

# Hydrogen and total mass

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Assumptions:

- Matter is composed of H and He only.
- Helium abundance is 10%

This abundance is the ratio of helium atoms to hydrogen atoms,

$$n(\text{He})/n(\text{H}) = 10/100 = 0.1. \quad (\text{AQ2004: } 0.098)$$

The mass ratio will be

$$M(\text{He})/M(\text{H}) = 0.4. \quad (\text{AQ2004: } 0.39)$$

Thus, the ratio of total mass (H+He) to H mass will be

$$M(\text{H} + \text{He})/M(\text{H}) = 1.4.$$

In general,

$$M_{\text{total}} = 1.4 M(\text{H}). \quad (\text{AQ2004: } 1.4163)$$

For atomic H:

Mean atomic mass of interstellar gas:

$$m_{\text{gas}} = \frac{M(\text{H} + \text{He})}{n(\text{H}) + n(\text{He})} = \frac{1.4 M(\text{H})}{1.1 n(\text{H})} = \frac{1.4}{1.1} m_{\text{H}} = 1.27 m_{\text{H}}. \quad (\text{AQ2004: } 1.30)$$

Mean atomic mass per H atom:

$$m_{\text{gas}/\text{H}} = \frac{M(\text{H} + \text{He})}{n(\text{H})} = \frac{1.4}{1} m_{\text{H}} = 1.4 m_{\text{H}}. \quad (\text{AQ2004: } 1.41)$$

For molecular H, H<sub>2</sub>:

The number-of-particles ratio (atoms or molecules) is

$$n(\text{He})/n(\text{H}_2) = 10/50 = 0.2.$$

The mass ratio remain the same, independently of hydrogen state:

$$M(\text{H}_2 + \text{He})/M(\text{H}_2) = 1.4.$$

and

$$M_{\text{total}} = 1.4 M(\text{H}_2).$$

Mean molecular mass of interstellar gas:

$$\mu_{\text{gas}} = \frac{M(\text{H}_2 + \text{He})}{n(\text{H}_2) + n(\text{He})} = \frac{1.4 M(\text{H}_2)}{1.2 n(\text{H}_2)} = \frac{1.4}{1.2} 2 m_{\text{H}} = 2.33 m_{\text{H}}.$$

For instance, the sound speed is  $c_s = \sqrt{kT/(2.33 m_{\text{H}})}$ .

Mean molecular mass per H molecule:

$$\mu_{\text{gas/H}} = \frac{M(\text{H}_2 + \text{He})}{n(\text{H}_2)} = \frac{1.4}{1} 2 m_{\text{H}} = 2.8 m_{\text{H}}.$$

For instance, the total-mass density is  $\rho = 2.8 m_{\text{H}} n(\text{H}_2)$ .

[AQ2004] Cox, A. E. (editor) 2004, *Allen's Astrophysical Quantities*, Springer