Galactic Astrophysics Sample Problem Piljay

A cloud of pure hydrogen has a density of $n = 150\ cm^{-3}$ and is 18 K. Assume the hydrogen molecule has a diameter of 110 picometers.

a) What is the mean free path of a given molecule in this cloud?

b) What speed can we expect this molecule to have inside the cloud?

c) How long can we expect this molecule to fly around inside the cloud until it collides with another molecule?

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a) $mfp = \frac{1}{\pi d^2 n}$

$= \frac{1}{\pi (1.1 \times 10^{-10}\,m)^2 (1.5 \times 10^{8}\,m^{-3})}$

$= 1.754 \times 10^{11}\,m$

b) $v = \left(\frac{3kT}{m}\right)^{1/2}$

$= \left(\frac{3(1.38 \times 10^{-23}\,J/K)(18\,K)}{2(1.67 \times 10^{-27}\,kg)}\right)^{1/2}$

$= 472.3\ m/s$

c) $t = \frac{mfp}{v}$

$= \frac{1.754 \times 10^{11} m}{472.3\,m/s}$

$= 3.713 \times 10^{8}\,s \quad = 11.77$ years