744.

Problem 51.7 (RHK)

We have to calculate the binding energy of the hydrogen atom in the first excited state.

Solution:

The allowed energy of the stationary states of the hydrogen atom are given by the equation

$$E_n = -\frac{1}{2\times n^2} mc^2 \times \left(\frac{e^2}{4\pi\varepsilon_0 \mathrm{hc}}\right),\ n = 1, 2, 3..$$

$$= -\frac{0.51}{2n^2} \times \left(\frac{1}{137}\right)^2 \mathrm{MeV} = -\frac{13.58}{n^2}\ \mathrm{eV},$$

we have used the result that the fine structure constant $\alpha = \dfrac{e^2}{4\pi\varepsilon_0 \mathrm{hc}} = \dfrac{1}{137}$.

The first excited state of the hydrogen atom corresponds to the principal quantum number $n = 2$. Therefore, the energy of the first excited state of hydrogen atom will be

$$E_2 = -\frac{13.58}{2^2}\ \mathrm{eV} = -3.39\ \mathrm{eV}.$$

The binding energy by definition is the minimum energy required for making electron from the atom free. The energy of a free electron is zero. Therefore, the binding energy of the first excited state of hydrogen atom will be $B_2 = 0 - E_2 = 3.39$ eV.