QB365

Important Questions - Atoms and Nuclei

12th Standard CBSE

Physics Reg.No. : | | | | | | |

Time : 01:00:00 Hrs

Total Marks : 50

Section-A

1) Taking the Bohr radius as a_0=53pm, the radius of Li^{++} ion its ground state, on the basis of Boh''s model, will be about **1**

(a) 53pm (b) 27pm (c) 18pm (d) 13pm

2) The binding energy of a H-atom, considering an electron moving around a fixed nuclei (proton), is $B=\frac{me^4}{8n^2\epsilon_0^2h^2}$ (m=electron mass.) if one decides to work in a frame of reference where the electron is at rest, the proton would be moving around it.By similar arguments, the binding energy would be $B=\frac{me^4}{8n^2\epsilon_0^2h^2}$ This last expression is not correct because **1**

(a) n would not be integral (b) Bohr-quantisation applies only to electron

(c) the frame in which the electron is at rest is not inertial

(d) the motion of the proton would not be in circular orbits, even approximately.

3) For the ground state, the electron in the H-atom has an angular momentum =h, according to the simple Bohr model.Angular momentum is a vector and hence there will be infinitely many orbits with the vector pointing in all possible directions.In actuality, this is not true, **1**

(a) because only one of these would have a minimum energy

(b) because only one of these would have a minimum energy

(c) angular momentum must be in the direction of spin of electron

(d) because electrons go arround only in horizontal obits.

4) O_2 molecule consists of two oxygen atoms.In the molecule, nuclear force between the nuclei of the two atoms **1**

(a) is not important because nuclear forces are short-ranged

(b) is as important as electrostatic force for binding the two atoms

(c) cancels the repulsive electrostatic force between the nuclei

(d) is not important because oxygen nucleus have equal number of neutrons and protons.

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6) Two H atoms in the ground state collide inelastically kinetic energy is reduced is **1**

(a) 10.20 eV (b) 20.40 eV (c) 13.6 eV (d) 27.2 eV

Section-B

7) Why is that mass of nucleus does not enter the formula for impact parameter but its charge does? **2**

8) In Rutherford scattering experiment, if a proton is taken instead of an alpha particle, then for same distance of closest approach, how much K.E. in comparison to K.E of α particle will be required? **2**

9) Defina distance of closest approach and impact parameter. **2**

10) The energy of electron in ground state of hydrogen atom is -13.6 eV.How much energy is required to take an electron in this atom from the ground state to first excited state. **2**

11) Show that Bohr's second postulate "The electron revolves around the nucleus only in certain fixed orbits without radiating energy" can be explained on the basis of de-Broglie hypothesis of wave nature of electron. **2**

12) The electron in the hydrogen atom passes from the n=4 energy level to the n=1 level.What is the maximum number of photons that can be emitted? and minimum number? **2**

Section-C

13) The gravitational attraction between electron and proton in a hydrogen atom is weaker than the Coulomb attraction by a factor of about 10^{-40} .An alternative way of looking at this fact is to estimate the radius of the first Bohr orbit of hydrogen atom if the electron and proton were bound by gravitational attraction.You will find the answer interesting. **3**

14) Obtain an expression for the frequency of the radiation emitted when a hydrogen atom de-excites from level n to level (n-1).For large n, show that this frequency equals the classical frequency of revolution of the electron in the orbit. **3**

15) If Bohr's quantization postulate (angular momentum=nh/2π) is a basic law of nature, it should be equally valid for the case of planetary motion also.Why then do we never speak of quantization of orbits of planets around the sun? **3**

16) Obtain the first Bohr radius and the ground state energy of a 'muonic hydrogen atom'(i.e. an atom in which a negatively charged moun (μ^-) of mass about 207 m_e orbits around a proton. **3**

Section-D

17) What is the distance of closest approach when a 5.0 MeV proton approaches a gold nucleus? **5**

18) In a Geiger-Marsden experiment, calculate the distance of closest approach to the nucleus of Z=80, when an $\alpha - particle$ of 8MeV energy impinges on it before it comes momentarily to rest and reverses its direction. **5**

19) Calculate the impact parameter of a 5MeV alpha particle scattered by 10° when it approaches a gold nucleus. Take Z=79 for gold. **5**

20) In a Geiger-Marsden experiment, calculate energy of $\alpha \quad particle$whose distance of closest approach to the nucleus of Z=79 is $2.8 \times 10^{-14} m$How will the distance of closest approach be affected when the kinetic energy of the $\alpha \quad particle$is doubled? **5**

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Section-A

1) (c) 18pm **1**

2) (c) the frame in which the electron is at rest is not inertial **1**

3) (a) because only one of these would have a minimum energy **1**

4) (a) is not important because nuclear forces are short-ranged **1**

5) (a) is not important because nuclear forces are short-ranged **1**

6) (a) 10.20 eV **1**

Section-B

7) **2**

The scattering of α- particles occurs due to electrostatic field of the nucleus.That is why charge on nucleus enters the expression for impact parameter and not its mass.

8) At the distance of closest approach (r_0), **2**

$KE_\alpha = \frac{(Ze)(2e)}{4\pi\epsilon_0 r_0}$ and $KE_p = \frac{(Ze)(e)}{4\pi\epsilon_0 r_0}$.

Clearly, $KE_p = \frac{1}{2}KE_\alpha$.

9) **2**

Distance of closest approach is the distance between the centre of nucleus and the point from which the alpha particle approaching directly to the nucleus returns.
Impact parameter is the perpendicular distance of the velocity vector of the alpha particle from the central line of the nucleus, when the particle is far away from the atom.

10) Energy in ground state $E_1 = -13.6eV$ **2**

Energy is first excited state,

$E_2 = \frac{-13.6}{2^2} = -3.4eV$.

$\therefore$ Required energy = $E_2 - E_1$

$= -3.4 - (-13.6) = 10.2eV$

11) **2**

When an electron of mass m is confined to move on a line of length l with velocity v, the de-Broglie wavelength λ associated with electron is

$\lambda = \frac{h}{mv} = \frac{h}{p} \qquad or \qquad p = \frac{h}{\lambda} = \frac{h}{2l/n} = \frac{nh}{2l}$

When electron revolves in a circular orbit of radius r; then $2l = 2\pi r$

$\therefore \qquad p = \frac{nh}{2\pi r}$

$or \qquad p \times r = \frac{nh}{2\pi}$

i.e., angular momentum $(p \times r)$ of electron is integral multiple of $h/2\pi$. This is Bohr's quantization condition of angular momentum.

12) **2**

When an electron in hydrogen atom passes from n=4 energy level to n=1 level, max. a number of photons =6, corresponding to transitions $4 \to 3; 3 \to 2; 2 \to 1; 4 \to 2, 3 \to 1, 4 \to 1.$ The minimum number of photons can be one only corresponding to the transition $4 \to 1.$

Section-C

13) If electron and proton were bounded by gravitational attraction, then 3

$F = G\frac{m_e m_p}{r^2}$

This force provides necessary centripetal force

$F = \frac{m_e v^2}{r}$

$\therefore \ \frac{m_e v^2}{r} = \frac{G m_e m_p}{r^2}$

or $m_e v^2 r = G m_e m_p$ ....(i)

From Bohr's condition

$m_e v r = \frac{nh}{2\pi}$

or $m_e^2 v^2 r^2 = \frac{n^2 h^2}{4\pi^2}$ ....(ii)

Dividing Eq.(ii) by (i) we get

$m_e r = \frac{n^2 h^2}{4\pi^2 G m_e m_p}$

or $r = \frac{n^2 h^2}{4\pi^2 G m_e^2 m_p}$

For 1st orbit n=1

so

$r_1 = \frac{1 \times (6.62 \times 10^{-34})^2}{4 \times 9.87 \times 6.67 \times 10^{-11} \times (9.1 \times 10^{-31})^2 \times 1.67 \times 10^{-27}}$

or $r_1 = 1.21 \times 10^{29}$m

This is much greater than the estimated size of the whole universe.

14) We known that 3

$v = \frac{me^4}{\epsilon_0^2 h^3}\left[\frac{1}{(n-1)} - \frac{1}{n^2}\right]$

$v = \frac{me^4 (2n-1)}{[8\epsilon_0^2 h^3 n^2 (n-1)^2]}$

For large n, $v \cong \frac{me^4}{4\epsilon_0^2 h^3 n^3}$

[$2n-1 \simeq 2n$ and $n-1 \simeq n$]

Orbital frequency $v_c = \frac{v}{2\pi r}$

Now in Bohr's model,

$v\frac{nh}{2\pi mr} and\ r = \frac{n^2 h^2 \epsilon_0}{\pi m e^2}$

So $v_c = \frac{nh}{2\pi(2\pi mr)r} = \frac{nh}{4\pi^2 m r^2}$

Putting the value of r, we get

$v_c = \frac{nh}{4\pi^2 m}\frac{\pi^2 m^2 e^4}{n^4 h^4 e d^2}$

or $v_c = \frac{me^4}{4\epsilon_0^2 h^3 n^3}$

which is the same as v for large n.

15) 3

Angular momenta associated with planetary motion are large relative to h.For example, angular momentum of the earth in its orbital motion is of the order to 10^7 h.In terms of the Bohr,s quantization postulate his corresponds to very large value of h (of the order of 10^{70}).For such large values of h, the differences in the successive energies and angular momenta of the quantized levels of the Bohr model are so small compared to the energies and angular moments respectively of the levels that one can, for all practical purpose, consider the level continuous.

16) r_0=0.53 x 10^{-10}m; 3

(E_1)=13.6 eV;

m_μ=207m; r_μ=?; (E_1)=?

Now, $r = \frac{\epsilon_0 n^2 h^2}{\pi m e^2}$

$\therefore \quad r \infty \frac{1}{m}$

Hence, $\frac{r_\mu}{r_0} = \frac{m_e}{m_\mu}$

and $r_\mu = r_0 \frac{m_e}{m_\mu} = \frac{0.53 \times 10^{-10}}{207}$

$r_\mu = 2.56 \times 101^{-13}$

Also $E_\mu = -\frac{me^4}{8\epsilon_o^2 h^2 n^2}$

$E \infty m$

Hence, $\frac{E_\mu}{E_e} = \frac{m_\mu}{m_e}$

$E_\mu = E_e = \frac{m_\mu}{m_e} = -13.6 \times 207$

=-2815.2 eV

=-2.81452 keV.

Section-D

17) $Here, \quad r_0 = ?$ 5

$K.E. = \frac{1}{2} mv^2 = 5.0 MeV = 5 \times 1.6 \times 10^{-13} J$

$Z = 79 \quad for \quad gold.$

$r_0 = \frac{1}{4\pi\varepsilon_0} \frac{(Ze) \quad (e)}{\left(\frac{1}{2} mv^2\right)}$

$= \frac{9 \times 10^9 \times 79 \left(1.6 \times 10^{-19}\right)^2}{5 \times 1.6 \times 10^{-13}}$

$2.27 \times 10^{-14} m$

18) $Here, \quad r_0 = ? \quad Z = 80$ 5

$\frac{1}{2} mv^2 = 8 MeV = 8 \times 1.6 \times 10^{-13} J$

$r_0 = \frac{1}{4\pi\varepsilon_0} \frac{(Ze) \quad (2e)}{\left(\frac{1}{2} mv^2\right)}$

$= \frac{9 \times 10^9 \times 2 \times 80 \left(1.6 \times 10^{-19}\right)^2}{8 \times 1.6 \times 10^{-13}}$

$2.82 \times 10^{-14} m$

19) $Here, \quad K.E = \frac{1}{2} mv^2 = 5 MeV$ 5

$= 5 \times 1.6 \times 10^{-13} J$

$\theta = 10^\circ, Z = 79, b = ?$

$As \quad b = \frac{Ze^2 cot\theta/2}{4\pi\varepsilon_0 \left(\frac{1}{2} mv^2\right)}$

$b = \frac{9 \times 10^9 \times 79 \left(1.6 \times 10^{-19}\right)^2 cot5^\circ}{5 \times 1.6 \times 10^{-13}}$

$= \frac{9 \times 79 \times 1.6 \times 1.6 \times 10^{-16}}{8 \times 0.0875}$

$= 2.6 \times 10^{-13} m$

20) $Here, \quad r_0 = 2.8 \times 10^{-14} m, Z = 79,$
$E = ?$
$From \quad E = \frac{1}{4\pi\varepsilon_0} \frac{(Ze)(2e)}{r_0}$
$E = \frac{1}{4\pi\varepsilon_0} \frac{2Ze^2}{r_0} = \frac{9\times10^9 \times 2\times 79 \left(1.6\times10^{-19}\right)^2}{2.8\times10^{-14}}$
$= 1.300 \times 10^{-12} J$
$= \frac{1.300\times10^{-12}}{1.6\times10^{-13}} MeV = 8.125 MeV$
$As \quad E \quad is \quad doubled, r_0 \quad becomes \quad half$
$\frac{r_0}{2} = 1.4 \times 10^{-14} m$