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Problem 34.14 (RHK)

S.A. Goudsmit devised a method for measuring accurately the masses of heavy ions by timing their period of revolution in a known magnetic field. A singly charged ion of iodine makes 7.00 rev *in a field of* 45.0 mT *in* 1.29 ms. *We have to calculate its mass, in atomic mass units. Actually, the mass measurements are carried out to much greater accuracy than these approximate data suggest.*

Solution:

Let R be the radius of the circular orbit of charged iodine ion in a uniform magnetic field, B, perpendicular to its velocity, v. Equation of motion for the circular motion of the charged ion is

$$m_I \frac{v^2}{R} = evB,$$

or

$$\omega = \frac{v}{R} = \frac{eB}{m_I}.$$

Number of revolutions that an ion would make per second will, therefore, be

$$n_{\text{rev}} = \frac{\omega}{2\pi} = \frac{eB}{2\pi m_I},$$

and

$$m_I = \frac{eB}{2\pi n_{\text{rev}}}.$$

Data of the problem are:

$$B = 45.0 \text{ mT} = 45.0\times10^{-3} \text{ T},$$

$$n_{\text{rev}} = \frac{7.0}{1.29\times10^{-3}} = 5426 \text{ rev s}^{-1}.$$

$$\therefore\ m_I = \frac{1.6\times10^{-19}\times45\times10^{-3}}{2\pi\times5426} \text{ kg} = 2.112\times10^{-25} \text{ kg}.$$

As

$$1 \text{ u} = 1.6605\times10^{-27} \text{ kg},$$

mass of the iodine ion in atomic mass units will be

$$m_I = \frac{2.112\times10^{-25}}{1.6605\times10^{-27}} \text{ u} = 127.19 \text{ u}.$$

The precisely measured value of the mass of an iodine atom is 126.948 u.

With the developments in the mass-spectrometry, the mass measurements are carried out to much greater accuracy than what the approximate data of Goudsmit suggests.