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Deexcitation Probabilities of $Ne(^3P_2)$ by Kr for the Case E << D

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Abstract

The deexcitaion probability calculation of the total Penning ionization cross section for $Ne(^3P_2)$ by Kr has been made in the region of the collisional energy from 18.5 to 38.1 meV. Considering the magnitude of the mean collisional energy with respect to D, the application of the analysis in the case E >> D is expected to be more appropriate than in the case E << D. Theoretical investigations of $Ne(^3P_2)$ by Kr for the case E >> D are also needed.

Keywords: *metastable atoms, resonance atoms, deexcitation cross sections, pulse radiolysis, impact parameter.*

Introduction

Collisional deexcitation of excited rare gas atoms by atoms and molecules is of great importance in both fundamental and applied sciences, which provides the essential features of chemical reactions, in particular, those including electronic energy transfer.[1-4] The collisional deexcitation is a key also to understand fundamental processes in the interaction of ionizing radiation with matter and the phenomena in ionized gases.[4,5]

Collisional deexcitation processes of excited neon atoms have not been extensively studied in comparison with those of excited helium atoms.[1-6] The rate constants or the cross sections have been measured by using beam, flowing afterglow, and pulse radiolysis methods. Theoretical investigation has also been reported.[7-9] However, *ab initio* calculations are still limited to some simple cases.[10-14] On the other hand, few experimental works have been reported for the resonance or the radiative states in spite of much theoretical work because of experimental difficulty.[15] However, several experimental results on the collisional energy dependence of the cross sections for deexcitation of the resonance and metastable states have been obtained by the present authors.[15-18]

In this paper, the deexcitaion probability calculation of the total Penning ionization cross section for $Ne(^3P_2)$ by Kr has been made in the region of the collisional energy from 18.5 to 38.1 meV. Considering the magnitude of the mean collisional energy with respect to

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potential well depth (D), the application of the analysis in the case E >> D is expected to be more appropriate than in the case of E << D. The present result suggest that theoretical investigations of $Ne(^3P_2)$ by Kr for the case E>>D are also needed.

Experimental Method and Calculation Procedure

For measuring the deexcitation cross sections a pulse radiolysis method is employed. Details of the apparatus and procedure of the present pulse radiolysis method used for measurements of cross sections for the deexcitation have been described elsewhere.[3,4,15-18] The calculation procedure has been described in detail previously.[19]

At the limit of the case E << D the deexcitation probability should be obtained as

$$P = \frac{\sigma_M}{\pi b_c^2} \quad (1)$$

However, the reported cross section is thermally averaged over the Maxwellian distribution of f(v) so that in the present analysis[16]

$$P_c = \frac{\sigma_M}{<\sigma_c>} \quad (2)$$

is taken, where

$$<\sigma_c> = \frac{k_c}{<v>} = \int \frac{v\left(\pi b_c^2\right)f(v)dv}{<v>} \quad (3)$$

Results and Discussion

The obtained experimental data are analyzed by considering the case E<<D.[16]For the case E << D, the reported deexcitation cross sections, σ_M and deexcitation probabilities, P_c are listed in Table 1.[16] The values of P_c in Table 1 increased slightly or constant with increasing the mean collisional energy for the deexcitation of $Ne(^3P_2)$ by Kr, which shows that the assumption of P(b) = P (constant) at b< b_c to derive eq., $\sigma = P\pi b^2_c$ is not appropriate.

Table 1: Deexcitation probabilities P_c of $Ne(^3P_2)$ by Kr for the case E<<D.

Collisional energy (meV)	38.1	35.3	32.7	30.1	27.5	24.9	22.4	19.8	18.5
σ_{Kr} (Å^2)	18.0±1.4	18.1±1.4	17.9±1.6	17.2±1.8	17.4±1.8	16.0±1.1	16.0±0.9	16.7±1.7	15.7±1.8
P_c	0.17±0.01	0.17±0.01	0.17±0.02	0.15±0.02	0.15±0.02	0.13±0.01	0.13±0.01	0.13±0.01	0.12±0.01

It is found that the region of collisional energy which fills the $0 < E < D$ coincides with the region where the cross section obtained by cross beam experiments dispersively increased with decreasing the collisional energy.[20] Since the present thermally averaged cross sections are the averaged values of cross sections weighted by the Maxwellian distribution, a small amount of contribution of the collisions for $0 < E < D$ is involved. In other words, if the results in crossed beam experiments are correct, the thermally averaged cross sections as a function of the mean collisional energy should reflect such dispersive collisional energy dependence.[20] However, an extrapolation of P_c together with the collisional energy dependence of πb^2_c by eq., $P = \sigma_M/\pi b^2_c$ to the region $0 < E < D$ does not appear to give such a collisional energy dependence that cross sections decrease with decreasing E. Thus considering the magnitude of the mean collisional energy with respect to potential well depth, D, the application of the analysis in the case $E >> D$ is expected to be more appropriate than the case $E << D$. Moreover, further theoretical investigations of $Ne(^3P_2)$ by Kr for the case $E >> D$ are also needed. In order to get deeper insight in such investigations more experimental and theoretical data should be obtained for $Ne(^3P_2)$ by atoms and molecules.

Conclusions

In the present investigation, the deexcitaion probability calculation of the total Penning ionization cross section for $Ne(^3P_2)$ by Kr has been made in the region of the collisional energy from 18.5 to 38.1 meV. Considering the magnitude of the mean collisional energy with respect to D, the application of the analysis in the case $E >> D$ is expected to be more appropriate than in the case $E << D$. Further theoretical investigations of $Ne(^3P_2)$ by Kr for the case $E>>D$ are also needed. The present result would be helpful for studies of the collisional deexcitation of electronically excited atoms by atoms or molecules. The quantum mechanical optical model calculations and *ab initio* calculations of the optical potentials and further absolute measurements of the cross sections in an adequately wide collisional energy region are also needed.

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