# Molecular Astrophysics: Exercise 5

1)

Assume that the rate of a 3-body reaction between a molecular ion $XY^+$ and two H2 molecules

$$XY^+ + H_2 + H_2 \;\rightarrow\; XYH_2^+ + H_2 ,$$

is given by

$$R = k_3 \; n(H_2)^2 .$$

Where $k_3$ is the three-body rate coefficient $k_3$=1.5 x $10^{-29}$ $cm^6\, s^{-1}$, and the $H_2$ density is given by $n(H_2)$.

Calculate the reaction rate R for an $H_2$ pressure of 1 bar (at room temperature, make sure to use consistent units for the ideal gas equation) and for interstellar cloud conditions with $n(H_2)$ = 1000 $cm^{-3}$ . What do we learn from the result? Do we need to consider three-body processes in the Interstellar Medium?

2)

The classical Langevin collision rate coefficient between an ion and a neutral collision partner is given by

$$R_L = 2.34 \, x \, 10^{-9} \left(\frac{\alpha}{\mu}\right)^{1/2} ,$$

where α is the polarizability (in $10^{-24}$ $cm^3$) of the neutral, and μ is the reduced mass

$$\mu = \frac{m_1 m_2}{m_1 + m_2} .$$

The polarizability of $H_2$ molecules is α = 4.29 x $10^{-25}$ $cm^3$, and the polarizability of H atoms is α = 6.66 x $10^{-25}$ $cm^3$.
Calculate the Langevin rate coefficient $R_L$ for collisions of

a) $H_2^+$ with H,
b) $H_2^+$ with $H_2$,
c) $CO^+$ with H,
d) $CO^+$ with $H_2$.

How does the Rate coefficient vary with mass? Consider collisions of heavier molecular ions with hydrogen atoms and molecules. What range of values do you expect for the classical Langevin rate coefficient?