

## Muonium

In the simple orbital model of the Hydrogen atom, the electron orbits the proton in a planetary fashion. The electron and proton's opposite charge provides a strong attractive force between them. The electron's high speed rotation about the proton provides a centripetal force to counter-balance the electrostatic force. Bohr postulated that angular momentum comes in discrete quanta;  $m_e v r = \frac{n\hbar}{2\pi} = n\hbar$ . Thus, we have:

$$\frac{m_e v^2}{r} = k \frac{q_e q_p}{r^2} \quad (1)$$

$$v^2 = \frac{n^2 \hbar^2}{m_e^2 r^2} \quad (2)$$

$$r = \frac{n^2 \hbar^2}{k m_e q_e q_p} \quad (3)$$

$$(4)$$

So, the classical (or Bohr) radius of the Hydrogen atom is dependent on the energy level  $n$  and the mass of the electron  $m_e$ . For the ground state,  $n = 1$ , we plug in numbers and get  $r = 0.529 \times 10^{-10}\text{m}$ , or  $0.529 \text{ \AA}$ . This ground state is usually called  $a_0$ . The radius  $a_0$  is a constant, and the formula for the radii is usually re-written in terms of this constant:

$$r = a_0 n^2 \quad (5)$$

So what is a muon? A muon is a particle that behaves just like an electron, but whose mass is 206.6 times greater than that of the electron. Muons are typically shown by the symbol  $\mu$  and are a commonplace particle for high energy researchers. Cosmic rays from outer space are mostly made up of very high energy  $\mu$ s. Since there is such an abundance of these particles, they are surprisingly easy to study; they stream through our atmosphere 24 hours a day.

If a  $\mu$  happened to slow down enough to be captured in the attractive pull of a proton, it would begin orbiting just like the electron. But, since its mass is so much greater, its orbit would be 206.6 times smaller. So, the radii of the  $\mu$ -Hydrogen (called muonium) are given by

$$r = \frac{a_0}{206.6} n^2 \quad (6)$$

However, the ground state orbit is now  $0.00256 \text{ \AA}$ , which is close enough to quantum mechanically interfere with the proton. And, the  $\mu$  has a decay time of a few microseconds anyway. So, while it is detectible though the muonium "modified Balmer and Lyman" spectral lines, it doesn't last too long.