

# Atomic and Nuclear Physics

# SET Self Evaluation Test - 26

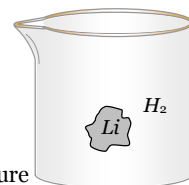
- In Bohr model of hydrogen atom, the force on the electron depends on the principal quantum number as
  - $F \propto 1/n^3$
  - $F \propto 1/n^4$
  - $F \propto 1/n^5$
  - Does not depend on  $n$
- A nucleus  ${}_Z X^A$  emits  $9\alpha$ -particles and  $5p$  particle. The ratio of total protons and neutrons in the final nucleus is
  - $\frac{Z-13}{(A-Z-23)}$
  - $\frac{(Z-18)}{(A-36)}$
  - $\frac{(Z-13)}{(A-36)}$
  - $\frac{(Z-13)}{(A-Z-13)}$
- If  $t_{1/2}$  is the half life of a substance then  $t_{3/4}$  is the time in which substance
  - Decays  $\frac{3}{4}$  th
  - Remains  $\frac{3}{4}$  th
  - Decays  $\frac{1}{2}$
  - Remains  $\frac{1}{2}$
- The energy level diagram for an hydrogen like atom is shown in the figure. The radius of its first Bohr orbit is
 

0 eV		$n = \infty$
- 6.04 eV		$n = 3$
- 13.6 eV		$n = 2$
- 54.4 eV		$n = 1$

  - 0.265 Å
  - 0.53 Å
  - 0.132 Å
  - None of these
- How much work must be done to pull apart the electron and the proton that make up the Hydrogen atom, if the atom is initially in the state with  $n = 2$ 
  - $13.6 \times 1.6 \times 10^{-19} J$
  - $3.4 \times 1.6 \times 10^{-19} J$
  - $1.51 \times 1.6 \times 10^{-19} J$
  - 0
- The nuclide  ${}^{131}I$  is radioactive, with a half-life of 8.04 days. At noon on January 1, the activity of a certain sample is 60089. The activity at noon on January 24 will be
  - 75 Bq
  - Less than 75 Bq
  - More than 75 Bq
  - 150 Bq
- $U^{238}$  decays into  $Th^{234}$  by the emission of an  $\alpha$ -particle. There follows a chain of further radioactive decays, either by  $\alpha$ -decay or by  $\beta$ -decay. Eventually a stable nuclide is reached and after that, no further radioactive decay is possible. Which of the following stable nuclides is the end product of the  $U^{238}$  radioactive decay chain
  - $Pb^{206}$
  - $Pb^{207}$
  - $Pb^{208}$
  - $Pb^{209}$
- If the mass of a radioactive sample is doubled, the activity of the sample and the disintegration constant of the sample are respectively
  - Increases, remains the same
  - Decreases, increases
  - Decreases, remains same
  - Increases, decreases
- When a sample of solid lithium is placed in a flask of hydrogen gas then following reaction happened
 
$${}_1^1H + {}_3^7Li \rightarrow {}_2^4He + {}_2^4He$$

This statement is

  - True
  - False
  - May be true at a particular pressure
  - None of these
- Consider an initially pure  $M$  gm sample of  ${}^A X$ , an isotope that has a half life of  $T$  hour, what is its initial decay rate ( $N_A =$  Avogadro No.)
  - $\frac{M N_A}{T}$
  - $\frac{0.693 M N_A}{T}$
  - $\frac{0.693 M N_A}{AT}$
  - $\frac{2.303 M N_A}{AT}$
- At a given instant there are 25% undecayed radioactive nuclei in a sample. After 10 sec the number of undecayed nuclei reduces to 6.25%, the mean life of the nuclei is
  - 14.43 sec
  - 7.21 sec
  - 5 sec
  - 10 sec
- Highly energetic electrons are bombarded on a target of an element containing 30 neutrons. The ratio of radii of



nucleus to that of Helium nucleus is  $14^{1/3}$ . The atomic number of nucleus will be

- (a) 25 (b) 26  
(c) 56 (d) 30

13. The ratio of ionization energy of Bohr's hydrogen atom and Bohr's hydrogen like lithium atom is

- (a) 1 : 1 (b) 1 : 3  
(c) 1 : 9 (d) None of these

14. What is the angular momentum of an electron in Bohr's hydrogen atom whose energy is  $-0.544 \text{ eV}$ .

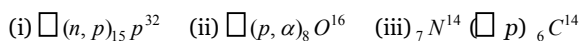
- (a)  $\frac{h}{\pi}$  (b)  $\frac{2h}{\pi}$   
(c)  $\frac{5h}{2\pi}$  (d)  $\frac{7h}{2\pi}$

15. Consider a hypothetical annihilation of a stationary electron with a stationary positron. What is the wavelength of resulting radiation.

- (a)  $\frac{h}{2m_0c}$  (b)  $\frac{h}{m_0c}$   
(c)  $\frac{2h}{m_0c}$  (d)  $\frac{h}{m_0c^2}$

( $h$  = Planck's constant,  $c$  = speed of light,  $m_0$  = rest mass)

16. Nuclear reactions are given as



missing particle or nuclide (in b  $\square$ ) in these reactions are respectively

- (a)  $\text{S}^{32}, \text{F}^{19}, {}_0n^1$  (b)  $\text{F}^{19}, \text{S}^{32}, {}_0n^1$   
(c)  $\text{Be}^9, \text{F}^{19}, {}_0n^1$  (d) None of these

17. In a sample of hydrogen like atoms all of which are in ground state, a photon beam containing photons of various energies is passed. In absorption spectrum, five dark lines, are observed. The number of bright lines in the emission spectrum will be (assume that all transitions takes place).

- (a) 5 (b) 10  
(c) 15 (d) None of these

18. A hydrogen atom emits a photon corresponding to an electron transition from  $n = 5$  to  $n = 1$ . The recoil speed of hydrogen atom is almost (mass of proton  $\approx 1.6 \times 10^{-27} \text{ kg}$ ).

- (a)  $10 \text{ ms}^{-1}$  (b)  $2 \times 10^{-2} \text{ ms}^{-1}$   
(c)  $4 \text{ ms}^{-1}$  (d)  $8 \times 10^2 \text{ ms}^{-1}$

19. Number of nuclei of a radioactive substance at time  $t = 0$  are 1000 and 900 at time  $t = 2 \text{ s}$ . Then number of nuclei at time  $t = 4 \text{ s}$  will be

- (a) 800 (b) 810  
(c) 790 (d) 700

20. The ratio between total acceleration of the electron in singly ionized helium atom and hydrogen atom (both in ground state) is

- (a) 1 (b) 8  
(c) 4 (d) 16

21. If the series limit of Lyman series for Hydrogen atom is equal to the series limit of Balmer series for a hydrogen like atom, then atomic number of this hydrogen like atom will be

- (a) 1 (b) 2  
(c) 3 (d) 4

22. Which sample contains greater number of nuclei :

a  $5.00\text{-}\mu\text{Ci}$  sample of  ${}^{240}\text{Pu}$  (half-life  $6560\text{y}$ ) or a  $4.45\text{-}\mu\text{Ci}$  sample of  ${}^{243}\text{Am}$  (half-life  $7370\text{y}$ )

- (a)  ${}^{240}\text{Pu}$  (b)  ${}^{243}\text{Am}$   
(c) Equal in both (d) None of these

23. The fission of  ${}^{235}\text{U}$  can be triggered by the absorption of a slow neutrons by a nucleus. Similarly a slow proton can also be used. This statement is

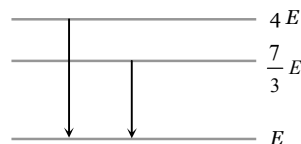
- (a) Correct (b) Wrong  
(c) Information is insufficient (d) None of these

24. The radioactivity of a given sample of whisky due to tritium (half life 12.3 years) was found to be only 3% of that measured in a recently purchased bottle marked "7 years old". The sample must have been prepared about

- (a) 220 years back (b) 300 years back  
(c) 400 years back (d) 70 years back

25. The following diagram indicates the energy levels of a certain atom when the system moves from  $4E$  level to  $E$ . A photon of wavelength  $\lambda_1$  is emitted. The wavelength of photon produced during it's transition from  $\frac{7}{3}E$  level to

$E$  is  $\lambda_2$ . The ratio  $\frac{\lambda_1}{\lambda_2}$  will be

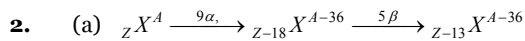


- (a)  $\frac{9}{4}$  (b)  $\frac{4}{9}$   
(c)  $\frac{3}{2}$  (d)  $\frac{7}{3}$

# AS Answers and Solutions

(SET -26)

1. (b)  $F \propto \frac{v^2}{r}$  also  $v \propto \frac{1}{n}$  and  $r \propto n^2 \Rightarrow F \propto \frac{1}{n^4}$



Number of protons = ( $Z = 13$ )

Number of neutrons =  $(A - 36) - (Z - 13) = (A - Z - 23)$

$$\therefore \frac{P}{N} = \frac{(Z-13)}{(A-Z-23)}$$

3. (a) You must remember that  $t_{1/2}$  is time in which substance decays half. Hence in  $t_{3/4}$  time substance decays  $\frac{3}{4}$  th.

4. (a) We know that  $E_n = -13.6 \frac{Z^2}{n^2} eV$  and  $r_n = 0.53 \frac{n^2}{Z} (\text{\AA})$

Here for  $n=1$ ,  $E_1 = -54.4 eV$

$$\text{Therefore } -54.4 = -13.6 \frac{Z^2}{1^2} \Rightarrow Z = 2$$

Hence radius of first Bohr orbit

$$r = \frac{0.53(1)^2}{2} = 0.265 \text{ \AA}$$

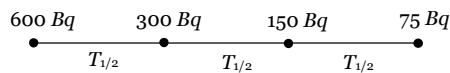
5. (b) The electrostatic P.E. is zero when the electron and proton are far apart from each other. Work done in pulling electron and proton far away from each other

$$W = E_f - E_i = 0 - E_i = -\left(-\frac{13.6}{n^2} eV\right)$$

$$\Rightarrow W = \frac{13.6}{(2)^2} \times 1.6 \times 10^{-19} J = 3.4 \times 1.6 \times 10^{-19} J.$$

6. (c) Number of days from January 1<sup>st</sup> to January 24<sup>th</sup> = 23 days.

$$\text{Number of half lives } n = \frac{23}{8.04} = 2.86 (< 3)$$



In three half lives activity becomes 75 Bq, but the given number of half lives are lesser than 3 so activity becomes greater than 75 Bq.

7. (a)  $(4n+2)$  series starts from  $U^{238}$  and its stable end product is  $Pb^{206}$ .

8. (a) Activity depends upon mass, but  $\lambda$  doesn't change.

9. (b) The given reaction is a nuclear reaction, which can take place only if a proton (a hydrogen nucleus) comes into contact with a lithium nucleus. If the hydrogen is in the atomic form, the interaction between its electron cloud and the electron cloud of a lithium atom keeps the two nuclei from getting close to each other. Even if isolated protons are used, they must be fired at the Li atom with enough kinetic energy to overcome the electric repulsion between the proton and Li atom.

10. (c)  $N = N_0 e^{-\lambda t} \Rightarrow \left| \frac{dN}{dt} \right| = N_0 \lambda e^{-\lambda t}$

$$\text{Initially at } t = 0, \left| \frac{dN}{dt} \right|_{t=0} = N_0 \lambda$$

where  $N_0$  = Initial number of undecayed atoms

$$= \frac{\text{Mass of the sample}}{\text{Mass of a single atom of X}} = \frac{M}{A/N_A} = \frac{MN_A}{A}$$

$$\therefore \left| \frac{dN}{dt} \right|_{t=0} = \frac{MN_A \lambda}{A} = \frac{0.693 MN_A}{AT}$$

11. (b) In 10 sec, number of nuclei has been reduced to one fourth (25% to 6.25%).

Therefore its half life is  $T_{1/2} = 5$  sec.

$$\therefore \text{Mean life } T = \frac{T_{1/2}}{0.693} = \frac{5}{0.693} = 7.21 \text{ sec.}$$

12. (b) By using  $R = R_0 A^{1/3} \Rightarrow \frac{R_1}{R_2} = \left( \frac{A_1}{A_2} \right)^{1/3}$

$$\Rightarrow \frac{R}{R_{He}} = \left( \frac{A}{4} \right)^{1/3} \Rightarrow (14)^{1/3} = \left( \frac{A}{4} \right)^{1/3}$$

$$\Rightarrow A = 56 \text{ so } Z = 56 - 30 = 26.$$

13. (c) Energy of an electron in ground state of an atom (Bohr's hydrogen like atom) is given as

$$E = -13.6 Z^2 eV \quad (Z = \text{atomic number of the atom})$$

$$\Rightarrow E_{\text{ionisation}} = 13.6 Z^2$$

$$\Rightarrow \frac{(E_{\text{ion}})_H}{(E_{\text{ion}})_{Li}} = \left( \frac{Z_H}{Z_{Li}} \right)^2 = \left( \frac{1}{3} \right)^2 = \frac{1}{9}$$

14. (c) By using  $E = -\frac{13.6}{n^2} eV$  (for  $H_2$  atom)

$$\Rightarrow -0.544 = -\frac{13.6}{n^2} \Rightarrow n^2 = 25 \Rightarrow n = 5$$

∴ Angular momentum =  $n \frac{h}{2\pi} = \frac{5h}{2\pi}$ .

15. (b) From conservation of momentum, two identical photons must travel in opposite directions with equal magnitude of momentum and energy  $\frac{hc}{\lambda}$

from conservation of energy  $\frac{hc}{\lambda} + \frac{hc}{\lambda} = m_0c^2 + m_0c^2$

⇒  $\lambda = \frac{h}{m_0c}$ .

16. (a) (i)  ${}_{16}S^{32} + {}_0n^1 \rightarrow {}_{15}P^{32} + {}_1H^1$   
 (ii)  ${}_9F^{19} + {}_1H^1 \rightarrow {}_2He^4 + {}_8O^{16}$   
 (iii)  ${}_7N^{14} + {}_0n^1 \rightarrow {}_6C^{14} + {}_1H^1$

17. (c) Number of lines in absorption spectrum =  $(n-1)$   
 ⇒  $5 = n - 1 \Rightarrow n = 6$   
 ∴ Number of bright lines in the emission spectrum  
 =  $\frac{n(n-1)}{2} = \frac{6(6-1)}{2} = 15$ .

18. (c) The Hydrogen atom before the transition was at rest. Therefore from conservation of momentum.

$$p_{H\text{-atom}} = p_{\text{photon}} = \frac{E_{\text{radiated}}}{c} = \frac{13.6 \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right) eV}{c}$$

$$1.6 \times 10^{-27} \times v = \frac{13.6 \left( \frac{1}{1^2} - \frac{1}{5^2} \right) \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

⇒  $v = 4.352 \text{ m/s} \approx 4 \text{ m/sec}$ .

19. (b) In 2 sec only 90% nuclei are left behind. Thus in next two second 90% of 900 or 810 nuclei will be left.

20. (b) Acceleration  $a \propto \frac{v^2}{r}$

where  $v \propto \frac{Z}{n}$  and  $r \propto \frac{n^2}{Z} \Rightarrow a \propto \frac{Z^3}{n^4}$

Since both are in ground state i.e.,  $n = 1$

so  $a \propto Z^3 \Rightarrow \frac{a_{He^+}}{a_H} = \left( \frac{Z_{He^+}}{Z_H} \right)^3 = \left( \frac{2}{1} \right)^3 = \frac{8}{1}$ .

21. (b) By using  $\frac{1}{\lambda} = RZ^2 \left[ \frac{1}{n_1^2} - \frac{1}{n_2^2} \right]$

For Hydrogen atom  $\frac{1}{(\lambda_{\min})_H} = R \left[ \frac{1}{1^2} - \frac{1}{\infty} \right] = R$

⇒  $(\lambda_{\min})_H = \frac{1}{R}$  .....(i)

For hydrogen like atom  $\left( \frac{1}{\lambda_{\min}} \right)_{\text{atom}} = RZ^2 \left( \frac{1}{2^2} - \frac{1}{\infty} \right)$

⇒  $(\lambda_{\min})_{\text{atom}} = \frac{4}{RZ^2}$  .....(ii)

From equation (i) and (ii)  $\frac{1}{R} = \frac{4}{RZ^2} \Rightarrow Z = 2$ .

22. (c) The activity  $\left( -\frac{dN}{dt} \right) = \lambda N \Rightarrow N = \left( -\frac{dN}{dt} \right) \left( \frac{T_{1/2}}{\log_e 2} \right)$

Taking the ratio of this expression for  ${}^{240}\text{Pu}$  to this same expression for  ${}^{243}\text{Am}$ ,

$$\frac{N_{Pu}}{N_{Am}} = \frac{\left( -\frac{dN_{Pu}}{dt} \right) (T_{1/2})_{Pu}}{\left( -\frac{dN_{Am}}{dt} \right) (T_{1/2})_{Am}} = \frac{(5 \mu\text{Ci}) \times (6560 \text{ y})}{(4.45 \mu\text{Ci}) \times (7370 \text{ y})} = 1$$

i.e. the two samples contains equal number of nuclei.

23. (b) Because the neutron has no electric charge, it experience no electric repulsion from a  $U^{235}$  nucleus. Hence a slow moving neutron can approach and enter a  $U^{235}$  nucleus, thereby providing the excitation needed to trigger fission. By contrast a slow moving proton feels a strong repulsion from a  $U^{235}$  nucleus. It never get's close to the nucleus, so it cannot trigger fission.

24. (d) After one half life period, the activity of Tritium becomes 50%.

After 2 half life period 25%

After 3 half life period 12.5%

After 4 half life period 6.25%

After 5 half life period 3.12% ≈ 3%

It is  $5 \times 12.5 \text{ years} + 7 \text{ years}$  i.e. approximately 70 years only.

25. (b) Transition from  $4E$  to  $E$

$(4E - E) = \frac{hc}{\lambda_1} \Rightarrow \lambda_1 = \frac{hc}{3E}$  ..... (i)

Transition from  $\frac{7}{3}E$  to  $E$

$\left( \frac{7}{3}E - E \right) = \frac{hc}{\lambda_2} \Rightarrow \lambda_2 = \frac{3hc}{4E}$  ..... (i)

From equation (i) and (ii)  $\frac{\lambda_1}{\lambda_2} = \frac{4}{9}$