C/P/A 740 Winter Quarter 2008
Dr. Herbst

HOMEWORK ASSIGNMENT # 5
Due: Tuesday, 26 February

1. Use the steady-state method to derive the rate law for three-body association. Label the reactants A^+ and B, with the bath gas C. Label the rate coefficients k_1, k_{-1}, and k_2. Find the limiting laws at both high C density and low C density.

2. Now consider a system in which both three-body and radiative association occur. Obtain the effective two-body rate coefficient, defined by the relation

$$\frac{d[AB^+]}{dt} = k_{eff}[A^+][B]$$

and sketch its logarithm as a function of the logarithm of the bath gas density [C] from both the high density limit to the low density limit. Identify three regimes. You may assume that $k_{-1} >> k_r$.

3. Estimate the radiative association rate coefficient at low temperature for the following process:

$$C^+ + H_2 \text{ --> } CH_2^+ + h\nu$$

Use the quantum RRK approach. For this reaction, the radiative stabilization step is rather fast: $k_r = 10^6$ s^{-1}. The bond energy is about 4.3 eV (1 eV of energy corresponds to 8065 cm^{-1} after division by hc) , and the average frequency of the complex is 2000 cm^{-1} (s=3).

4. Assuming that H atoms do not react on grain surfaces, calculate the average number of H atoms per grain at steady state in a dense cloud at 10 K and at 20 K by considering accretion and thermal desorption processes. You may assume that the gas-phase H atom concentration is 1 cm^{-3}. What does your answer say about the possible efficiency of H_2 formation at the two temperatures? Use the silicate binding energy $E_D/k = 373$ K.