Quantum Mechanics

K and L lines

Problem 1.- A nickel target is bombarded with fast electrons. Estimate the minimum kinetic energy needed to produce x-rays of the K series.

Solution: We need to remove an electron from the shell n=1. We can estimate the energy by approximating it as a hydrogenic atom with charge Z-1. The "1" comes from the other electron in the same orbital that shields some of the charge of the nucleus.

$$E = 13.6eV(Z-1)^2 = 13.6eV(28-1)^2 = \mathbf{9{,}910eV}$$

Problem 2.- The ratio of the energies of the $K\alpha$ X-rays of carbon (Z=6) to those of sodium (Z=11) is most nearly:

(A) 1/3 (B) 1/2 (C) 1/4 (D) 2 (E) 4

Solution: The energies of the $K\alpha$ lines can be approximated by the hydrogenic energies:

$$\Delta E = \left(\frac{1}{1^2} - \frac{1}{2^2}\right) 13.6eV(Z-1)^2$$

The "-1" in the Z-1 factor comes from the single electron that would occupy the n=1 energy level when we knock off the other electron. In the case of X-rays of carbon (Z=6) and sodium (Z=11) the ratio is:

$$\frac{\Delta E_{Carbon}}{\Delta E_{Sodium}} = \frac{(6-1)^2}{(11-1)^2} = \frac{1}{4}$$

Answer: C

Problem 3.- Calculate the energy of the K-α line of lead.

Solution: This line is produced when an electron from the shell n=2 jumps to occupy the hole left by an electron in the shell n=1. The process could be approximated by a hydrogenic atom where the charge is Z-1 (the "1" comes from the other electron in the first shell).

$$\Delta E = -13.6eV(Z-1)^2\left(\frac{1}{2^2} - \frac{1}{1^2}\right) = -13.6eV(82-1)^2\left(\frac{1}{2^2} - \frac{1}{1^2}\right) = \mathbf{66{,}900eV}$$