

Deexcitation Probabilities of $\text{Ne}(^3\text{P}_2)$ by Xe for the Case $E \ll D$

Deba Bahadur khadka*

Central Department of Chemistry, Tribhuvan University, Kirtipur, Kathmandu, Nepal.
e-mail: khadkadeba@yahoo.com.

Abstract

The deexcitation probability calculation of the total Penning ionization cross section for $\text{Ne}(^3\text{P}_2)$ by Xe has been made in the region of the collisional energy from 18.5 to 38.1 meV. The experimental cross sections have been compared with the deexcitation probability for $\text{Ne}(^3\text{P}_2)$ by Xe. Considering the magnitude of the mean collisional energy with respect to D , the application of the analysis in the case $E \gg D$ is expected to be more appropriate than in the case $E \ll D$. For further insight into this results, it is also of great importance to evaluate theoretical investigations of $\text{Ne}(^3\text{P}_2)$ by Xe for the case $E \gg D$.

Keywords: Metastable atoms, deexcitation probabilities, pulse radiolysis, collisional energy, potential well depth.

Introduction

Investigation of deexcitation processes 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 transfer¹⁻⁴. The deexcitation processes of excited rare gas atoms play a key also to understand fundamental processes in the interaction of ionizing radiation with matter and the phenomena in ionized gases^{4,5}.

The rate constants or the cross sections for the deexcitation processes have been measured by several methods such as a flowing afterglow technique, a beam method, and a pulse radiolysis method. A few measurements of the rate constants or cross sections for the deexcitation of excited neon atoms have been studied in comparison with the excited helium atoms¹⁻⁶. The excitation energy of a rare gas atom is sufficiently large to excite electronically or ionize various atoms and molecules. The lowest excited atoms are divided as short-lived resonant atoms and long-lived metastable atoms. Theoretical formulations of the deexcitation of metastable atoms have also been studied⁷⁻¹². However, *ab initio* calculations are still limited to some simple cases.¹³⁻¹⁷ On the contrary, few experimental works have been reported for the resonance or the radiative states in spite of much theoretical work because of experimental difficulty^{18,19}. However, several experimental and

* *Corresponding author*

theoretical results on the collisional energy dependence of the cross sections for deexcitation of the resonance states as well as metastable states have been obtained by the present author²⁰⁻²².

In this paper, the deexcitation probability calculation of the total Penning ionization cross section for Ne(³P₂) by Xe has been made in the region of the collisional energy from 18.5 to 38.1 meV. Comparing 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. The experimental cross sections have been compared with the deexcitation probability as a function of the collisional energy for Ne(³P₂) by Xe suggest that further theoretical calculations of case E >> D are needed.

Experimental Method and Calculation Procedure

The experimental apparatus for measuring the rate constants or cross sections for the deexcitation a pulse radiolysis method is employed. The experimental method and calculation procedures have been described elsewhere^{3,4,18-24}.

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 analysis²⁰

$$P_c = \frac{\sigma_M}{\langle \sigma_c \rangle} \quad (2)$$

is taken, where

$$\langle \sigma_c \rangle = \frac{k_c}{\langle v \rangle} = \int \frac{v(\pi b_c^2) f(v) dv}{\langle v \rangle} \quad (3)$$

Results and Discussion

A major part of total Penning ionization cross sections of the reported experimental cross sections are considered to be due to collisional ionization of Xe by Ne(³P₂) including both Penning ionization and associative ionization. This is because the excitation energy of Ne(³P₂) greater than the ionization potentials of Xe is enough to ionize the Xe through the transfer of excitation energy by deexcitation.

The reported experimental data are analyzed by considering the case E << D²⁰. For the case E << D, the obtained deexcitation cross sections (σ_M) and deexcitation probabilities (P_c) are shown in Table 1²⁰. In [figure 1](#), the cross sections values for Ne(³P₂) by Xe are plotted as a function of collisional energy. The cross section values slightly decrease or constant with increasing the collisional energy. In [figure 2](#), the deexcitation probabilities for Ne(³P₂) by Xe are plotted as a function of collisional energy. The deexcitation probability

values of P_c in Fig. 2 slightly decrease or constant with increasing the collisional energy for the deexcitation of $\text{Ne}(^3\text{P}_2)$ by Xe. It shows that the assumption for the constant value of $P(b) = P$ at $b < b_c$ to derive $\sigma = P\pi b_c^2$ is not appropriate. 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.²⁵

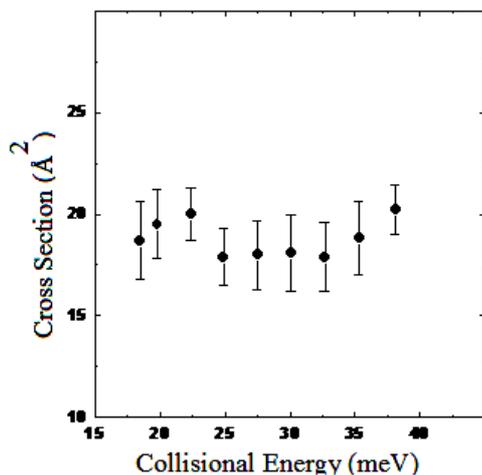


Figure 1: Cross sections vs collisional energy for the deexcitation of $\text{Ne}(^3\text{P}_2)$ by Xe.

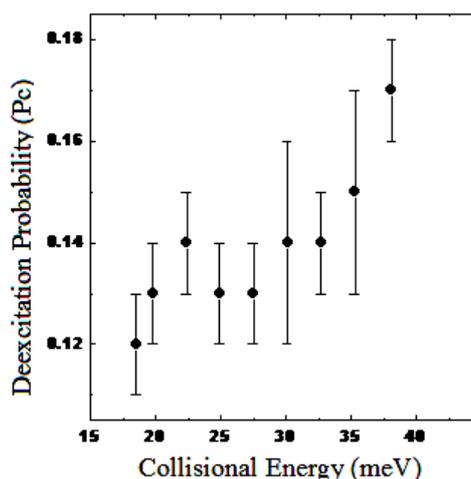


Figure 2: Deexcitation probability vs collisional energy for the deexcitation of $\text{Ne}(^3\text{P}_2)$ by Xe.

Table 1: Deexcitation probabilities P_c of $\text{Ne}(^3\text{P}_2)$ by Xe for the case $E \ll D$.

Collisional energy (meV)	38.1	35.3	32.7	30.1	27.5	24.9	22.4	19.8	18.5
$\sigma_{\text{Xe}} (\text{Å}^2)$	20.2 ± 1.2	18.8 ± 1.8	17.9 ± 1.7	18.1 ± 1.9	18.0 ± 1.7	17.9 ± 1.4	20.0 ± 1.3	19.5 ± 1.7	18.7 ± 1.9
P_c	0.17 ± 0.01	0.15 ± 0.02	0.14 ± 0.01	0.14 ± 0.02	0.13 ± 0.01	0.13 ± 0.01	0.14 ± 0.01	0.13 ± 0.01	0.12 ± 0.01

Since the obtained 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. An extrapolation of P_c together with the collisional energy dependence of πb_c^2 by $P = \sigma_M / \pi b_c^2$ to the region $0 < E < D$ does not appear to give such a collisional energy dependence. The experimental cross sections have been compared with the deexcitation probability as a function of the collisional energy for $\text{Ne}(^3\text{P}_2)$ by Xe and considering the magnitude of the mean collisional energy with respect to potential well depth suggests that further theoretical calculations for case $E \gg D$ are needed. For further understanding of deexcitation of $\text{Ne}(^3\text{P}_2)$, the quantum mechanical optical model calculations and *ab initio* calculations of the optical potentials and further absolute measurements of the rate constants or cross sections in a adequately wide collisional energy region are also needed.

Conclusions

In this paper, the deexcitation probability calculation of the total Penning ionization cross section for $\text{Ne}(^3\text{P}_2)$ by Xe 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 $E \gg D$ is expected to be more appropriate than in the case $E \ll D$. The experimental cross sections have been compared with the deexcitation probability as a function of the collisional energy for $\text{Ne}(^3\text{P}_2)$ by Xe suggest that further theoretical calculations for case $E \gg D$ are needed. The quantum mechanical optical model calculations and *ab initio* calculations of the optical potentials and further absolute measurements of the rate constants or cross sections in a adequately wide collisional energy region are also needed for further understanding of deexcitation of $\text{Ne}(^3\text{P}_2)$.

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