Speed Test-26

1. **(b)** $P.E. = \frac{-Ze^2}{4\pi\varepsilon_0 r}$. Negative sign indicates that revolving electron is bound to the positive nucleus.
So, it decreases with increase in radii of orbit.

2. **(b)** $E = Rhc\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

E will be maximum for the transition for which $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum. Here n_2 is the higher energy level.

Clearly, $\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ is maximum for the third transition, i.e. $2 \to 1$. I transition represents the absorption of energy.

3. **(a)** Number of emission spectral lines

$$N = \frac{n(n-1)}{2}$$

$\therefore 3 = \frac{n_1(n_1-1)}{2}$, in first case.

Or $n_1^2 - n_1 - 6 = 0$ or $(n_1 - 3)(n_1 + 2) = 0$
Take positive root.
$\therefore n_1 = 3$

Again, $6 = \frac{n_2(n_2-1)}{2}$, in second case.

Or $n_2^2 - n_2 - 12 = 0$ or $(n_2 - 4)(n_2 + 3) = 0$.
Take positive root, or $n_2 = 4$

Now velocity of electron $\upsilon = \frac{2\pi KZe^2}{nh}$

$\therefore \frac{\upsilon_1}{\upsilon_2} = \frac{n_2}{n_1} = \frac{4}{3}$.

4. **(c)** $N \propto \frac{1}{\sin^4\theta/2}$; $\frac{N_2}{N_1} = \frac{\sin^4(\theta_1/2)}{\sin^4(\theta_2/2)}$

or $\frac{N_2}{5\times10^6} = \frac{\sin^4(60°/2)}{\sin^4(120°/2)}$

or $\frac{N_2}{5\times10^6} = \frac{\sin^4 30°}{\sin^4 60°}$

or $N_2 = 5\times10^6 \times \left(\frac{1}{2}\right)^4\left(\frac{2}{\sqrt{3}}\right)^4 = \frac{5}{9}\times10^6$

5. **(c)** Magnetic moment of the hydrogen atom, when the electron is in n^{th} excited state, i.e., $n' = (n+1)$
As magnetic moment $M_n = I_n A = i_n(\pi r_n^2)$

$$i_n = eV_n = \frac{mz^2e^5}{4\varepsilon_0^2 n^3 h^3}$$

$$r_n = \frac{n^2h^2}{4\pi^2 kzme^2}\left(k = \frac{1}{4\pi\epsilon_0}\right)$$

Solving we get magnetic moment of the hydrogen atom for n^{th} excited state

$$M_{n'} = \left(\frac{e}{2m}\right)\frac{nh}{2\pi}$$

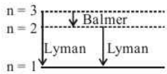
6. **(a)** $E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.62\times10^{-34}\times3\times10^8}{12.5\times1.6\times10^{-19}}$
$= 993\,A°$

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

(where Rydberg constant, $R = 1.097\times10^7$)

or, $\frac{1}{993\times10^{-10}} = 1.097\times10^7\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$

Solving we get $n_2 = 3$
Spectral lines
Total number of spectral lines = 3
Two lines in Lyman series for $n_1 = 1$, $n_2 = 2$ and $n_1 = 1$, $n_2 = 3$ and one in Balmer series for $n_1 = 2$, $n_2 = 3$



7. **(b)** $l = \frac{nh}{2\pi}, |E| \propto Z^2/n^2; n = 3$

$\Rightarrow l_H = l_{Li}$ and $|E_H| < |E_{Li}|$

8. **(b)** $r \propto n^2$

$\therefore \frac{\text{radius of final state}}{\text{radius of initial state}} = n^2$

$\frac{21.2\times10^{-11}}{5.3\times10^{-11}} = n^2$

$\therefore n^2 = 4$ or $n = 2$

9. **(a)** $R = \frac{R_0 n^2}{Z}$

Radius in ground state $= \frac{R_0}{Z}$

Radius in first excited state $= \frac{R_0\times4}{Z}$ $(\because n = 2)$

Hence, radius of first excited state is four times the radius in ground state.

10. **(a)** Speed of electron in nth orbit

$$V_n = \frac{2\pi KZe^2}{nh}$$

$$V = (2.19 \times 10^6 m/s)\,\frac{Z}{n}$$

$$V = (2.19 \times 10^6)\,\frac{2}{3}\ (Z = 2\ \&\ n = 3)$$

$$V = 1.46 \times 10^6\ m/s$$

11. **(b)** $KE_{max} = 10eV$

$\phi = 2.75\,eV$

Total incident energy

$E = \phi + KE_{max} = 12.75\ eV$

$\therefore$ Energy is released when electron jumps from the excited state n to the ground state.

$\because\ E_4 - E_1 = \{-0.85 - (-13.6)\,ev\}$

$= 12.75eV$

$\therefore$ value of n = 4

12. **(a)** As the electron comes nearer to the nucleus the potential energy decreases

$$\left(\because \frac{-k.Ze^2}{r} = \text{P.E. and } r \text{ decreases}\right)$$

The K.E. will increase $\left[\because \text{K.E.} = \frac{1}{2}|\,\text{P.E.}\,| = \frac{1}{2}\frac{kZe^2}{r}\right]$

The total energy decreases $\left[\text{T.E.} = -\frac{1}{2}\frac{kZe^2}{r}\right]$

13. **(d)** When one e^- is removed from neutral helium atom, it becomes a one e^- species.
For one e^- species we know

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

For helium ion, $Z = 2$ and for first orbit $n = 1$.

$$\therefore\quad E_1 = \frac{-13.6}{(1)^2} \times 2^2 = -54.4\,\text{eV}$$

$\therefore$ Energy required to remove this $e^- = +54.4$ eV

$\therefore$ Total energy required = 54.4 + 24.6 = 79 eV

14. **(b)** For 2^{nd} line of Balmer series in hydrogen spectrum

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

For Li^{2+} $\left[\frac{1}{\lambda} = R \times 9\left(\frac{1}{x^2} - \frac{1}{12^2}\right) = \frac{3R}{16}\right]$

which is satisfied by $n = 12 \rightarrow n = 6$.

15. **(d)** For an atom following Bohr's model, the radius is given by

$r_m = \frac{r_0 m^2}{Z}$ where r_0 = Bohr's radius and m = orbit number.

For *Fm*, $m = 5$ (Fifth orbit in which the outermost electron is present)

$$\therefore\ r_m = \frac{r_0 5^2}{100} = nr_0\ \text{(given)} \Rightarrow n = \frac{1}{4}$$

16. **(a)** Energy of electron in n^{th} orbit is

$$E_n = -(Rch)\,\frac{Z^2}{n^2} = -54.4\,eV$$

For He^+ is ground state

$$E_1 = -(Rch)\,\frac{(2)^2}{(1)^2} = -54.4 \Rightarrow Rch = 13.6$$

$\therefore$ For Li^{++} in first excited state (n = 2)

$$E' = -13.6 \times \frac{(3)^2}{(2)^2} = -30.6\ eV$$

17. **(a)** Angular momentum = mrv = J

$$\therefore\quad v = \frac{J}{mr}$$

$$\text{K. E. of electron} = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{J}{mr}\right)^2$$

$$= \frac{J^2}{2mr^2}$$

18. **(b)** When $F = \frac{k}{r}$ = centripetal force, then $\frac{k}{r} = \frac{mv^2}{r}$

$\Rightarrow mv^2$ = constant $\Rightarrow$ kinetic energy is constant

$\Rightarrow T$ is independent of n.

19. **(b)** $\frac{1}{\lambda'} = \frac{1}{\lambda}\sqrt{\frac{c-v}{c+v}}$

Here, $\lambda' = 706$ nm, $\lambda = 656$ nm

$$\therefore\quad \frac{c-v}{c+v} = \left(\frac{\lambda}{\lambda'}\right)^2 = \left(\frac{656}{706}\right)^2 = 0.86$$

$$\Rightarrow\quad \frac{v}{c} = \frac{0.14}{1.86}$$

$$\Rightarrow\quad v = 0.075 \times 3 \times 10^8 = 2.25 \times 10^7 m/s$$

20. **(d)** $\because\ B = \frac{\mu_0 I}{2r}$ and $I = \frac{e}{T}$

$$B = \frac{\mu_0 e}{2rT}\ [r \propto n^2, T \propto n^5];\quad B \propto \frac{1}{n^5}$$

21. **(a)** 53 electrons in iodine atom are distributed as 2, 8, 18, 18, 7

$\therefore n = 5$

$$r_n = (0.53 \times 10^{-10})\frac{n^2}{Z}$$

$$= \frac{0.53 \times 10^{-10} \times 5^2}{53} = 2.5 \times 10^{-11}\,m$$

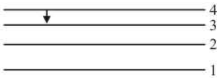
22. **(a)** At closest distance of approach, the kinetic energy of the particle will convert completely into electrostatic potential energy.

Kinetic energy K.E. $= \frac{1}{2}mv^2$

Potential energy P.E. $= \frac{KQq}{r}$

$$\frac{1}{2}mv^2 = \frac{KQq}{r} \Rightarrow r \propto \frac{1}{m}$$

23. **(c)** $\frac{n(n-1)}{2} = 6$



$n^2 - n - 12 = 0$

$(n-4)(n+3) = 0$ or $n = 4$

24. **(c)** The wavelength of spectrum is given by

$$\frac{1}{\lambda} = Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad \text{where } R = \frac{1.097 \times 10^7}{1 + \frac{m}{M}}$$

where m = mass of electron

M = mass of nucleus.

For different M, R is different and therefore λ is different.

25. **(a)** $\because T \propto n^3$

$Tn_1 = 8\, Tn_2$ (given)

Hence, $n_1 = 2n_2$

26. **(d)** $\Delta E = h\nu$

$$\nu = \frac{\Delta E}{h} = k\left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right] = \frac{k(2n-1)}{n^2(n-1)^2}$$

$$\approx \frac{2k}{n^3} \quad \text{or} \quad \nu \propto \frac{1}{n^3}$$

27. **(c)** A spectrum is observed, when light coming directly from a source is examined with a spectroscope. Therefore spectrum obtained from a sodium vapour lamp is emission spectrum.

28. **(a)** Energy of ground state 13.6 eV

Energy of first excited state

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

Energy of second excited state

$$= -\frac{13.6}{9} = -1.5\,\text{eV}$$

Difference between ground state and 2nd excited state $= 13.6 - 1.5 = 12.1$ eV

So, electron can be excited upto 3rd orbit

No. of possible transition

$1 \to 2, 1 \to 3, 2 \to 3$

So, three lines are possible.

29. **(b)** In Bohr's model, angular momentum is quantised i.e

$$\ell = n\left(\frac{h}{2\pi}\right)$$

30. **(b)** The smallest frequency and largest wavelength in ultraviolet region will be for transition of electron from orbit 2 to orbit 1.

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

$$\Rightarrow \frac{1}{122 \times 10^{-9} m} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R\left[1 - \frac{1}{4}\right] = \frac{3R}{4}$$

$$\Rightarrow R = \frac{4}{3 \times 122 \times 10^{-9}} m^{-1}$$

The highest frequency and smallest wavelength for infrared region will be for transition of electron from ∞ to 3rd orbit.

$$\therefore \frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \frac{1}{\lambda} = \frac{4}{3 \times 122 \times 10^{-9}}\left(\frac{1}{3^2} - \frac{1}{\infty}\right)$$

$$\therefore \lambda = \frac{3 \times 122 \times 9 \times 10^{-9}}{4} = 823.5\text{nm}$$

31. **(c)** $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ where R = Rydberg constant

$$\frac{1}{\lambda_{32}} = \left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5}{36}$$

$$\Rightarrow \lambda_{32} = \frac{36}{5}$$

Similarly solving for λ_{31} and λ_{21}

$$\lambda_{31} = \frac{9}{8} \text{ and } \lambda_{21} = \frac{4}{3}$$

$$\therefore \frac{\lambda_{32}}{\lambda_{31}} = 6.4 \text{ and } \frac{\lambda_{21}}{\lambda_{31}} \simeq 1.2$$

32. **(d)** $b = \dfrac{Ze^2 \cot\left(\frac{\theta}{2}\right)}{4\pi \epsilon_0 k_i} = 0 \Rightarrow \cot\left(\frac{\theta}{2}\right) = 0$

$$\Rightarrow \frac{\theta}{2} = 90° \text{ or } \theta = 180°$$

33. **(a)** Speed of electron in nth orbit

$$V_n = \frac{2\pi KZe^2}{nh}$$

$$V = (2.19 \times 10^6 \text{m/s}) \frac{Z}{n}$$

$$V = (2.19 \times 10^6) \frac{2}{3} \,(Z = 2 \,\&\, n = 3)$$

$V = 1.46 \times 10^6$ m/s

34. **(d)** $E = E_4 - E_3$

$$= -\frac{13.6}{4^2} - \left(-\frac{13.6}{3^2}\right) = -0.85 + 1.51$$

$= 0.66$ eV

35. **(d)** $\because$ The frequency of the transition $\nu \propto \frac{1}{n^2}$, when $n = 1, 2, 3$.

36. **(c)** According to Bohr's theory, the wave number of the last line of the Balmer series in hydrogen spectrum,

For hydrogen atom z = 1

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

$$= 10^7 \times 1^2\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$\Rightarrow$ wave number $\frac{1}{\lambda} = 0.25 \times 10^7\ m^{-1}$

37. **(a)** Velocity of electron in n^{th} orbit of hydrogen atom is given by :

$$V_n = \frac{2\pi KZe^2}{nh}$$

Substituting the values we get,

$$V_n = \frac{2.2 \times 10^6}{n} \text{m/s} \quad \text{or} \quad V_n \propto \frac{1}{n}$$

As principal quantum number increases, velocity decreases.

38. **(c)** $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\Rightarrow \frac{1}{970.6 \times 10^{-10}} = 1.097 \times 10^7\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right] \Rightarrow n_2 = 4$$

$\therefore$ Number of emission line $N = \frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6$

39. **(a)** We have $E_n = \frac{-2\pi^2 mK^2Z^2e^4}{n^2h^2}$. For helium $Z = 2$. Hence requisite answer is $4E_n$

40. **(c)** As α-particles are doubly ionised helium He^{++} i.e. Positively charged and nucleus is also positively charged and we know that like charges repel each other.

41. **(b)** $\bar{v} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$, where $n_1 = 2, n_2 = 4$

$$\bar{v} = R\left(\frac{1}{4} - \frac{1}{16}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{12}{4 \times 16}\right) \quad \Rightarrow \quad \lambda = \frac{16}{3R}$$

42. **(a)** The kinetic energy of the projectile is given by

$$\frac{1}{2}mv^2 = \frac{Ze(2e)}{4\pi\varepsilon_0 r_0} = \frac{Z_1 Z_2}{4\pi\varepsilon_0 r_0}$$

Thus energy of the projectile is directly proportional to Z_1, Z_2

43. **(a)** We know that $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

The wave length of first spectral line in the Balmer series of hydrogen atom is 6561Å. Here $n_2 = 3$ and $n_1 = 2$

$$\therefore \frac{1}{6561} = R(1)^2\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5R}{36} \quad \text{...(i)}$$

For the second spectral line in the Balmer series of singly ionised helium ion $n_2 = 4$ and $n_1 = 2$; $Z = 2$

$$\therefore \frac{1}{\lambda} = R(2)^2\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{4} \quad \text{...(ii)}$$

Dividing equation (i) and equation (ii) we get

$$\frac{\lambda}{6561} = \frac{5R}{36} \times \frac{4}{3R} = \frac{5}{27}$$

$\therefore \quad \lambda = 1215$ Å

44. **(a)** For Lyman series

$$\upsilon = R_C\left[\frac{1}{1^2} - \frac{1}{n^2}\right]$$

where n = 2, 3, 4, ...

For the series limit of Lyman series, $n = \infty$

$$\therefore \quad \upsilon_1 = R_C\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = R_C \quad \text{...(i)}$$

For the first line of Lyman series, $n = 2$

$$\therefore \quad \upsilon_2 = R_C\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}R_C \quad \text{...(ii)}$$

For Balmer series

$$\upsilon = R_C\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$$

where n = 3, 4, 5 .....

For the series limit of Balmer series, $n = \infty$

$$\therefore \quad \upsilon_3 = R_C\left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = \frac{R_C}{4} \quad \text{...(iii)}$$

From equation (i), (ii) and (iii), we get

$\upsilon_1 = \upsilon_2 + \upsilon_3$ or $\upsilon_1 - \upsilon_2 = \upsilon_3$

45. **(d)** As $r \propto \frac{1}{m}$ $\quad \therefore r_0' = \frac{1}{2}r_0$

As $E \propto m$ $\quad \therefore E_0' = 2(-13.6) = -27.2$ eV