Atomic Structure II: Wave-Particle Duality

1. Using de Broglie's equation, calculate the apparent wavelength of an electron with a velocity of 40.2 m/s. ($m_{electron}$ = 9.11 x 10^{-28} g)

$$\lambda = \frac{h}{mv} = \frac{6.626\times10^{-34}\,\mathrm{J\cdot s}}{(9.11\times10^{-31}\mathrm{kg})(40.2\,\frac{\mathrm{m}}{\mathrm{s}})} = 1.81\times10^{-5}\,\mathrm{m} = 18{,}100\ \mathrm{nm}$$

2. What is the "wavelength" of a baseball (0.181 kg) pitched at this speed? (FYI, 40.2 m/s = ~90 mi/hr)

$$\lambda = \frac{h}{mv} = \frac{6.626\times10^{-34}\,\mathrm{J\cdot s}}{(0.181\ \mathrm{kg})(40.2\,\frac{\mathrm{m}}{\mathrm{s}})} = 9.11\times10^{-35}\,\mathrm{m}$$

3. What prevents us from actually measuring the wavelength calculated in problem 2?

The wavelength of the pitched baseball is many orders of magnitude smaller than the diameter of an atom. There is no practical way to measure wavelengths this small.

4. Just for fun… What is the velocity of a rubidium atom when its de Broglie wavelength is equal to its atomic radius? The atomic radius of Rb is 248 pm. Approximately what temperature is this? Incidentally, this is called the Bose-Einstein condensate.

$$M_{\text{Rb}} = 85.468\,\tfrac{\text{g}}{\text{mol}}$$

$$m_{\text{Rb}} = 85.468\,\tfrac{\text{g}}{\text{mol}} \times \frac{1\text{ mol}}{6.022\times10^{23}\text{ atoms}} \times \frac{1\text{ kg}}{1000\text{ g}} = 1.4193\times10^{-25}\text{ kg}$$

$$\lambda = \frac{h}{m\text{v}} \quad \text{so...} \quad \text{v} = \frac{h}{m\lambda} = \frac{6.626\times10^{-34}\,\text{J}\cdot\text{s}}{(1.4193\times10^{-25}\text{ kg})(248\times10^{-12}\text{ m})} = 18.8\,\tfrac{\text{m}}{\text{s}}$$

$$u = \sqrt{\frac{3RT}{M}} \quad \text{so...} \quad T = \frac{u^2 M}{3R} = \frac{(18.8\,\tfrac{\text{m}}{\text{s}})^2(0.085468\,\tfrac{\text{kg}}{\text{mol}})}{3(8.314\,\tfrac{\text{J}}{\text{mol}\cdot\text{K}})} = 1.21\text{ K}$$