Homework 01

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2020 年 10 月 6 日

1

The nuclear reaction in the experiment where Rutherford observed protons is

$$^{14}N + \alpha \to \ ^{17}O + p.$$

According to the mass of proton and each atom, the energy of α should above

$$M(^{17}O) + M(p) - M(^{14}N) - M(\alpha) = 1.279 \times 10^{-3}\text{amu}.$$

Now, consider this nuclear reaction

$$^{16}O + \alpha \to \ ^{19}F + p.$$

The energy of α in this case should above

$$M(^{19}F) + M(p) - M(^{16}O) - M(\alpha) = 8.711 \times 10^{-3}\text{amu}$$

which is much higher than that in the case of N_2 gas. This is why Rutherford observed protons with N_2 gas instead of O_2. To observe proton with O_2 gas, the energy needed of α is

$$8.711 \times 10^{-3}\text{amu} \approx 8.134\text{MeV}$$

2

The rest mass of proton is $M_0(p)$

$$E_0(p) = M_0(p)c^2 = 9.4085 \times 10^2\text{MeV}$$

The Total energy of the proton is

$$E(p) = \nu M_0(p)c^2 = E_0(p) + 5.7\text{MeV} = 9.4655 \times 10^2\text{MeV}$$

where

$$\nu = \frac{1}{\sqrt{1-(v/c)^2}} = 1.00606$$
$$\Rightarrow v = 0.32878 \times 10^8\text{m/s}$$

where v is the velocity of the outgoing proton. And the momentum of the proton is

$$P(p) = \nu M_0(p)v$$

We suppose that the deflection angle of the γ-ray is π. In this case, we obtain the minimum energy of the γ-ray:

$$E(\gamma) = \frac{P(p)}{2}c = 8.29885 \times 10^{-12}\text{J} \approx 51.868\text{MeV}$$

according to the conservation of momentum.