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<u>Problem 52.23 (RHK)</u>

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* $= 5.14\ \text{eV}$) *and potassium* (*ionization energy* $= 4.34\ \text{eV}$). (b) *For each element, we have to find what fraction is this of the actual nuclear charge* Z?

<u>Solution:</u>

(a) and (b)

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

$$\text{Na}\ (Z = 11):\ \ 1s^2 2s^2 2p^6 3s^1.$$

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

$$\text{K}\ (Z = 19):\ \ 1s^2 2s^2 2p^6 3s^2 3p^6 4s^1.$$

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 .