CHAPTER OVERVIEW

15: The Hydrogen Atom

The last chapters introduced you to quantum mechanical fundamentals starting from the de Broglie hypothesis. You learned about eigenvalue equations, operators and wavefunctions, and you tackled harder subjects like multidimensional Hamiltonians and rotational motion. Most important, the mathematics of probability and statistics have been shown to be essential for our interpretation of quantum mechanical principles. It is ironic that we wrap up this part of our learning exactly where Schrödinger began; he introduced the world to quantum mechanics by solving the energy levels of the hydrogen atom in the 1926 paper "Quantization as an Eigenvalue Problem." In it, the electron is described with a wavefunction that is centered over a stationary nucleus. And while there are plenty of quantum problems beyond the hydrogen atom, this is the last "pen-and-paper" example that we can solve for reasons you will see at the end of this chapter.

We begin with a historical note on the first explorations on the electronic structure of hydrogen starting with Johann Balmer in 1855. At this time it was known that excited hydrogen emits light over a few discrete wavelengths as shown in Figure 15.1A. Balmer and Johannes Rydberg demonstrated that the emission can be described by the equation:

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where λ is the emission wavelength, n_1 and n_2 are whole numbers, and $R = 1.097 \times 10^7\ m^{-1}$ is a constant named after Rydberg. This introduces the question, why would discrete emissions be observed, and what model for the hydrogen atom would have atomic energy levels that scale according to the square of a whole number? One of the first attempts to model hydrogen that correctly predicted this behavior was developed by Niels Bohr (Nobel Prize, 1922) as discussed below. This attempt also reveals another aspect of science, which is that a scientific theory is either everything or it is nothing.

Reference

1. L. M. Haffner *et al* 2003 *ApJS* **149** 405.