290.

Problem 27.36 (RHK)

In the radioactive decay of $^{238}\mathrm{U}$ ($^{238}\mathrm{U} \rightarrow {}^{4}\mathrm{He} + {}^{234}\mathrm{Th}$), *the centre of the emerging* $^{4}\mathrm{He}$ *particle is, at a certain instant,* 12×10^{-15} m *from the centre of the residual* $^{234}\mathrm{Th}$ *nucleus. We have to find at that instant* (a) *the force on the* $^{4}\mathrm{He}$ *particle, and* (b) *its acceleration.*

Solution:

We note that the atomic number of Th is 92. That is a nucleus of Th has $+92e$ units of charge; and that the atomic number of He is 2 and it has $+2e$ units of charge. Therefore, at the instant when $^{4}\mathrm{He}$ particle is 12×10^{-15} m from the $^{234}\mathrm{Th}$ particle, the magnitude of the electrostatic force on it will be

$$F_c = \frac{(2e)\times(92e)}{4\pi\varepsilon_0 d^2} = \frac{8.99\times10^9\times184\times\left(1.6\times10^{-19}\right)^2}{\left(12\times10^{-15}\right)^2}\ \mathrm{N}$$

$$= 294\ \mathrm{N}.$$

(b)

Molar mass of ^{4}He is 4.0026 g. Therefore, rest mass of a ^{4}He particle will be

$$m_{^{4}\text{He}} = \frac{4.0026}{6.02\times 10^{23}}\,\text{g} = 0.665\times 10^{-26}\ \text{kg}.$$

Acceleration of the ^{4}He particle at that instant, if calculated using the Newtonian mechanics, will be

$$a = \frac{F_c}{m_{^{4}\text{He}}} = \frac{294}{0.665\times 10^{-26}}\ \text{m s}^{-2} = 4.42\times 10^{28}\ \text{m s}^{-2}.$$

But as the ^{4}He particle will be relativistic, we should use its relativistic mass in calculating its acceleration.