

# A Survey of H<sub>2</sub>, <sup>12</sup>CO, and <sup>13</sup>CO in Diffuse Molecular Clouds

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We assembled the most extensive sample to date of sight lines that show CO absorption in ultraviolet STIS/HST spectra, and extracted column densities of CO and H<sub>2</sub> (from FUSE). We derived complementary CH, CH<sup>+</sup>, and CN abundances from high-resolution ground-based spectroscopy at McDonald and ESO. Correlations among carbon-bearing species and H<sub>2</sub> are well fit with two distinct slopes, with breaks occurring at  $\log N(\text{CO}) = 14.1$ ,  $\log N(\text{H}_2) = 20.4$  (see Figure), and  $\log N(\text{CH}^+) = 13.2$  ( $\pm 0.1$  uncertainties). The break in H<sub>2</sub> is mirrored by a break in  $\log N(\text{CH}) = 13.0$  thanks to their tight relationship. The breaks in CO and CH<sup>+</sup> appear to pinpoint the transition between two regions of CO photochemistry resulting from lower- and higher-density processes. We show that  $N(\text{CN})/N(\text{CH}^+)$  is a better density indicator than  $N(\text{CN})/N(\text{CH})$ . Our CO sample also provided the most extensive set of sight lines with observed <sup>13</sup>CO absorption. The data on  $N(^{12}\text{CO})/N(^{13}\text{CO})$  show that 68% of the sight lines have 12-to-13 ratios indistinguishable from 70, the ambient value of <sup>12</sup>C/<sup>13</sup>C in the ISM. Deviations correspond either to selective photodissociation (highest 12/13) or to isotopic charge exchange with C<sup>+</sup> (lowest 12/13). Interestingly, sight lines that show detectable amounts of <sup>13</sup>CO are characterized by lower values of T<sub>01</sub>, the kinetic temperature derived from the ortho and para ground states of H<sub>2</sub>. The average of T<sub>01</sub> is lower by ~20 K than the average T<sub>01</sub> for sight lines without <sup>13</sup>CO. A survey of the literature shows that the presence of detectable amount of C<sub>2</sub> occurs along sight lines with T<sub>01</sub> lower by about 26 K, and with T<sub>02</sub> for C<sub>2</sub> being 30 K lower still.

