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Entanglement of excited atom-pair produced by the photo dissociation

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1 Introduction

A pair of H(2*p*) atoms produced in the photodissociation of H_2 [1] is potentially entangled [2,3],

$$H_2(X^1\Sigma_g^+)+\gamma_{ex}\rightarrow H_2(Q_2{}^1\Pi_u(1))\rightarrow H(2p_0)+H(2p_{\pm1}) \rightarrow H(1s)+H(1s)+\gamma_{Ly\text{-}\alpha}+\gamma_{Ly\text{-}\alpha}, \quad (1)$$

where γ_{ex} is the incident photon and $\gamma_{Ly\text{-}\alpha}$ the Lyman–α photon. The subscripts of 0 and ±1 attached to 2*p* are the magnetic quantum numbers *m* with respect to the internuclear axis. The angular correlation function (ACF) of the Lyman-α photon-pair shows the features due to the entanglement in the H(2*p*) pair [2,3]. Recently we measured the ACF of the Lyman-α photon-pair in process (1) mediated by the linearly polarized light and found that there is a considerable difference in the variation magnitude between those experimental and theoretical ACFs [4].

To clarify the origin of the difference between the experimental and theoretical ACFs, the study on the isotope effect of the ACFs, that is, the comparison of the ACFs of H_2, HD, and D_2 is useful. Before measuring the ACFs, the precursor doubly excited states for the pair of H(2*p*) atoms was determined from the cross section curves of the H(2*p*) atom pair formation for D_2[5] and HD[6], and an unexpected isotope effect on the cross section of 2p pair formation was found in the photoexcitation of H_2, D_2 and HD.

2 Experiment

Linearly polarized light was introduced into a gas cell filled with hydrogen gas. The pair of Lyman-α photons emitted from the 2p atom pairs were detected in coincidence by two detectors. It was confirmed that the coincidence count rates were proportional to the target gas pressure in the present range, i.e. below ~2Pa. The procedure of obtaining the absolute values of the cross sections of the 2p+2p pair formation from the coincidence counts was described in reference [5].

3 Results and Discussion

In general, the heavier isotope substitution brings about the smaller oscillator strength of the neutral dissociation because of the following reasons. The potential energy curve and resonance width of a doubly excited state, which determines the rate of the autoionization, have no isotope effects. On the other hand, the relative velocity of two nuclei down the potential energy curve in D_2 is $1/\sqrt{2}$ of that in H_2, thus D_2 needs more time than H_2 to reach the region of the internuclear distance where the autoionization does not occur. As a result, D_2 should have lower probability of escaping from the autoionization than H_2.

However in experiment [6], the ratio of the oscillator strengths of the 2p+2p pair formation from the Q_2 $^1\Pi_u(1)$ state was determined that H_2 : HD : D_2 = 1 : 1.1 : 0.71. We compared the experimental ratio with that of the calculated survival probabilities of the Q_2 $^1\Pi_u(1)$ state based on the semiclassical treatment for the decay dynamics of the Q_2 $^1\Pi_u(1)$ state with using its potential energy and resonance width [7]. The survival probability means the probability that a doubly excited hydrogen molecule dissociates into a pair of neutral hydrogen atoms escaping from the autoionization. The ratio of the calculated survival probabilities is H_2 : HD : D_2 = 1 : 0.81 : 0.58, which are able to be compared with the ratio of the oscillator strengths of the 2p+2p pair formation mentioned above since the oscillator strength of the electronic excitation has just small isotope effect [5]. The experimental ratio, D_2 / H_2= 0.71, is in agreement with the calculated ratio, D_2 / H_2= 0.58. On the other hand, the experimental ratio, HD/ H_2= 1.1, is remarkably larger than the calculated ratio, HD/ H_2= 0.81.

References

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