First detection of $HC^{18}O^+$ in a protoplanetary disk: exploring oxygen isotope fractionation of CO

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The element oxygen has three stable isotopes: ^{16}O, ^{17}O, and ^{18}O. It has been well established that the solar system materials, including chondrules, Ca-Al-rich inclusions (CAIs), and the Earth's ocean, are enriched in ^{17}O and ^{18}O compared to the Sun, and their oxygen isotope compositions show mass-independent variations. The oxygen isotope fractionation scenario, which has been developed to explain the oxygen isotope anomaly in the solar system materials, predicts that CO gas is depleted in ^{18}O and ^{17}O in protoplanetary disks, while H_2O is enriched in ^{18}O and ^{17}O (e.g., Yurimoto & Kuramoto 2004; Lyons & Young 2005). One way to test the scenario is to measure the oxygen isotopic composition of CO gas in protoplanetary disks. However, it is not straightforward, because $C^{16}O$ is often optically thick in disks.

Based on ALMA observations, we report the first detection of $HC^{18}O^+$ in a Class II protoplanetary disk (TW Hya). This detection allows us to explore the oxygen isotope fractionation of CO in the TW Hya disk from optically thin HCO+ isotopologues as a proxy of optically thicker CO isotopologues. Using the $H^{13}CO^+$ data previously obtained with SMA, we derived the $H^{13}CO^+/HC^{18}O^+$ ratio in the central ~100 au regions of the disk. We construct a chemical model of the TW Hya disk with carbon and oxygen isotope fractionation chemistry, and estimate the conversion factor from $H^{13}CO^+/HC^{18}O^+$ to $^{13}CO/C^{18}O$. With the conversion factor (=0.8), the $^{13}CO/C^{18}O$ ratio is estimated to be 8.3 +- 2.6, which is consistent with the elemental abundance ratio in the local ISM (8.1 +- 0.8) within error margin. Then there is no clear evidence of ^{18}O depletion in CO gas in the central ~100 au regions of the disk, although we could not draw any robust conclusion due to uncertainties. In conclusion, optically thin lines of HCO^+ isotopologues are useful tracers of CO isotopic ratios, which are hardly constrained directly from optically thick lines of CO isotopologues. Future higher sensitivity observations of $H^{13}CO^+$ and $HC^{18}O^+$ would be able to allow us to better constrain the oxygen fractionation in the disk.

Keywords: Protoplaneatry disk, Oxygen isotope fractionation

