X-ray photoelectron spectroscopy is a method for detecting the presence of atoms on a surface. In this method a high energy X-ray ionizes the molecule by kicking out a core electron (i.e. an electron from a 1s orbital). Any excess energy leaves with the electron as kinetic energy.

A. Calculate the kinetic energy in Joules of an electron ejected from a nitrogen atom using a 100 eV X-ray. (Hint: assume that nitrogen is just a hydrogen atom with a different nuclear charge)

Solution:

a. The energy necessary to remove an e^- from an atom is known as the ionization energy.
b. If one were to treat the system as a hydrogen atom, then the ionization energy is the amount of energy required to raise an e^- from the ground state to the continuum. However, nitrogen has a nuclear charge of 7. Therefore, the energy is

$$E = -\frac{ZR}{n^2}$$

c. In units of eV R = 13.6 eV. Here, n = 1 since the electron is in a 1s orbital. Therefore, the ionization energy is:

$$IE = -ZR = -7(13.6\ eV) = 95.2\ eV$$

The kinetic energy is:

$$T = eE - IE = 100\ eV - \ 95.2\ eV = 4.8\ eV$$

In Joules

$$T = 1.602\ x\ 10^{-19}\ C(4.8\ eV) = 7.68\ x\ 10^{-19}\ J$$

B. Calculate the velocity of the electron in m/s.

$$v = \sqrt{\frac{2T}{m}} = \sqrt{\frac{2(7.68\ x\ 10^{-19}\ J)}{9.1\ x\ 10^{-31}\ kg}} = 1.30\ x\ 10^{6}\ m/s$$

C. Calculate the wavelength of the electron.

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mT}} = \frac{6.626\ x\ 10^{-34}\ Js}{\sqrt{2(9.1\ x\ 10^{-31}\ kg)(7.68\ x\ 10^{-19}\ J)}}$$

$$\lambda = 5.6\ x\ 10^{-10}\ m = 5.6\ \text{Å}$$