

How big is a Hydrogen Atom?

It is very difficult for us to understand the size of things which are widely outside of our normal frame of reference. Let's look at how large a simple hydrogen atom is by comparing it to something more familiar.

What is hydrogen (and why do we care)?

Hydrogen is the simplest chemical element, with an atomic number of 1, meaning its nucleus consists of a single proton. In its normal state (a gas), a hydrogen atom has a single proton nucleus around which "orbits" (the Bohr model) a single electron, giving it a stable net charge of zero. Hydrogen is also the most abundant chemical element in the universe, constituting approximately 75% of all chemical elemental mass [1]. It is not surprising, then, that our own sun (which contains the vast majority of the mass in our solar system) consists of about 73% hydrogen by mass [2].

How big are protons and electrons?

A proton is obviously tiny and is estimated to have a diameter of 1.6-1.7 femtometers = $\sim 1.6 \times 10^{-15}$ meters [3]. The electron is even smaller, having a relative mass of $1/1,836^{\text{th}}$ that of the proton.

As a rough simplification, if one were to assume that the internal density of a proton and an electron were the same, the volume of the electron scales down directly proportional to the mass. If you further simplify that they are spherical in shape, then the diameter of the electron will scale down by the cube root of the volume and thus by the cube root of the relative mass. Let's cast this into terms we can comprehend:

- Assume a proton is the size of a regulation basketball = ~ 75 cm circumference = ~ 24 cm dia
- If you assume protons and electrons are spherical and have the same internal density, then:
$$\text{Diameter electron} = (\text{diameter proton}) * \sqrt[3]{(\text{their relative mass})}$$
- So in our scaled world, if a proton is the size of a basketball, then an electron has:
$$\text{Diameter electron} = (24 \text{ cm}) * \sqrt[3]{1/1836} = \sim 2 \text{ cm}$$
- An average golf ball has a diameter of ~ 1.7 cm, so if our proton were the size of a basketball, the electron "in orbit" around it would be just a bit larger than a golf ball.

So how big is a hydrogen atom?

In the classical, Bohr orbital atomic model, the average distance between the proton and electron in a hydrogen atom at its ground state is called the "Bohr radius", which is $\sim 5.3 \times 10^{-11}$ meters [5]. Let's apply our basketball analogy again:

- Assume a proton is the size of a regulation basketball = ~ 75 cm circumference = ~ 24 cm dia
- Then in a classical, Bohr orbital atomic model, the distance to the electron is given by:
$$\text{Distance to electron} = \text{Bohr radius} * (\text{ratio of the diameters basketball to proton})$$
$$= 5.3 \times 10^{-11} \text{ meters} * \left(\frac{0.24 \text{ meters}}{1.6 \times 10^{-15} \text{ meters}} \right) = \sim 8,000 \text{ meters}$$

So, if our hydrogen atom had a proton in it the size of a basketball, at ground state, the electron would be about the size of a golf ball and would be flying around it about **8 km (~5 miles)** away!!! Stop for a moment and think about the incredible emptiness this represents at the atomic level!

References

- [1] <http://en.wikipedia.org/wiki/Hydrogen>
- [2] <http://en.wikipedia.org/wiki/Sun>
- [3] <http://en.wikipedia.org/wiki/Proton>
- [4] <http://en.wikipedia.org/wiki/Electron>
- [5] http://en.wikipedia.org/wiki/Bohr_radius