The Bond Length of Water

September 9, 2011

Points Awarded

1. Zero points: no work at all/not in class to participate
2. 1 point: attempted the problem
3. 2 points: solved the problem (correct units and number, but ignore significant figures in the answer)

Solution

A water molecule (H_2O) has an electric dipole moment $p = 6.2 \times 10^{-30}\,\mathrm{C \cdot m}$ and contains 10 protons and 10 electrons. The angle between the two hydrogen atoms, relative to the center of the oxygen atom, is about 105°. What is the bond length of water between one hydrogen and one oxygen atom?

The dipole moment is related to the separation of the charges as follows:

$$p = qd$$

and we need to hypothesize what the magnitude of the charge on each end of the dipole could be. We easiest assumption is to say that all the negative charge migrates to one side and all the positive to the other, making $q = 10e$. We can then solve for the dipole separation:

$$d = p/q = 3.87 \times 10^{-12}\,\mathrm{m}.$$

But we need the *bond length*, the distance not between the positive side and the negative side but between one hydrogen atom and the oxygen atom. The dipole length forms one side of a right triangle, the bond length forms the hypotenuse of that triangle, and the angle between the two is half of 105°. Thus:

$$l = d/\cos(52.5^\circ) = 6.4 \times 10^{-12}\,\mathrm{m} = 6.4\,\mathrm{pm}.$$

The typical atomic size is a few Angstrom; this is much smaller! This molecular bond forms a quantum structure that is more compact that any single atom.