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Problem 3.34 (R)

The nucleus of a carbon atom initially at rest in the laboratory goes from one state to another by emitting a photon of energy 4.43 MeV. *The atom in its final state has a rest mass of* 12.0000 amu. (1 amu *corresponds to* 931.478 MeV). *We have to find (a) the momentum of the carbon atom after the decay, as measured in the laboratory; (b) the kinetic energy, in* MeV, *of the carbon atom after the decay, as measured in the laboratory system.*

Solution:

(a)

Energy of the photon emitted by the carbon atom,

$h\nu = 4.43\ \text{MeV} = 4.43 \times 1.602 \times 10^{-13}\ \text{J} = 7.0968 \times 10^{-13}\ \text{J}.$

Momentum of the photon,

$$p = \frac{h\nu}{c} = \frac{7.0968 \times 10^{-13}}{3 \times 10^{8}}\ \text{kg m s}^{-1} = 2.3656 \times 10^{-21}\ \text{kg m s}^{-1}.$$

As the carbon atom was at rest when it emitted the photon, and as the momentum is conserved, the magnitude of the momentum of the atom after it has emitted the photon will be equal to that of the photon. Therefore, the momentum of the carbon atom as measured in the laboratory frame will be 2.3656×10^{-21} kg m s^{-1}.

(b)

Mass of the carbon atom after it has emitted the photon,

$$m = 12 \text{ amu} = \frac{12\times931.478\times1.602\times10^{-13}}{\left(3\times10^{8}\right)^{2}} \text{ J} = 1.989\times10^{-26} \text{ kg.}$$

Kinetic energy of the carbon atom after it has emitted the photon will be

$$KE = \frac{p^2}{2m} = \frac{\left(2.36\times10^{-21}\right)^2}{2\times1.99\times10^{-26}} \text{ J}$$

$$= 1.40\times10^{-16} \text{ J} = 1.40\times10^{-16}\times6.242\times10^{12} \text{ MeV}$$

$$= 8.74\times10^{-4} \text{ MeV.}$$