Atoms

Que 1: Bohr proposed a new model of atom to overcome a problem of Rutherford's atom model.

a) Which specific problem of the Rutherford model was attempted to be solved by Bohr model?

b) What are the basic postulates of Bohr model?

c) The radius of the inner most electron orbit of a hydrogen atom is 5.3 x 10 -11 m. What are the radii of then n =2 and n=3 orbits? ***Marks :(5)***

Ans: a) stability of atom

b) *Electrons in an atom can revolve in certain stable orbits without radiating energy.*

The electron revolves around the nucleus only in those orbits for which the angular momentum is some integral multiple of h/2π where h is the Planck's constant (= 6.6 × 10–34 J s).

An electron might make a transition from one of its specified non-radiating orbits to another of lower energy.

c) $r_n = a_0 n^2$

r2 = 5.3 x 10 -11 x 4= 21.2 x 10 -11m

r4 = 5.3 x 10 -11 x 16= 84.8 x 10 -11m

Que 2: The wavelength associated with a particle is called the de Broglie wavelength. From Bohr's postulate of quantization of angular momentum arrive at an expression for the wavelength of an orbital electron. Comment on the result. ***Marks :(2)***

Ans:

$$2\pi r_n = n\lambda, \quad n = 1, 2, 3\ldots$$

$$2\pi r_n = n h/m v_n \quad \text{or} \quad m v_n r_n = nh/2\pi$$

This shows that electrons behaves as particle waves.

Que 3: a. List out any two limitations of Bohr atom model.

b. According to de Broglie's explanations of Bohr's second postulate of quantization, the standing particle wave on a circular orbit for n = 4 is given by

i) 2πrn = 4/λ ii) 2π/ λ = 4rn iii) 2πrn = 4λ iv) λ / 2π = 4rn ***Marks :(3)***

Ans:

1. Bohr’s theory is applicable only to single electron atoms, This theory gives no idea about relative intensities of spectral lines, Could not explain the fine structure of hydrogen spectrum
2. iii) $2\pi rn = 4\lambda$

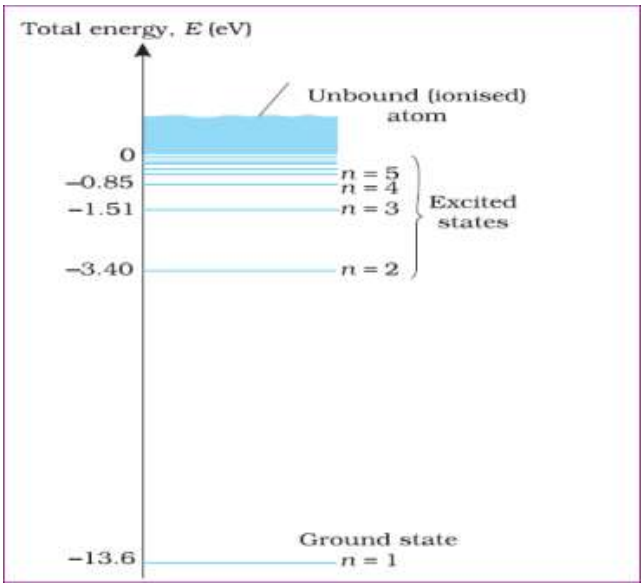
Que 4: The atomic hydrogen emits lines spectrum consisting of various series.

(a) Name the series observed first.

(b) Draw the energy level diagram of hydrogen atom. ***Marks :(3)***

Ans: 1. Balmer series

2.



Que 5: The simple Bohr model is not applicable to He4 atoms because

a) He4 is an inert gas

b) He4 has neutrons in the nucleus

c) He4 has one more electron

d) Electrons are not subjected to central forces ***Marks :(1)***

Ans: c) He4 has one more electron

Que 6: The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of the electron in this state? ***Marks :(2)***

Ans:

$$KE = \frac{1}{8\pi\varepsilon_0}.\frac{e^2}{r} \qquad PE = \frac{-1}{4\pi\varepsilon_0}.\frac{e^2}{r}$$

$$\therefore KE = -\frac{1}{2}PE$$

Total energy = E = KE+PE = −13.6 eV

$$i.e., PE - \frac{1}{2}PE = -13.6\,eV$$

$$PE = -27.2\,eV$$
$$\therefore KE = 13.6\,eV$$

Que 7: A difference of 2.3 eV separates two energy levels in an atom. What is the frequency of radiation emitted when the atom makes a transition from the upper level to the lower level? ***Marks :(2)***

Ans: $E = 2.3\,eV = 2.3 \times 1.6 \times 10^{-19} J$

h= 6.626x 10^{-34} Js

$$E = h\upsilon, \upsilon = \frac{E}{h}$$

$$\therefore \upsilon = \frac{2.3 \times 1.6 \times 10^{-19}}{6.626 \times 10^{-34}} = 5.56 \times 10^{14}\,Hz$$

Que 8: What is the shortest wavelength present in the Paschen series of spectral lines ***Marks :(2)***

Ans:

$$n = \infty, R = 1.097 \times 10^7 m^{-1}$$

$$\frac{1}{\lambda} = R\left[\frac{1}{3^2} - \frac{1}{n^2}\right]$$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left[\frac{1}{9}\right]$$

$$\lambda = \frac{9}{1.097 \times 10^7}\left[\frac{1}{9}\right]$$

$$= 8.199 \times 10^{-7} = 8199\,\mathring{A}$$

Que 9: Suppose you are given a chance to repeat the alpha-particle scattering experiment using a thin sheet of solid hydrogen in place of the gold foil. (Hydrogen is a solid at temperatures below 14 K) What results do you expect?
Marks :(2)

Ans: The nucleus of a hydrogen atom is a proton. The mass of it is $1.67 \times 10^{-27} kg$.

Whereas the mass of an incident α particle won't bounce back in even in a head on collision. It is similar to a football colliding with a tennis ball at rest. Thus, there would be no large-angle scattering.

Que 10: The positively charged part of the atom possesses most of the mass in .....(Rutherford's model/both the models). ***Marks :(1)***

Ans: Both the models

Que 11: The positively charged part of the atom possesses most of the mass in .....(Rutherford's model/both the models). ***Marks :(1)***

Ans: Both the models

Que 12: An atom has a nearly continuous mass distribution in a .....but has a highly non-uniform mass distribution in ..... (Thomson's model/Rutherford's model) ***Marks :(2)***

Ans: Thomson's model; Rutherford's model

Que 13: A classical atom based on .....is doomed to collapse. (Thomson's model/Rutherford's model.) ***Marks :(1)***

Ans: Rutherford's model

Que 14: In the ground state of ..... electrons are in stable equilibrium, while in..... electrons always experience a net force. (Thomson's model/Rutherford's model.)
Marks :(2)

Ans: Thomson's model; Rutherford's model

Que 15: The size of the atom in Thomson's model is ..... the atomic size in Ruther ford's model. (much greater than/not different from/much less than)
Marks :(1)

Ans: Not different from

Que 16: Louis de Broglie argued that electron in circular orbit as proposed by Bohr, must be seen as a Particle wave.

a) From Bohr's postulate of angular quantization momentum, arrive at an expression for wave length of an orbital electron?

b) Comment on the above result. ***Marks :(5)***

Ans:

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

$\lambda = \frac{h}{mv}$

From (1) & (2)

$\frac{hr}{\lambda} = \frac{nh}{2\pi}$

$\lambda = \frac{2\pi r}{n}$

c) Since $\lambda = \frac{2\pi r}{n}$, length of the first orbit is the de- Broglie wave length of the orbit.

Que 17: Bohr combined classical and early quantum concept and gave his theory in form of three postulates.

a) State three postulates of Bohr Model of atom?

b) The total energy of an electron in ground state of an hydrogen atom is - 13.6 eV. What is the significance of negative sign?

c) The radius of inner most electron orbit of hydrogen atom is 5.3×10^{-11} m. What are the radii of n=2 and n=3 orbits? ***Marks :(5)***

Ans: a) State 3 Postulates

1) Atom consists of a positively charged centre called nucleus.

2) The electrons revolve around the nucleus in circular orbits. Only those orbits are allowed in which the angular momentum is an integral multiple of h/2π.

3) An electron revolving in a permitted orbit does not radiate energy. So the energy in an orbit remains constant. The permitted orbits are called stationary orbits.

4) When electron jumps from higher orbit to lower orbit, electromagnetic radiation is emitted.

The equation is $h\upsilon = E_2 - E_1$

b) Negative sign implies that the electrons are strongly bounded to the nucleus

c) $r_n = n^2 a_0 = 5.3 \times 10^{-11} m$

$r_1 = a_0 = 5.3 \times 10^{-11} m$

$r_2 = 4a_0 = 21.2 \times 10^{-11} m$

$r_3 = 9a_0 = 47.7 \times 10^{-11} m$

Que 18: Study of emission line spectra of a material serve as a fingerprint for identification of the gas.

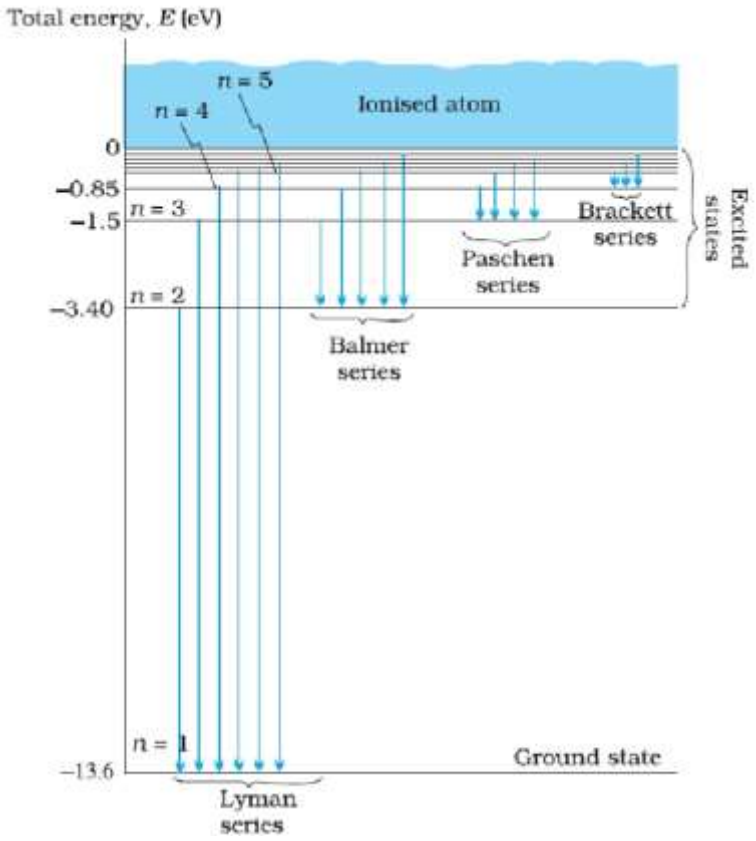
a) Name different series of lines observed in hydrogen spectrum

b) Draw energy level diagram of hydrogen atom?

c) Write down the Balmer formula for wavelength of H_α line. (1)

d) Given Rydberg constant as 1. 097x10^7 m^{-1}. Find the longest and shortest wavelength limit of Balmer Series. ***Marks :(5)***

Ans: a) Lyman series, Balmer series, Paschen series, Bracket series, Refund Series.



c) $\bar{\nu} = \frac{1}{\lambda} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R_H \left[\frac{1}{2^2} - \frac{1}{3^2}\right]$

d)

$\bar{\nu} = \frac{1}{\lambda} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Longest wavelength n_1 =2 and n_2 =3

$\bar{\nu} = \frac{1}{\lambda} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R_H \left[\frac{1}{2^2} - \frac{1}{3^2}\right] = 1.097 \times 10^7 \times \frac{5}{36}$

$\lambda = \frac{1}{R_H \left[\frac{1}{2^2} - \frac{1}{3^2}\right]} = 6563 \times 10^{-10} m$

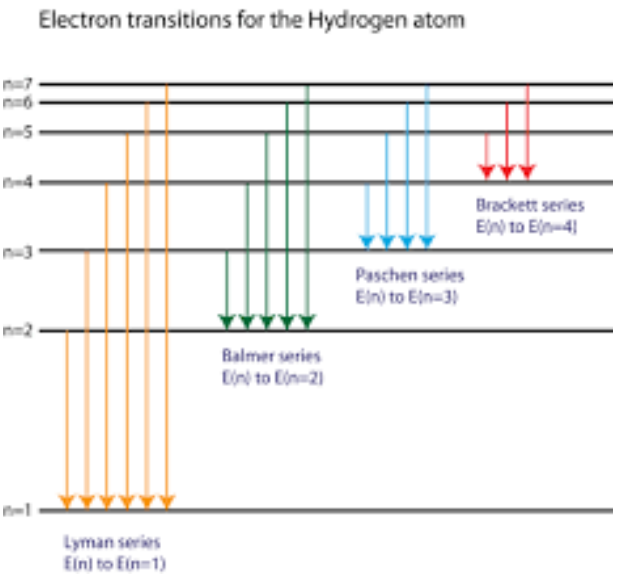
Shortest Wavelength n_1=2 and n_2 = α

$\bar{\nu} = \frac{1}{\lambda} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R_H \left[\frac{1}{2^2} - \frac{1}{\alpha^2}\right]$

$\lambda = \frac{1}{R_H \left[\frac{1}{2^2} - \frac{1}{\alpha^2}\right]} = \frac{1}{1.097 \times 10^7 \left(\frac{1}{4}\right)} = 3646 \times 10^{-10} m$

Que 19: Draw the energy level diagram of hydrogen spectrum ***Marks :(2)***

Ans:



Que 20: In Rutherford's α particles scattering experiment ,he used particles of energy 5.5 MeV and gold foil of thickness as small as 2.1×10^{-10}m

a) What will be the angle of scattering when impact parameter is zero

b) How does the angle of scattering change with impact parameter

c) Why the size of gold foil is made extremely small

d) Can you conduct the experiment with aluminium foil ***Marks :(5)***

Ans: a) 180^0

Impact parameter $b = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze^2 \cot\left(\frac{\theta}{2}\right)}{E_k}$

where, Z = atomic number of the nucleus, E_k = kinetic energy of the c-particle and θ = angle of scattering.

As the impact parameter b increases cot(Ɵ/2) increases, and hence the angle of scattering Ɵ decreases

c) Gold foil can be made extremely small comparable with the size of gold nucleus

d) No, Aluminium foil cannot be made as much thin. more over atomic number of aluminium is small compared with gold so that the repulsive force is small and scattering is a mall

Que 21: Louis de Broglie argued that electron in circular orbit as proposed by Bohr, must be seen as a Particle wave.

a) From Bohr's postulate of angular quantization momentum, arrive at an expression for wave length of an orbital electron?

b) Comment on the above result. ***Marks :(3)***

Ans:

(a) $mvr = nh$ ..... (1)

2π

$\lambda = \frac{h}{mv}$ ..... (2)

From (1) & (2)

$\frac{hr}{\lambda} = \frac{nh}{2\pi}$

$\lambda = \frac{2\pi r}{n}$

(b) Since **λ** =2πr/n, length of the first orbit is the de- Broglie wave length of the orbit.

Que 22: Study of emission line spectra of a material serve as a fingerprint for identification of the gas.

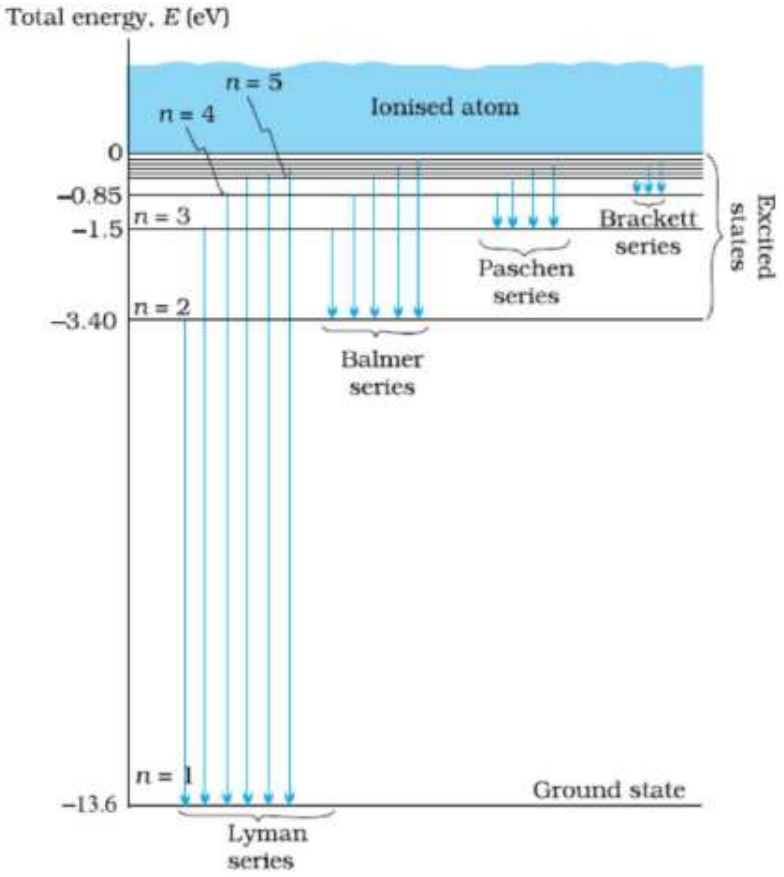
(a) Name different series of lines observed in hydrogen spectrum

(b) Draw energy level diagram of hydrogen atom?

(c) Write down the Balmer formula for wave length of Hα line.

(d) Given Rydberg constant as 1. 097x10^{7} m$^{-1.}$ Find the longest and shortest wavelength limit of Balmer Series. ***Marks :(5)***

Ans: (a) Lyman series, Balmer series, Paschen series, Bracket series, P fund Series.



c) $\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$

d) $\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Longest wavelength $n_1 = 2$ and $n_2 = 3$

$$\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = 1.097\times10^{7}\times\frac{5}{36}$$

$$\lambda = \frac{1}{R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right]} = 6563\times10^{-10}\,m$$

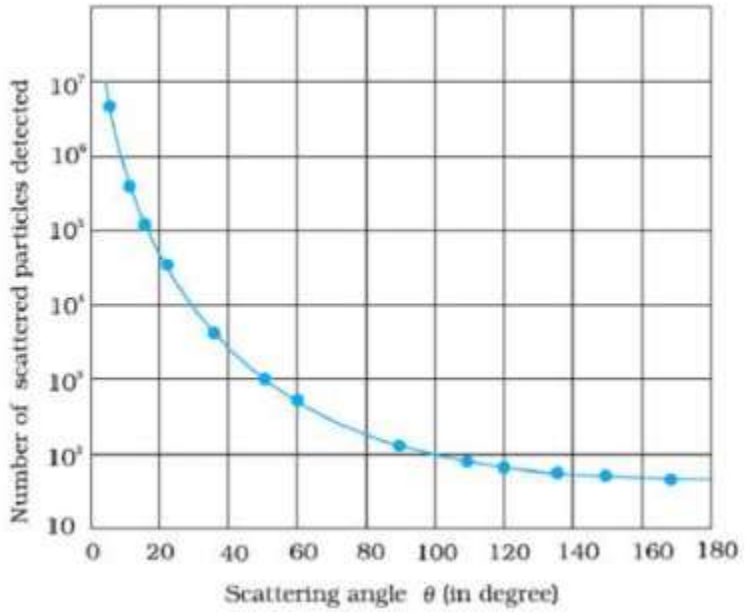
Shortest Wavelength $n_1=2$ and $n_2 = \alpha$

$$\bar{\nu} = \frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R_H\left[\frac{1}{2^2} - \frac{1}{\alpha^2}\right]$$

$$\lambda = \frac{1}{R_H\left[\frac{1}{2^2} - \frac{1}{\alpha^2}\right]} = \frac{1}{1.097\times10^7\left(\frac{1}{4}\right)} = 3646\times10^{-10}\,m$$

Que 23: In Geiger-Marsden Scattering experiment alpha particles of 5.5 MeV is allowed to fall on a thin gold foil of thickness 2.1x10-7m.

(a) Draw Schematic diagram of above experimental arrangement.

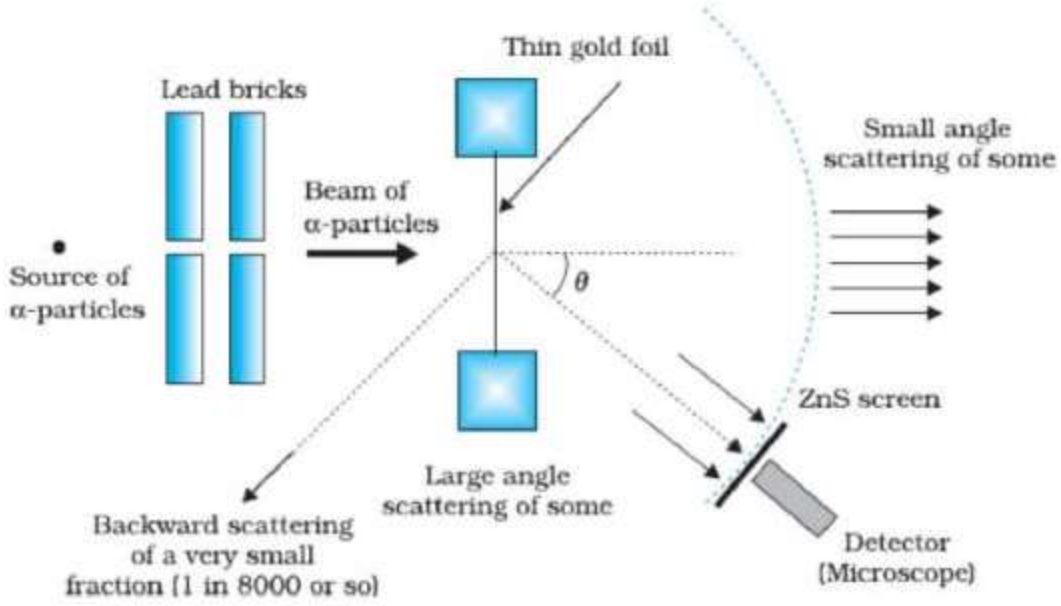


b) In the above graph nearly 10^7 particles were detected when scattering angle is Zero. What you understand by it?

(c) Why gold foil is used in this experiment?

(d) Does there exist any relation between impact parameter and scattering angle? If yes explain your answer? ***Marks :(5)***

Ans:



(b) Most of the alpha particles get unscattered means that most of the space in an atom is empty.

(c) Atomic number of gold is 79, so number of protons is very high. Hence scattering between alpha and nucleons is larger. Gold foil can be made very thin so that the alpha particles suffer not more than one scattering.

(d) Yes, As impact Parameter increases, scattering angle decreases.

Que 24: A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. What series of wavelengths will be emitted? ***Marks :(1)***

Ans:

$$E=\frac{hc}{\lambda}, \lambda=\frac{hc}{E}=\frac{6.626\times10^{-34}\times3\times10^{8}}{12.5\times1.6\times10^{-19}}=99\,\text{nm}$$

On de-excitation, they may produce Balmer series, also i.e., Lyman series

Que 25: The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} . What are the radii of the n = 2 and n =3 orbits? ***Marks :(2)***

Ans:

$$r_n=\text{Kn}^2, K=\frac{4\pi\varepsilon_0 h^2}{4\pi^2 \text{me}^2}=0.53\times10^{-10}=5.3\times10^{-11}m$$

n = 1, $r_1=K$ ¿ $5.3\times10^{-11}m$

$n=2, r_2=4K=21.2\times10^{-11}m$

n = 3, $r_3=9K=47.7\times10^{-11}m$