THE POPULATIONS OF H_2 VIBRATIONAL STATES IN INTENSE UV FIELDS NEAR O-B STARS

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In most places where molecular hydrogen exists in the interstellar medium, it will be found in the ground vibrational and ground electronic state. This will not be so, however, near O or early B stars where, in the region just beyond the ionization boundary, populations will be determined by UV fields up to 10^5 times more intense than the mean interstellar value (4×10^{-16} ergs cm^{-3} s^{-1} = 1 Habing unit). The H_2 absorbs Lyman-Werner band photons longwards of λ91 nm and subsequent decays to the ground electronic state may lead to dissociation (vibrational continuum) or to one of 14 vibrationally excited states. Molecules in these states have lifetimes of order 10^{10} s and, in the intense fields, will be exposed to further Lyman-Werner excitation. The probability of dissociation is therefore greatly enhanced by this 'multiple excitation', since the number of lines available to vibrationally excited H_2 is many times that available to ground-state H_2 (Shull, 1978).

Calculations of the rate of dissociation near HII regions (Roger and Dewdney, this volume) require a knowledge of the distribution of molecules amongst the various bound vibrational states. We have determined that this distribution is mainly a function of the local UV intensity and that it is possible to generate a table of pre-calculated values for use in the dissociation model calculations.

Finding the populations of the states involves summing all the entry and exit terms for a given vibrational state. The complete set of linear differential equations can be solved by standard techniques. Oscillator strengths for the Lyman and Werner transitions, and the transition probabilities for subsequent decay have been taken from Allison and Dalgarno (1970). Transition probabilities for vibrational transitions in the ground electronic state are from Turner et al. (1977). Values of the "cascade entry matrix" are from Shull (1978).

Figure 1 shows the distribution of populations amongst each of the vibrational levels (v) for UV intensities ranging from 1 to 10^5 Habing units.

Figure 2 shows the "stabilization time" plotted against UV energy density for the case in which all the H_2 is initially in the ground vibrational state. Similar curves will apply to other

Figure 1. The fraction of H_2 molecules in each vibrational state for UV radiation densities ranging from the mean interstellar value to 10^5 times this value. At high levels of UV intensity the populations are close to being evenly distributed amongst the vibrational states.
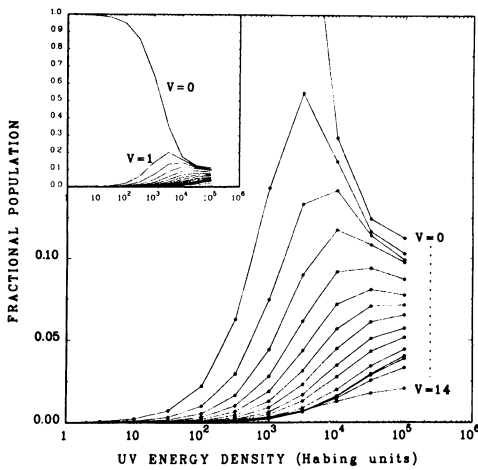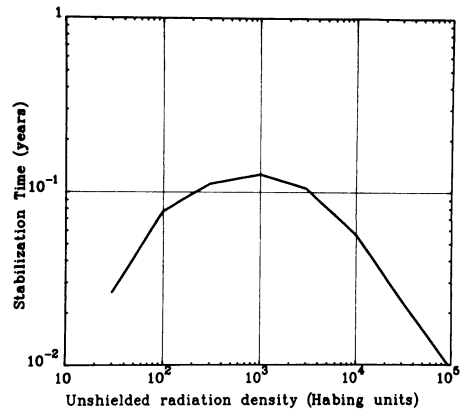
Figure 2. The time taken for the relative population in the ground vibrational state to stabilize to within 1% of its final value for various values of the local UV energy density.

initial conditions. The criterion for stabilization used here is that the fraction of the population in the ground (v=0) state has settled to within 1% of its final asymtotic value. Regardless of the initial conditions, the relative populations of the various bound states tend to stabilize in about 10^6 s.

The active region, in which these excited populations of H_2 exist, forms the advancing dissociation front. The time taken for the front to advance a distance equal to its own thickness depends upon the detailed conditions beyond the ionization boundary but is always much greater than the corresponding stabilization time. This permits the use of the tabular data shown in Figure 1 for calculations of dissociation rates.

Advancing dissociation fronts near O and B stars should be readily detectable in the infrared emission of the vibrational transitions, especially near 2 μm (Δv=1) and near 1 μm (Δv=2).

References

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Turner, J., Kirby-Docken, and Dalgarno, A., 1977, Ap.J. Suppl., 35, 281