902.

Problem 56.2 (RHK)

Some of the GUTs predict the following decay schemes for the proton:

$$\mathrm{p} \rightarrow \mathrm{e}^{+} + \gamma,$$
$$\mathrm{p} \rightarrow \mathrm{e}^{+} + \pi^{0}.$$

We have to calculate (a) *the* Q*-values for these decays*. (b) *We have to show that the decays do not violate the conservation of charge, relativistic energy, or linear momentum. The rest energy of a proton is* 938.27 MeV, *of an electron* 0.511 MeV, *and of a neutral pion is* 135 MeV.

Solution:

(a)

Using the rest mass energies of proton, positron and that of the neutral pion we will calculate Q-values for the decays

$\mathrm{p} \rightarrow \mathrm{e}^{+} + \gamma,$

$\mathrm{p} \rightarrow \mathrm{e}^{+} + \pi^{0}.$

The Q value for the decay $\mathrm{p} \rightarrow \mathrm{e}^{+} + \gamma$ will be

$$Q_{\mathrm{p}\to \mathrm{e}^+ + \gamma} = \left(m_{\mathrm{p}}c^2 - m_{\mathrm{e}}c^2\right)$$
$$= \left(938.27\ - 0.511\right)\ \mathrm{MeV} = 937.59\ \mathrm{MeV}.$$

The Q value for the decay The Q value for the decay $\mathrm{p} \to \mathrm{e}^+ + \pi^0$ will be

$$Q_{\mathrm{p}\to \mathrm{e}^+ + \pi^0} = \left(m_{\mathrm{p}}c^2 - m_{\mathrm{e}}c^2 - m_{\pi}c^2\right)$$
$$= \left(938.27\ - 0.511 - 135\right)\ \mathrm{MeV} = 802.76\ \mathrm{MeV}.$$

(b)

As the charge of a proton is one *e* and that of the positron is also one *e*, and photon and π^0 are electrically neutral, therefore in these decays the electric charge is conserved. Also, as the proton decays into two particles in each of the two decays the conservation of relativistic energy and momentum will determine the energy and momentum of the decay products.