Blue Print (As per PU Board)

Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
Atoms	–	–	–	1	5

One mark questions

1. **Define impact parameter as referred to scattering of $\alpha-$particles experiment. What is its value for head on collision?**
Answer: Impact parameter is defined as the perpendicular distance of the initial velocity vector of the $\alpha-$particles from the centre of the nucleus. The value of impact parameter is zero for head on collision.

2. **How do the (i) Orbital speed and time period of an electron vary with the principal quantum number?**
Answer: If v is the orbital speed of an electron in the n^{th} orbit,

$v \propto \frac{1}{n}$ | $T \propto n^3$

$\frac{v_1}{v_2} = \frac{n_2}{n_1}$ | $\frac{T_1}{T_2} = \frac{n_1^3}{n_2^3}$

3. **Define excitation energy and ionisation energy.**
Answer: Excitation energy is defined as the energy required to make an electron jump from a lower orbit to a higher orbit.
Ionisation energy is defined as the energy required to remove an electron from the ground state of the atom.

Two marks questions

4. **The radius of the innermost electron orbit of a hydrogen atom is $5.3 \times 10^{-11}\text{m}$. What are the radii of the $n=2$ and $n=3$ orbits?**
Answer: $r_1 = 5.3 \times 10^{-11}\text{m}$

$r_n = n^2 r_1$

$r_2 = 2^2 r_1 = 4 \times 5.3 \times 10^{-11}\text{ m} = 2.12 \times 10^{-10}\text{m}$ (1 mark)

$r_3 = 3^2 r_1 = 9 \times 5.3 \times 10^{-11}\text{ m} = 4.77 \times 10^{-11}\text{m}$ (1 mark)

5. **What is the shortest wavelength present in the Paschen series of spectral lines? Given Rydberg's constant of hydrogen $= 1.097 \times 10^7\text{ m}^{-1}$.** **(2 marks)**
Answer: $\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{\infty^2}\right] = \frac{R}{9}$ (1 mark)

$\lambda = \frac{9}{R} = \frac{9}{1.097 \times 10^7} = 8.204 \times 10^{-7}\text{ m}$

$\lambda = 820\text{nm}$ (1 mark)

6. **The ground state energy of hydrogen atom is -13.6eV. What are the kinetic and potential energies of the electron in this state?** **(2 marks)**
Answer: Total energy $= -13.6\text{eV} = E$

Kinetic energy $= +13.6\,\text{eV}$ (1 mark)

Potential energy $= 2E$

$= -27.2\,\text{eV}$ (1 mark)

Three marks questions

7. A $12.5\,\text{eV}$ electron beam is used to bombard gaseous hydrogen at room temperature. What series of wavelengths will be emitted? **(3 marks)**

Answer: $\Delta E = 12.51 - 13.60 = -1.51\,\text{eV}$ (1 mark)

$12.5\,\text{eV}$ Electrons beam can strike electrons in the $n = 1$ energy level when they can get excited up to $n = 3$ energy level. So transitions can occur from $n = 3$ to $n = 1$ and $n = 2$ (1 mark)

Hence we get Lyman series and Balmer series of spectral lines. (1 mark)

8. State the basic postulates of Bohr's theory.

Answer:

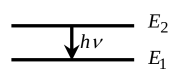
(i) An electron cannot move round the nucleus in all orbits. It can move only in certain discrete discontinuous orbits. (1 mark)

(ii) The permitted orbits are those in which the angular momentum of the electron is an integral multiple of $\frac{h}{2\pi}$.

$mvr = \frac{nh}{2\pi}$ (1 mark)

(iii) When the electron moves in these orbits, energy is not given out. Energy is given out only when an electron from a higher permitted orbit jumps down to a lower permitted orbit. The difference in energies is emitted in the form of radiation

$(E_2 - E_1) = h\nu$



(1 mark)

9. Calculate the energy of various energy levels and draw the energy level diagram for hydrogen.

Answer: The total energy of an electron in the n[th] orbit of hydrogen atom is given by

$E_n = -\frac{13.6}{n^2}\,\text{eV}$ (1 mark)

In the first orbit, $n = 1$, $E_1 = -13.6\,\text{eV}$

In the second orbit, $n = 2$, $E_2 = -3.4\,\text{eV}$

In the third orbit, $n = 3$, $E_3 = -1.51\,\text{eV}$

In the fourth orbit, $n = 4$, $E_4 = -0.85\,\text{eV}$

In the fifth orbit, $n = 5$, $E_5 = -0.54\,\text{eV}$

(1 mark)

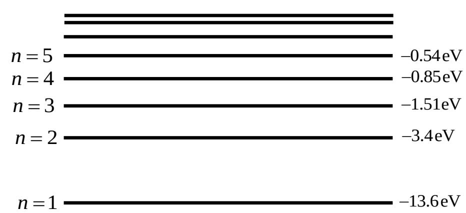
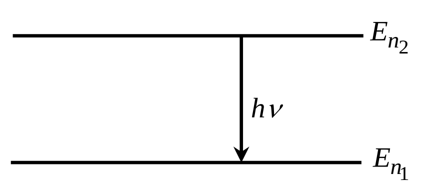


fig. (1 mark)

Five marks questions

10. Assuming expression for the total energy of an electron in the n[th] orbit of hydrogen atom derive an expression for the wave number of the emitted spectral line **(5 marks)**

Answer: Consider an electron in the n_2^{th} orbit where it has energy E_{n_2}. In a lower energy state, n_1^{th} orbit of it has energy E_{n_1}. When the electron jumps down from the n_2^{th} orbit to the n_1^{th} orbit, the difference in energies is emitted in the form of a quantum of light energy. i.e., a photon of frequency ν is emitted.



$E_{n_2} - E_{n_1} = h\nu$ (1 mark)

If λ is the wave length of the emitted photon

Then, $E_{n_2} - E_{n_1} = \frac{hc}{\lambda}$ … (1)

$E_{n_2} = -\dfrac{Z^2 e^4 m}{8\varepsilon_o^2 n_2^2 h^2}$, $E_{n_1} = -\dfrac{Z^2 e^4 m}{8\varepsilon_o^2 n_1^2 h^2}$ (1 mark)

$E_{n_2} - E_{n_1} = -\dfrac{Z^2 e^4 m}{8\varepsilon_o^2 n_2^2 h^2} - \left[-\dfrac{Z^2 e^4 m}{8\varepsilon_o^2 n_1^2 h^2}\right]$

$= \dfrac{Z^2 e^4 m}{8\varepsilon_o^2 h^2}\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$

But $E_{n_2} - E_{n_1} = \dfrac{hc}{\lambda}$ (1 mark)

$R = \dfrac{Z^2 e^4 m}{8\varepsilon_0^2 c h^3}$

$\therefore \dfrac{hc}{\lambda} = \dfrac{Z^2 e^4 m}{8\varepsilon_0^2 h^2}\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$; $\dfrac{1}{\lambda} = \dfrac{Z^2 e^4 m}{8\varepsilon_0^2 c h^3}\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right] \Rightarrow \dfrac{1}{\lambda} = R\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$ (1 mark)

$R = \dfrac{Z^2 e^4 m}{8\varepsilon_o^2 c h^3}$ is a constant called Rydberg's constant. It is a constant for a given element. (1 mark)

11. A hydrogen atom initially in the ground level absorbs a photon which excites it to the $n = 4$ level. Determine the wavelength and frequency of photon.

Answer: $\Delta E = E_4 - E_1$ (1 mark)

$= -0.85 - (-13.6)$

$= 12.75\,\text{eV} = 12.75 \times 1.6 \times 10^{-19} J = 30.4 \times 10^{-19}\,\text{J}$ (1 mark)

$\Delta E = 3.04 \times 10^{-18}\,\text{J}$

$\Delta E = h\nu$ (1 mark)

$\nu = \dfrac{\Delta E}{h} = \dfrac{3.04 \times 10^{-18}}{6.625 \times 10^{-34}}$

$= 0.458 \times 10^{16}$

$\nu = 4.58 \times 10^{15}\,\text{Hz}$ (1 mark)

$\lambda = \dfrac{c}{\nu} = \dfrac{3 \times 10^8}{4.58 \times 10^{15}}$

$= 0.655 \times 10^{-7}\,\text{m}$

$\lambda = 655\text{Å}$ (1 mark)

12. (a) Using Bohr's model calculate the speed of the electron in the hydrogen atom in the $n = 1, 2$ and 3 levels.
(b) Calculate the orbital period in each of these levels.

Answer:

(a) $v_n = \dfrac{e^2}{2nh\varepsilon_o}$ (1 mark)

$v_1 = \dfrac{(1.6 \times 10^{-19})^2}{2 \times 6.625 \times 10^{-34} \times 8.854 \times 10^{-12}}$

$= \dfrac{2.56 \times 10^{-38}}{13.250 \times 8.854 \times 10^{-46}}$

$= 0.0218 \times 10^8$

$= 2.18 \times 10^6\,\text{ms}^{-1}$

$$v_2 = \frac{v_1}{2} = \frac{2.18\times10^6}{2} = 1.09\times10^6\,\text{ms}^{-1}$$

$$v_3 = \frac{v_1}{3} = \frac{2.18\times10^6}{3} = 0.73\times10^6\,\text{ms}^{-1}$$ (1 mark)

(b) $T_1 = \frac{2\pi r_1}{v_1} = \frac{2\pi\times0.53\times10^{-10}}{2.18\times10^6}$ (Taking $r_1 = 0.53\text{Å}$) (1 mark)

$$= \frac{1.06\times3.14}{2.18}\times10^{-16}\,\text{s}$$

$= 1.52\times10^{-16}\,\text{s}$ (1 mark)

$$T_2 = 2^3 T_1$$

$$= 8\times1.52\times10^{-16}$$

$$T_2 = 12.16\times10^{-16}\,\text{s}$$

$$= 1.22\times10^{-15}\,\text{s}$$

$$T_3 = 3^3 T_1$$

$= 27\times1.52\times10^{-16}\,\text{s} = 4.104\times10^{-15}\,\text{s}$ (1 mark)