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Cross Sections for the Destruction of an Alignment in the Metastable 6 $^3P_2$-State of Hg by Collisions with H_2, N_2 and CO_2

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The cross sections for destruction of an alignment in the metastable 6 $^3P_2$-state of mercury atoms by collisions with H_2, N_2 and CO_2 molecules have been determined from the observation of transient signals. The results were (in units of 10^{-16} cm^2) H_2: 63 (7); N_2: 104 (13); CO_2: 663 (68).

The cross sections for depolarization of aligned Hg atoms in the metastable 6 $^3P_2$-state by collisions with noble gases have been studied by several authors [1–4]. It seemed to be of some interest to extend these measurements to collisions with other molecules. In this paper we report on an investigation of relaxation processes caused by collisions with H_2, N_2 and CO_2 molecules.

The experimental arrangement was as follows: The Hg atoms (even isotopes) were excited to the metastable 6 $^3P_2$-state in a vhf. discharge (ν = 215 MHz) which was driven by the electric field (about 150 V/cm) between the two plates of a capacitor outside the resonance vessel which contained the mercury vapour and the foreign gas. The direction of the electric field vector was chosen parallel to an external static magnetic field H_0 ($\approx 2.6 \cdot 10^{-4}$ Tesla). With these conditions a longitudinal component of an alignment in the excited state could be produced [5]. It was necessary to work with a continously pumped system instead of the usual sealed-off resonance cell in order to avoid variations of the foreign gas pressure by clean-up effects in the gas discharge [6]. By stimulating rf transitions $\Delta m = \pm 1$ between the Zeeman sublevels of the metastable state by a magnetic rf field H_1 perpendicular to H_0 the alignment will be disturbed. The change of the alignment can be monitored by the absorption of linearly polarized radiation at $\lambda = 5461$ Å corresponding to the transition $6\,^3P_2 \rightarrow 7\,^3S_1$. After switching off the disturbing rf field the alignment will be restored according to an exponential time law, which leads to transient signals in the absorption with a time constant τ_2. τ_2 is the relaxation time for collisional destruction of the alignment in the metastable state [7]. The transient signals have been detected by means of a sampling technique which was described elsewhere [7, 8].

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Figure 1 and Fig. 2 show the pressure dependence of the relaxation rate $1/\tau_2$ for H_2, N_2 and CO_2.

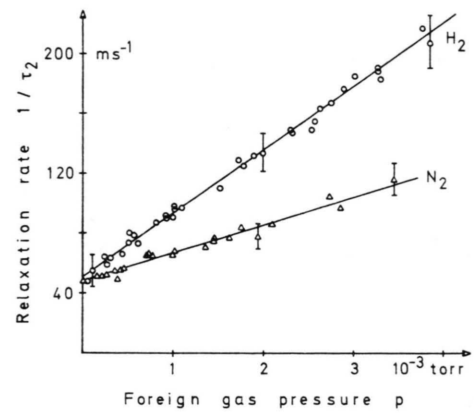

Fig. 1. Pressure dependence of the relaxation rate $1/\tau_2$ for H_2 and N_2.

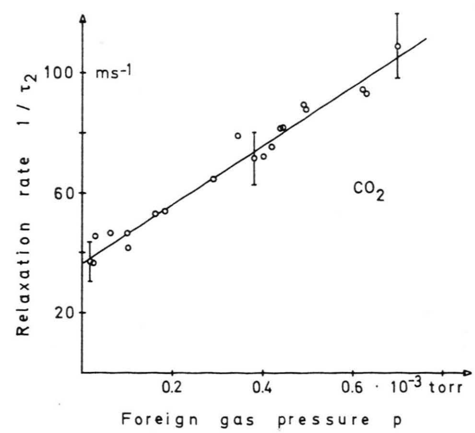

Fig. 2. Pressure dependence of the relaxation rate $1/\tau_2$ for CO_2.

Apart from the constant contribution of Hg-Hg collisions (rate $1/\tau_{Hg}$) the measured relaxation rate for the alignment $1/\tau_2$ is made up of two parts due to collisions with the foreign gas molecules:

$$\frac{1}{\tau_2} = \frac{1}{\tau_{Hg}} + \frac{1}{\tau_0} + \frac{1}{\vartheta_2} . \quad (1)$$

$1/\tau_0$ is the collisional quenching rate; $1/\vartheta_2$ describes the contribution of depolarizing collisions. The corresponding cross sections can be obtained from the following relations [9]:

$$1/\tau_0 = N\, \sigma_Q\, \bar{v}_{rel} \quad (2)$$

$$1/\vartheta_2 = N\, \sigma_2\, \bar{v}_{rel} \quad (3)$$

$$\bar{v}_{rel} = \sqrt{\frac{8}{\pi} \frac{kT}{m_0} \left(\frac{1}{M_{Hg}} + \frac{1}{M} \right)} ;$$

M_{Hg} = molecular weight of Hg,
M = molecular weight of the foreign gas,
N = density of the foreign gas,
m_0 = atomic mass unit,
k = Boltzmann factor,
T = temperature of the gas (303 K).

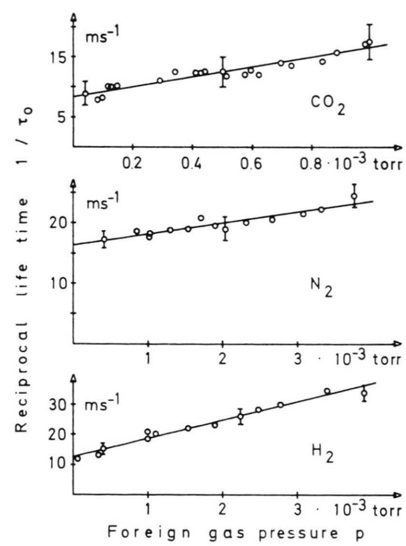

Fig. 3. Reciprocal life time $1/\tau_0$ as a function of the foreign gas pressure.

In order to obtain $1/\vartheta_2$ and the cross section for depolarizing collisions σ_2 which we where interested in, we have measured τ_0 as a function of the foreign gas pressure separately by means of the following method: The driving voltage of the gas discharge was square wave modulated (rise time $< 10\ \mu$sec) with a frequency of 1 kHz and a modulation level of about 10%. Consequently there is a periodical change in the excitation rate of the mercury atoms. The corresponding variation in the stationary number of metastable atoms is governed by the time constant τ_0. From the transient signal in the absorption of the 5461 Å line τ_0 can be determined. Figure 3 shows the reciprocal life time $1/\tau_0$ of the metastable Hg atoms as a function of the foreign gas pressure. The corresponding cross sections σ_Q for quenching collisions were calculated from Equation (2). The results are (in units of 10^{-16} cm^2): H_2: $\sigma_Q = 10.5(5)$; N_2: $\sigma_Q = 11(1)$; CO_2: $\sigma_Q = 63(5)$.

Using the experimental values for $1/\tau_2$ and $1/\tau_0$ the cross sections σ_2 for depolarizing collisions have been calculated from Equation (3). The results are indicated in the first column of Table 1. In the second column the cross sections σ_2 are compared to those for the $6\,^3P_1$-state of mercury [10]. From similar experiments [1–4, 10] the ratio of the cross sections $\sigma_2(6\,^3P_2)/\sigma_2(6\,^3P_1)$ for collisions with noble gases can be determined. One obtains values in the range from about 1.5 to 2.0. While the result for H_2 compares well with the noble gases there are deviations for CO_2 and N_2. Especially the ratio of the cross sections for N_2 is remarkably small.

Table 1. Cross sections σ_2 for depolarizing collisions.

	$\sigma_2(6\,^3P_2)/10^{-16}$ cm^2	$\sigma_2(6\,^3P_2)/\sigma_2(6\,^3P_1)$
H_2	63 (7)	1.91 (39)
N_2	104 (13)	0.77 (13)
CO_2	663 (68)	2.67 (44)

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