NARAYANA EDUCATIONAL INSTITUTIONS

SR-AZ JEE MAIN MODEL

PHYSICS

TOPIC: ATOMIC PHYSICS

1. The ratio of areas within the electron orbits for the first excited state to the ground state for hydrogen atom is
   1) $16:1$ 2) $18:1$ 3) $4:1$ 4) $2:1$

2. The electric potential between a proton and an electron is given by $V = V_0 \ln \frac{r}{r_0}$, where r_0 is a constant. Assuming Bohr's model to be applicable, write variation of r_n with 'n', n being the principal quantum number
   1) $r_n \alpha n$ 2) $r_n \alpha 1/n$ 3) $r_n \alpha n^2$ 4) $r_n \alpha 1/n^2$

3. The innermost orbit of the hydrogen atom has a diameter $1.06 A^o$. The diameter of tenth orbit is
   1) $5.3 A^o$ 2) $10.6 A^o$ 3) $53 A^o$ 4) $106 A^o$

4. If the binding energy of the electron in a hydrogen atom is $13.6 eV$, the energy required to remove the electron from the first excited state of Li^{++} is
   1) $122.4 eV$ 2) $30.6 eV$ 3) $-30.6 eV$ 4) $3.4 eV$

5. The ratio of the wavelengths for $2 \to 1$ transition in Li^{++}, He^{+} and H is
   1) $1:2:3$ 2) $1:4:9$ 3) $4:9:36$ 4) $3:2:1$

6. The wavelength of radiation emitted is λ_0 when an electron jumps from the third to the second orbit of hydrogen atom. For the electron jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be
   1) $\frac{16}{25}\lambda_0$ 2) $\frac{20}{27}\lambda_0$ 3) $\frac{27}{20}\lambda_0$ 4) $\frac{25}{16}\lambda_0$

7. If scattering particles are 56 for 90^o angle then this will be at 60^o angle
   1) 224 2) 256 3) 98 4) 108

8. The radiation emitted when an electron jumps from $n = 3$ to $n = 2$ orbit in a hydrogen atom falls on a metal to produce photoelectrons. The electrons from the metal surface with maximum kinetic energy are made to move perpendicular to a magnetic field of $(1/320)$ T in a radius of $10^{-3} m$. Then kinetic energy of electrons in eV is….
   1) 0.86 2) 0.086 3) 8.6 4) 0.0086

9. When an electron in hydrogen atom is excited, from its 4th to 5th stationary orbit, the change in angular momentum of electron is (Planck's constant: $h = 6.6 \times 10^{-34} J-s$)
   1) $4.16 \times 10^{-34} J-s$ 2) $3.32 \times 10^{-34} J-s$ 3) $1.05 \times 10^{-34} J-s$ 4) $2.08 \times 10^{-34} J-s$

10. The absorption transition between two energy states of hydrogen atom are 3. The emission transitions between these states will be
    1) 3 2) 4 3) 5 4) 6

11. The energy levels of a certain atom for 1st, 2nd and 3rd levels are E, $4E/3$ and $2E$ respectively. A photon of wavelength λ is emitted for a transition $3 \to 1$. What will be the wavelength of emissions for transition $2 \to 1$
    1) $\frac{\lambda}{3}$ 2) $\frac{4\lambda}{3}$ 3) $\frac{3\lambda}{4}$ 4) 3λ

12. A single electron orbits a stationary nucleus of charge $+Ze$, where Z is a constant. It requires $47.2 eV$ to excited electron from second Bohr orbit to third Bohr orbit. Find the value of Z
    1) 2 2) 5 3) 3 4) 4

13. Ratio of the wavelengths of first line of Lyman series and first line of Balmer series is
1) $1:3$ 2) $27:5$ 3) $5:27$ 4) $4:9$

14. The third line of Balmer series of an ion equivalent to hydrogen atom has wavelength of 108.5 nm. The ground state energy of an electron of this ion will be
1) 3.4 eV 2) 13.6 eV 3) -54.4 eV 4) 122.4 eV

15. Hydrogen atom in its ground state is excited by radiation of wavelength $975A^o$. How many lines wil be there in the emission spectrum.
1) 2 2) 4 3) 6 4) 8

16. In an atom, the two electrons move round the nucleus in circular orbits of radii R and $4R$. The ratio of the time taken by them to complete one revolution is
1) $1/4$ 2) $4/1$ 3) $8/1$ 4) $1/8$

17. In an electron in hydrogen atom is in its 2nd excited state, orbiting the nucleus in a stationary of orbit of radius $4.65A^o$. Then its debroglie wave length is
1) $12.9A^o$ 2) $3.5A^o$ 3) $9.7A^o$ 4) $6.6A^o$

18. Electron in a certain energy level $n = n_1$, can emit 3 spectral lines. When they are in another energy level $n = n_2$, they can emit 6 spectral lines. The ratio of orbital speeds of electrons is
1) $4:3$ 2) $3:4$ 3) $2:1$ 4) $1:2$

19. The ratio of speed of electron in the ground state of hydrogen atom to the speed of light in vacuum is
1) $\frac{1}{2}$ 2) $\frac{2}{237}$ 3) $\frac{1}{137}$ 4) $\frac{1}{237}$

20. An electron is revolving in nth orbit of radius $4.2A^o$, then the value of n is nearly……. $(r_1 = 0.5299)$
1) 4 2) 5 3) 6 4) 3

21. Taking the Bohr radius as $a_0 = 53pm$, the radius of Li^{++} ion in its ground state, on the basis of Bohr's model will be about
1) 53pm 2) 27pm 3) 18pm 4) 13pm

22. An electron in the ground state of hydrogen atom is revolving in anticlockwise direction in circular orbit of radius R, the orbital magnetic dipole moment of electron will be
1) $\frac{eh}{4\pi m}$ 2) $\frac{eh}{2\pi m}$ 3) $\frac{eh^2}{4\pi m}$ 4) $\frac{e^2h}{4\pi m}$

23. When an electron jumps from a level $n = 4$ to $n = 1$, the momentum of the recoiled hydrogen atom will be
1) $6.5\times10^{-27}kgms^{-1}$ 2) $12.75\times10^{-19}kgms^{-1}$ 3) $13.6\times10^{-27}kgms^{-1}$ 4) zero

24. Transitions between three energy levels in a particular atom give rise to three spectral lines of wavelengths in increasing magnitudes λ_1, λ_2 and λ_3. Which one of the following equations correctly relates λ_1, λ_2 and λ_3?
1) $\lambda_1 = \lambda_2 - \lambda_3$ 2) $\lambda_1 = \lambda_3 - \lambda_2$ 3) $\frac{1}{\lambda_1} = \frac{1}{\lambda_2} + \frac{1}{\lambda_3}$ 4) $\frac{1}{\lambda_1} = \frac{1}{\lambda_3} - \frac{1}{\lambda_2}$

25. The ratio (in SI units) magnitude of dipole moment to that of angular momentum of an electron of mass m kg and charge e coulomb in Bohr's orbits of hydrogen atom is
1) $\frac{e}{2m}$ 2) $\frac{e}{m}$ 3) $\frac{2e}{m}$ 4) $\frac{m}{2e}$

26. The force acting on electron in hydrogen atom depends upon principal quantum number as $F\alpha\frac{1}{n^x}$, then $x =$ ……..

27. In the coolidge tube experiment, if the applied voltage is increased to three times, the short wavelength limit of continuous X-ray spectrum shifts by 20 pm. What is the initial voltage (in kV) applied to the tube is…..

28. An X-ray tube operates at 20 kV. A particular electron loses 5% of its kinetic energy to emit an X-ray photon at the first collision. The wavelength corresponding to this photon in ……. nm

29. An X-ray tube operates at 20 kV. Find the maximum speed of the electrons striking the anode, (given the charge of electrons is 1.6×10^{-19} coulomb and mass of electron is $9\times10^{-31}kg$) is…….$\times10^7 m/s$

30. The wavelength of the characteristic X-ray K_α line emitted by a hydrogen-like element is $0.32A^o$. Calculate the wavelength of K_β line emitted by the same element is…….. A^o

ATOMIC PHYSICS KEY

1-10	1	1	4	2	3	2	1	1	3	4
11-20	4	2	3	3	3	4	3	1	3	4
21-30	3	1	1	3	1	4	41	1.24	8.4	0.27

HINTS

1. For a hydrogen atom,

Radius $r\alpha n^2 \Rightarrow \frac{r_1^2}{r_2^2}=\frac{n_1^4}{n_2^4} \Rightarrow \frac{\pi r_1^2}{\pi r_2^2}=\frac{n_1^4}{n_2^4} \Rightarrow \frac{A_1}{A_2}=\frac{n_1^4}{n_2^4}=\frac{2^4}{1^4}=16 \Rightarrow \frac{A_1}{A_2}=\frac{16}{1}$

2. Potential energy $U=eV=eV_0$ in $\frac{r}{r_0}$

$\therefore$ Force $F=-\left|\frac{dU}{dr}\right|=\frac{eV_0}{r}$

The force will provide the necessary centripetal force.

Hence, $\frac{mv^2}{r}=\frac{eV_0}{r} \Rightarrow v=\sqrt{\frac{eV_0}{m}}....(i)$

And $mvr=\frac{nh}{2\pi}......(ii)$

Dividing equation (i) by (ii), we have $mr=\left(\frac{nh}{2\pi}\right)\sqrt{\frac{m}{eV_0}}$ or $r\alpha n$

3. Using $r\alpha n^2 \Rightarrow \frac{r_2}{r_2}=\left(\frac{n_2}{n_1}\right)^2$ Or $\frac{d_2}{d_1}=\left(\frac{n_2}{n_1}\right)^2 \Rightarrow \frac{d_2}{1.06}=\left(\frac{10}{1}\right)^2 \Rightarrow d=106A^o$

4. Using $E_n=-\frac{13.6\times Z^2}{n^2}eV$

For first excited state $n=2$ and for Li^{++}, $Z=3$

$\therefore E=-\frac{13.6}{2^2}\times 3^2=-30.6eF$

Hence, remove the electron from the first excited state of Li^{++} be $30.6eV$

5. Using $\frac{1}{\lambda}=RZ^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right) \Rightarrow \lambda\alpha\frac{1}{Z^2} \Rightarrow \lambda_{Li}:\lambda_{He^+}:\lambda_H=\frac{1}{9}:\frac{1}{4}:\frac{1}{1}=4:9:36$

6. Wavelength of radiation in hydrogen atom is given by

$\frac{1}{\lambda}=R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right] \Rightarrow \frac{1}{\lambda_0}=R\left[\frac{1}{2^2}-\frac{1}{3^2}\right]=R\left[\frac{1}{4}-\frac{1}{9}\right]=\frac{5}{36}R......(i)$

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

From (i) & (ii), $\frac{\lambda^{'}}{\lambda} = \frac{5R}{36} \times \frac{16}{3R} = \frac{20}{27} \Rightarrow \lambda^{'} = \frac{20}{27}\lambda_0$

7. Using Scattering formula

$$N\alpha \frac{1}{\sin^4(\theta/2)} \Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin\left(\frac{\theta_1}{2}\right)}{\sin\left(\frac{\theta_2}{2}\right)}\right]^4 \Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin\left(\frac{90^o}{2}\right)}{\sin\left(\frac{60^o}{2}\right)}\right]^4 = \left[\frac{\sin 45^o}{\sin 30^o}\right]^4 = 4$$

$\Rightarrow N_2 = 4N_1 = 4 \times 56 = 224$

8. Radius $R = \frac{mv}{Bq} = \frac{\sqrt{2mKE}}{Bq}$

$KE = \frac{(BqR)^2}{2m} = 0.86eV$

9. Change in angular momentum

$$\Delta L = L_2 - L_1 = \frac{n_2 h}{2\pi} - \frac{n_1 h}{2\pi} = \frac{h}{2\pi}(n_2 - n_1) = \frac{6.6\times10^{-34}}{2\times3.14}(5-4) = 1.05\times10^{-34} J-s$$

10. Number of absorption lines $= (n-1) \Rightarrow 3 = (n-1) \Rightarrow n = 4$

Hence number of emitted lines $= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

11. For transition $3 \rightarrow 1$, $\Delta E = 2E - E = \frac{hc}{\lambda} \Rightarrow E = \frac{hc}{\lambda}$....$(i)$

For transition $2 \rightarrow 1$, $\frac{4E}{3} - E = \frac{hc}{\lambda^{'}} \Rightarrow E = \frac{3hc}{\lambda^{'}}$.....$(ii)$

From (i) & (ii), $\lambda^{'} = 3\lambda$

12. Excitation energy of hydrogen like atom for $n_2 \rightarrow n_1$

$\Delta E = 13.6Z^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 13.6 \times \frac{5}{36}Z^2$

$\Rightarrow Z^2 = \frac{47.2\times36}{13.6\times5} = 24.98 \simeq 25 \Rightarrow Z = 5$

13. For Lyman series $\frac{1}{\lambda_{L_1}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$.......$(i)$

For Balmer series $\frac{1}{\lambda_{B_1}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$.......$(ii)$

From eq (i) & (ii), $\frac{\lambda_{L_1}}{\lambda_{B_1}} = \frac{5}{27}$

14. Using $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \frac{1}{108.5\times10^{-9}} = 1.1\times10^7 \times Z^2\left(\frac{1}{2^2} - \frac{1}{5^2}\right)$

$$\Rightarrow \frac{1}{108.5\times10^{-9}} = 1.1\times10^{7}\times Z^{2}\times\frac{21}{100} \Rightarrow Z^{2} = \frac{100}{108.5\times10^{-9}\times1.1\times10^{-7}\times21} = 4 \Rightarrow Z = 2$$

Now energy in ground state $E = -13.6Z^{2}eV = -13.6\times2^{2}eV = -54.4eV$

15. Using $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{975\times10^{-10}} = 1.097\times10^{7}\left(\frac{1}{1^2} - \frac{1}{n^2}\right) \Rightarrow n = 4$

Now no. of spectral lines $N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

16. Time period $T\alpha\frac{n^3}{Z^2}$

For a given atom (Z=constant) So $T\alpha n^{3}....(i)$ and radius $R\alpha n^{2}....(ii)$

$\therefore$ From eq (i) & (ii), $T\alpha R^{3/2} \Rightarrow \frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} = \frac{1}{8}$

17. $2\pi r = n\lambda$

$2\pi\times4.65 = 3\lambda \Rightarrow \lambda = \frac{6.28\times4.65}{3} = 9.7A^{o}$

18. no. of emitted spectral lines, $N = \frac{n(n-1)}{2}$

Case-1: N=3,

$3 = \frac{n_1(n_1-1)}{2} \Rightarrow n_1 = 3$

Case-2, N=6,

$6 = \frac{n_2(n_2-1)}{2} \Rightarrow n_2 = 4$

$\frac{V_1}{V_2} = \frac{n_2}{n_1} = \frac{4}{3}$

19. $V_n = \frac{c}{137}\frac{z}{n}$

20. $r_n\alpha n^2, \frac{r_1}{r_2} = \left(\frac{n_1}{n_2}\right)^2$

$\frac{0.529}{4.2} = \left(\frac{1}{n_2}\right)^2 \Rightarrow n_2 = \sqrt{7.939} \simeq 3$

21. where $a_0 = 53pm, n = 1, z = 3$

$r_n = a_0\times\frac{n^2}{z} = 53\times\frac{1^2}{3} \simeq 18pm$

22. According to Bohr's theory, $mvr = n\frac{h}{2\pi} = \frac{h}{2\pi}$

$\therefore v = \frac{h}{2\pi mr}$

We know that rate of flow of charge is current

$\therefore I = e\left(\frac{v}{2\pi r}\right) = \frac{eh}{4\pi^2 mr^2}$

Magnetic moment $M = IA = \frac{eh}{4\pi^2 mr^2}\pi r^2 = \frac{eh}{4\pi m}$

23. Momentum of the recoiled hydrogen atom $p = \frac{h}{\lambda} = hR\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

24. Conceptual

25. Magnetic moment of a revolving electron $M = \frac{evr}{2}$

Angular momentum $L = mvr$

$\frac{M}{L} = \frac{\frac{evr}{2}}{mvr} = \frac{e}{2m}$

26. $F = \frac{mv^2}{r}$

But $v\alpha\frac{1}{m}$ and $r\alpha n^2$

$\Rightarrow F\alpha\frac{1}{n^4} \Rightarrow n = 4$

27. cut-off wavelength for continuous X-ray is given as $\lambda_{\min} = \frac{hc}{eV_0}$

$\therefore \frac{hc}{eV_0} = \lambda, \frac{hc}{3eV_0} = \lambda - \Delta\lambda$

$V_0 = \frac{2hc}{3e\Delta\lambda} = 41kV$

28. Kinetic energy acquired by the electron is $K = 20\times10^3 eV$

The energy of the photon is $0.05\times20\times10^3 eV = 10^3 eV$

Thus, $\frac{hc}{\lambda} = 10^3 eV$

$\Rightarrow \lambda = \frac{\left(4.14\times10^{-15} eV - s\right)\times\left(3\times10^8 ms^{-1}\right)}{10^3 eV} = \frac{1242eV - nm}{10^3 eV} = 1.24nm$

29. When an electron of charge 'e' is accelerated through a potential difference V, it acquires energy eV. If 'm' be the mass of the electron and $V_{\max}$ the maximum speed of electron,

then $\frac{1}{2}mv_{\max}^2 = eV$ or $v_{\max} = \sqrt{\left(\frac{2eV}{m}\right)}$

substituting the given values, we get $v_{\max} = \sqrt{\left(\frac{2\times\left(1.6\times10^{-19}\right)\times20000}{9\times10^{-31}}\right)} = 8.4\times10^7 ms^{-1}$

30. For hydrogen like element $\frac{1}{\lambda} = Z^2 R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For K_α line, $\frac{1}{\lambda_\alpha} = Z^2 R\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$........$(i)$

For λ_β line, $\frac{1}{\lambda_\beta} = Z^2 R\left(\frac{1}{1^2} - \frac{1}{3^2}\right)$........$(ii)$

Dividing, $\frac{\lambda_\beta}{\lambda_\alpha} = \frac{\frac{1}{1^2} - \frac{1}{2^2}}{\frac{1}{1^2} - \frac{1}{3^2}} = \frac{1 - \frac{1}{4}}{1 - \frac{1}{9}} = \frac{27}{32}$

$\therefore \lambda_\beta = \frac{27}{32}\lambda_\alpha = \frac{27}{32} \times 0.32 A^o = 0.27 A^o$