Isotopic differences in the formation of translationally cold rubidium molecules in a magneto-optical trap

A. Fioretti[1], M. Mazzoni[2] and C. Gabbanini

Istituto di Fisica Atomica e Molecolare del C.N.R., Area della Ricerca, Via Alfieri 1
56010 Ghezzano (Pisa), Italy Tel.39-50-3152529, Fax.39-50-3152230
E-mail: carlo@ifam.pi.cnr.it

[1] *also Unità INFM, Dip. di Fisica, Università di Pisa, Piazza Torricelli 2, 56127, Pisa, Italy*
[2] *Istituto di Elettronica Quantistica del C.N.R., Via Panciatichi 56, 50127 Firenze, Italy*

Recently it became possible to produce translationally cold molecules at temperatures near 100 μK and to store them into traps. Laser cooling, commonly used to cool atoms down to very low temperatures, cannot be directly applied to molecules, due to the absence of closed optical transitions. An alternative way is to create cold molecules by photoassociation (PA) of two cold colliding atoms. In fact, photoexcited molecules can spontaneously decay into the ground molecular state while remaining translationally cold. Translationally cold molecules have been produced by PA both in cesium [1], and in potassium [2]. The cesium molecules have also been trapped in a far-off-resonance dipolar trap [3].

Recently, we have observed translationally cold rubidium molecules for both ^{85}Rb and ^{87}Rb isotopes [4]. The molecules are formed by PA in a magneto-optical trap (MOT) in various vibrational levels of the $a^3\Sigma_u^+$ triplet ground state.

Remarkable differences in the behaviour of the two Rb isotopes have been observed. While cold molecules are produced by PA for both isotopes, only in the ^{85}Rb case a considerable molecular formation rate is observed even in absence of the PA laser. The application of the PA laser produces molecular formation in a series of frequencies (Fig. 1) for both isotopes, that have been identified as corresponding to free-bound transitions to vibrational levels of the 0_g^- long-range electronic state.

The MOT, produced inside a cell equipped with a channeltron multiplier for ion detection, is loaded with about $N \sim 10^7$ rubidium atoms at a peak density $n \sim 310^{10}$ cm^{-3}. A c.w. free running diode laser, focused at the trapped cloud position, produces PA. A dye laser, pumped by the second of a Nd:YAG laser, is used to ionize atoms and molecules. The produced ions are selected by time-of-flight before being detected by the channeltron. When the dye laser wavelength is tuned to the $600 - 609$ nm spectral region, it appears, besides the peak due to atomic ions, a second well defined peak at a delay corresponding to molecular ions. In the spectrum of the molecular ions as a function of the dye laser wavelength, shows a molecular band, identified as connecting the Rb_2 triplet ground state $a^3\Sigma_u^+$ to the excited $2^3\Pi_g$ state. The translational molecular temperature, measured by switching off the trapping laser and by detecting the number of molecular ions as a function of the delay in the application of the ionizing pulse, results to be 90 ± 50 μK.

In absence of a PA laser, two mechanisms can contribute to the molecular formation: the

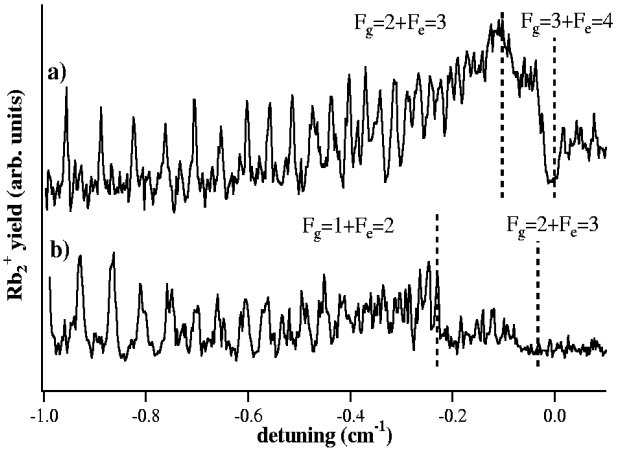

Figure 1: Molecular ion spectrum as a function of the PA laser photon energy for ^{85}Rb (a) and for ^{87}Rb (b). The vertical dashed lines indicate the positions of the excited molecular asymptotes.

PA action of the trapping and repumping lasers, and the three-body recombination process. The two mechanisms have a different dependence on the atomic density. We have investigated this dependence for ^{85}Rb by changing the magnetic field gradient of the trap. The measured formation rate per atom, as shown in Fig. 2, gives the quadratic dependence foreseen for three-body recombination, indicating this process as the main responsible for $^{85}Rb_2$ molecule production in absence of a PA laser. Huge three-body recombination rates for ^{85}Rb have been recently calculated [5], due to the large negative scattering length of this isotope.

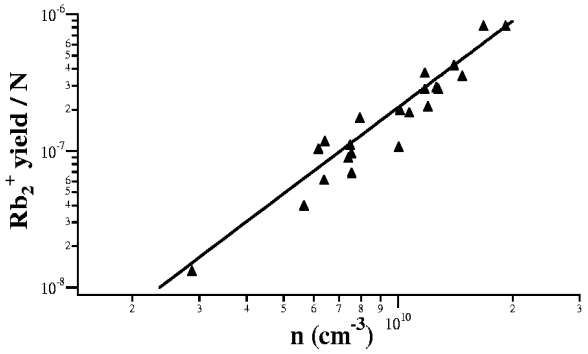

Figure 2: Molecular ions per trapped atom and per pulse as a function of the peak atomic density, together with the best fitting power function, having an exponent 2.1 ± 0.2.

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