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Problem 29.13P (HRW)

An ion source is producing ^6Li $(\text{mass} = 6.0\ \text{u})$, *each with a charge of* $+e$. *The ions are accelerated by a potential difference of* 10 kV *and pass horizontally in a region in which there is uniform magnetic field of magnitude* $B = 1.2\ \text{T}$. *We have to calculate the strength of the smallest electric field, to be set up over the same region, which will allow the* ^6Li *ions to pass through undeflected.*

$$1\ \text{u} = 1.6605 \times 10^{-27}\ \text{kg}.$$

Solution:

We will first determine the velocity that a ^6Li ion have after being accelerated by a 10 kV potential difference. Let us assume that the speed acquired is non-relativistic. That is

$$\frac{v}{c} = 1.$$

Mass of a ^6Li ion will be

$m_{\text{Li}} = 6 \text{ u} = 6 \times 1.6605 \times 10^{-27} \text{ kg} = 9.963 \times 10^{-27} \text{ kg}.$

Kinetic energy of a ^{6}Li ion of charge $+e$ after falling across a potential difference of 10 kV will be

$KE_{\text{Li}} = 10^{4} \times 1.6 \times 10^{-19} \text{ J} = 1.6 \times 10^{-15} \text{ J}.$

Velocity of ^{6}Li ion, when it enters the region where uniform electric and magnetic fields perpendicular to the velocity vector of the charged ion and orthogonal to each other, will be

$$v = \sqrt{\frac{2KE_{\text{Li}}}{m_{\text{Li}}}} = \sqrt{\frac{2 \times 1.6 \times 10^{-15}}{9.963 \times 10^{-27}}} \text{ m s}^{-1} = 0.5667 \times 10^{6} \text{ m s}^{-1}.$$

For ^{6}Li ions to go through undeflected in the region of uniform electric and magnetic fields the condition to be fulfilled is

$eE = evB,$

or

$E = vB.$

Magnetic field through which the ^{6}Li ions move is

$B = 1.2 \text{ T}.$

Therefore, the electric field has to be

$E = vB = 0.5667 \times 10^{6} \times 1.2 \text{ V m}^{-1} = 680 \text{ kV m}^{-1}.$