  $2m_1 + 3m_2 + 5m_3$

C.  $0.4m_1 + 0.6m_2 + m_3$



D.  $4m_1 + 6m_2 + 10m_3$

**Answer: A**

### Solution:

If  $m_1, m_2$  and  $m_3$  are masses of isotopes  $A, B$  and  $C$  respectively, and their relative abundances are in the ratio 2:3:5.

The average mass ( $M_{\text{avg}}$ ) is

$$M_{\text{avg}} = \frac{2m_1 + 3m_2 + 5m_3}{2 + 3 + 5}$$

$$M_{\text{avg}} = \frac{2m_1}{10} + \frac{3m_2}{10} + \frac{5m_3}{10}$$

$$M_{\text{avg}} = 0.2m_1 + 0.3m_2 + 0.5m_3$$

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## Question24

If  $F_1$  and  $F_2$  are the relative strengths of the gravitational and weak nuclear forces respectively, then  $F_2/F_1$  is nearly

**TS EAMCET 2023 (Online) 12th May Evening Shift**

**Options:**

A. 100

B.  $10^{39}$

C.  $10^{13}$

D.  $10^{26}$

**Answer: D**

### Solution:

When comparing the relative strengths of the gravitational force ( $F_1$ ) and the weak nuclear force ( $F_2$ ), the ratio  $F_2/F_1$  is approximately  $10^{26}$ .

**Explanation**



• **Gravitational Force ( $F_1$ ):** This is the weakest of the four fundamental forces in nature. It acts between bodies with mass and is responsible for the attraction between them.

**Weak Nuclear Force ( $F_2$ ):** This force plays a crucial role in nuclear processes such as beta decay, where protons can transform into neutrons and vice versa. Despite its name, it is significantly stronger than gravity.

The comparative strength of the weak nuclear force to the gravitational force is around  $10^{26}$ . This reflects just how much weaker gravity is compared to the weak nuclear force, emphasizing the vast difference in their magnitudes.

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## Question25

**The ratio of the energies of the electron in the hydrogen atom in the first and second excited states is**

**TS EAMCET 2023 (Online) 12th May Evening Shift**

**Options:**

A. 9 : 4

B. 4 : 1

C. 8 : 1

D. 1 : 8

**Answer: A**

**Solution:**

Given,

Hydrogen atom  $Z = 1$

1st excited state  $n = 2$

2nd excited state  $n = 3$

Energy associated with the  $n$ th orbit of an atom with  $z$  atomic number

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

Energy for 1st excited state

$$E_1 = \frac{-13.6}{4} \text{eV}$$

Energy for 2nd excited state

$$E_2 = \frac{-13.6}{9} \text{eV}$$

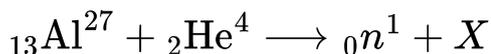
The ratio of  $E_2/E_1$  is  $9/4$

Hence, the ratio  $E_2 : E_1$  is  $9 : 4$

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## Question26

In the following nuclear reaction  $X$  is



**TS EAMCET 2023 (Online) 12th May Evening Shift**

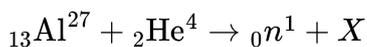
**Options:**



**Answer: C**

**Solution:**

In the given nuclear reaction:



We are asked to identify the element  $X$ .

**Conservation of Mass Number**

According to the law of conservation of mass number, the total number of protons and neutrons (mass number) must be equal on both sides of the reaction:

$$27 + 4 = 1 + a$$

Solving for  $a$ :

$$a = 30$$

This indicates that the mass number of element  $X$  is 30.

**Conservation of Atomic Number**



Similarly, the atomic number, which is the number of protons, must also be conserved:

$$13 + 2 = 0 + b$$

Solving for  $b$ :

$$b = 15$$

This tells us that the atomic number of element  $X$  is 15.

Therefore, the element  $X$  with atomic number 15 and mass number 30 is:



Thus, the element  $X$  is phosphorous-30 ( ${}_{15}\text{P}^{30}$ ).

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## Question27

**Nuclear fission and fusion can be explained on the basis of**

**TS EAMCET 2023 (Online) 12th May Evening Shift**

**Options:**

- A. Einstein's theory of relativity
- B. Einstein specific heat equation
- C. Einstein mass-energy equation
- D. Einstein photoelectric equation

**Answer: C**

**Solution:**

Nuclear fission and fusion are explained using Einstein's mass-energy equation,  $E = \Delta mc^2$ .

**Nuclear Fission:**

This is the process where a heavy nucleus splits into two or more lighter nuclei.

**Nuclear Fusion:**

This occurs when two or more light nuclei combine to form a heavier nucleus.

In both processes, the mass difference between the reactants and the products ( $\Delta m$ ) can be converted into energy, as described by the equation. Here,  $\Delta m$  represents the difference in mass between the reactants and the products. The energy produced is directly proportional to this mass difference, multiplied by the square of the speed of light ( $c^2$ ).



## Question28

If  $F_1$ ,  $F_2$  and  $F_3$  are the relative strengths of the gravitational, the weak nuclear and the electromagnetic forces respectively, then

TS EAMCET 2023 (Online) 12th May Morning Shift

Options:

A.  $F_1 > F_2 > F_3$

B.  $F_1 < F_2 < F_3$

C.  $F_1 = F_2 = F_3$

D.  $F_2 > F_3 > F_1$

**Answer: B**

**Solution:**

To understand the relative strengths of different fundamental forces, we need to compare their orders of magnitude. Here are the forces in question:

$F_1$ : Gravitational Force

$F_2$ : Weak Nuclear Force

$F_3$ : Electromagnetic Force

The ratios depicting the relative strengths of these forces are as follows:

Gravitational Force: 1

Weak Nuclear Force:  $10^{26}$

Electromagnetic Force:  $10^{36}$

This means that the gravitational force is the weakest, while the electromagnetic force is the strongest among these three. Thus, the forces can be ordered by strength as:

$$F_1 < F_2 < F_3$$

Here,  $F_1$  represents the gravitational force,  $F_2$  the weak nuclear force, and  $F_3$  the electromagnetic force.

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## Question29

If an electron is moving in the 4th orbit of the hydrogen atom, then the angular momentum of the electron in SI unit is

TS EAMCET 2023 (Online) 12th May Morning Shift

Options:

A.  $\frac{h}{\pi}$

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

C.  $\frac{4h}{\pi}$

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

**Answer: B**

**Solution:**

To solve this, we use the Bohr quantization rule for angular momentum:

In the Bohr model, the angular momentum  $L$  of an electron in a hydrogen atom is given by

$$L = n\hbar,$$

where  $n$  is the principal quantum number and

$\hbar = \frac{h}{2\pi}$  is the reduced Planck's constant.

For the 4th orbit, we have  $n = 4$ . Plugging this into the formula gives:

$$L = 4\hbar = 4 \left( \frac{h}{2\pi} \right) = \frac{4h}{2\pi} = \frac{2h}{\pi}.$$

Thus, the angular momentum in the 4th orbit is  $\frac{2h}{\pi}$ .

So, the correct answer is Option B.

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## Question30

The energy equivalent to a mass of 1 kg is

TS EAMCET 2023 (Online) 12th May Morning Shift

Options:

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

- B.  $9 \times 10^9$  J
- C.  $9 \times 10^{16}$  J
- D.  $9 \times 10^6$  J

**Answer: C**

### **Solution:**

To find the energy equivalent of a 1 kg mass, we use Einstein's famous equation:

$$E = mc^2$$

Here's how to calculate it:

Given:

Mass,  $m = 1$  kg

Speed of light,  $c \approx 3 \times 10^8$  m/s

Substitute the values into the equation:

$$E = 1 \times (3 \times 10^8)^2$$

Calculating the square of  $3 \times 10^8$ :

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

Thus, the energy equivalent is:

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

Therefore, the correct answer is Option C:  $9 \times 10^{16}$  J.

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### **Question31**

**If  $S$  is the surface area of a nucleus of mass number  $A$ , then**

**TS EAMCET 2023 (Online) 12th May Morning Shift**

**Options:**

A.  $S \propto A$

B.  $S \propto A^{1/3}$

C.  $S \propto A^2$



$$D. S \propto A^{2/3}$$

**Answer: D**

### **Solution:**

The surface area of a nucleus with mass number  $A$  can be determined as follows:

**Radius Relationship:** The radius  $R$  of a nucleus is proportional to  $A^{1/3}$ , given by the formula:

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

Here,  $R_0$  is a constant.

**Surface Area Calculation:** Since the nucleus is approximately spherical, its surface area  $S$  is calculated using the formula for the surface area of a sphere:

$$S = 4\pi R^2$$

Substituting the expression for  $R$ , we get:

$$S = 4\pi (R_0 A^{1/3})^2$$

**Proportional Relation:** Simplifying this expression, we find:

$$S \propto A^{2/3}$$

Thus, the surface area  $S$  is proportional to  $A^{2/3}$ .

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