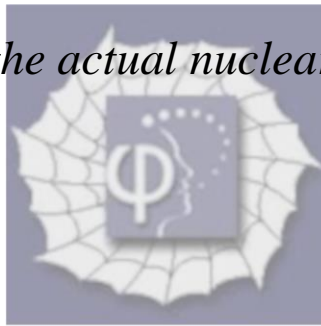


777.

Problem 52.23 (RHK)

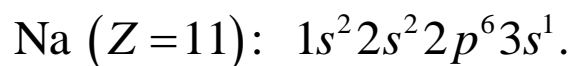
In the alkali metals there is one electron outside a closed shell. Using the Bohr theory, we have to calculate (a) the effective charge number of the nucleus as seen by the valence electron in sodium (ionization energy = 5.14 eV) and potassium (ionization energy = 4.34 eV). (b) For each element, we have to find what fraction is this of the actual nuclear charge Z ?



Solution:

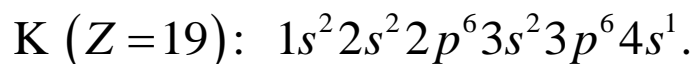
(a) and (b)

The electronic configuration of the lowest energy state of the Na atom is



We note that the valence electron of the Na atom is in the shell $n = 3$.

The electronic configuration of the lowest energy state of the K atom is



We note that the valence electron of the K atom is in the shell $n = 4$.

Let the effective charge that the valence electron sees be $Z'e$. In the Bohr model of atom the energy of the state with principal quantum number n of an electron in the Coulomb field of effective charge $Z'e$ is

$$E_n = -13.6 \times \frac{Z'^2}{n^2} \text{ eV.}$$

As the ionization energy of the Na atom is $= 5.14 \text{ eV}$, its effective charge will be $Z'e$. It is given by

$$5.14 \text{ eV} = 13.6 \times \frac{Z'^2}{3^2} \text{ eV,}$$

or

$$Z' = \left(\frac{5.14 \times 3^2}{13.6} \right)^{1/2} = 1.84.$$

As the actual nuclear charge of Na is $11e$, the fraction of the actual charge that the valence electron of the Na atom sees is 0.167.

As the ionization energy of the K atom is $= 4.34 \text{ eV}$, its effective charge will be $Z'e$. It is given by

$$4.34 \text{ eV} = 13.6 \times \frac{Z'^2}{4^2} \text{ eV},$$

or

$$Z' = \left(\frac{4.34 \times 4^2}{13.6} \right)^{1/2} = 2.26 .$$

As the actual nuclear charge of K is $19e$, the fraction of the actual charge that the valence electron of the K atom sees is 0.119 .

