Decay of metastable Ne (/sup 3/P/sub 2/)-atoms

DECAY OF METASTABLE Ne ($^3P_2$)-ATOMS

J.W.H. Dielis, F.J. de Hoog and D.C. Schram.

Eindhoven University of Technology, Eindhoven, the Netherlands.

Investigations on the destruction rates of metastable atoms as a function of gas density in neon and the other noble gases have been carried out in recent years. The experimental method most frequently used is the optical absorption technique. (1,2,3, 4). A tunable dye laser was used in (5) to study non resonant fluorescence in the afterglow of a positive column in neon to determine the decay frequency of 3s-states. In another experiment a time resolved study of the vacuum U.V. emission of Ne ($^1P_1$) and Ne ($^3P_1$) states was carried out to study the Ne ($^3P_2$) decay (6). At this moment the numerous mechanisms which govern the $^3P_2$ decay are fairly well understood (1,5). In the present work the afterglow of a Townsend discharge (T.D.) is used for mass spectrometrical determination of the Ne ($^3P_2$) decay at 77 and 295 K, using the Penning ionisation of N_2 impurities as a diagnostic reaction. Current densities smaller than 10^{-8} A/cm^2 provide cumulative processes, e.g. dissociative recombination, not to take place.

Theory

Because of this low current density $^3P_2$-atoms are only destroyed by i) diffusion to the wall (D), ii) excitation with a ground state atom to the nearest $^3P_1$-state (a.A) and iii) three body collisions with two ground state atoms (γ). (See fig. 1). The $^3P_2$ decay frequency reads

$$\nu = \frac{D}{N\Lambda^2} + \gamma N^2 + a.A.N. \left(1 - \frac{N_R}{a.N_M}\right) \qquad (1)$$

with N_R and N_M the $^3P_1$ and $^3P_2$ densities, N the gas density, A the de-excitation frequency, a the ratio of excitation to de-excitation and Λ the diffusion length.

Method

The Ne ($^3P_2$) decay rate is measured by using the Penning ionisation reaction Ne ($^3P_2$)+N_2→N_2^++Ne+e$^-$. The nitrogen density in the parent gas is so small that it does not affect the decay frequency. The rate of formation of N_2^+ ions is proportional to the $^3P_2$-state density. The T.D. is pulsed from burning voltage to a lower voltage in the afterglow. N_2^+-ions formed by the Penning reaction in the afterglow drift to the cathode which contains a small hole (10 μm). The ions are sampled, selected on mass by a Q-pole mass filter and are detected by a channeltron. The times of arrival of the N_2^+-ions after onset of the afterglow are processed by a microprocessor. Repeatedly pulsing gives a histogram of arrival times of N_2^+, identical to the relative density of the $^3P_2$-atoms as a function of time in the afterglow and hence yield the decay frequency. The T.D., placed in a cryostat, can be cooled to liquid nitrogen temperature of 77 K. Cataphoresis of the research grade neon gas provides the impurity degree to be less than a few p.p.m. (Fig.2: exp.)

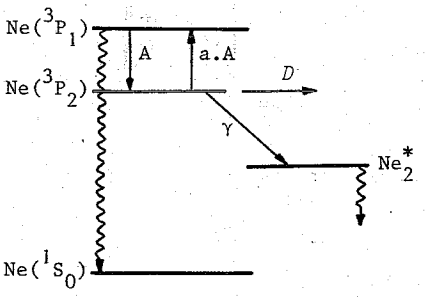

Fig 1: Diagram for the decay of Ne($^3P_2$) atoms.

Results

The measured decay frequencies as a function of gas density at 77 and 295 K are shown in fig. 3. By means of a nonlinear least mean square procedure eq. (1) is fitted to the data, obtaining the best values for D, A and γ, as given below

Temperature	295 K	77 K
D(10^{20}m^{-1}s^{-1})	4.8 ± 0.3	2.3 ± 0.2
A(10^{20}m^{3}s^{-1})	3.2 ± 0.1	0
γ(10^{-46}m^{6}s^{-1})	5.4 ± 0.3	0.52 ± 0.04

Diffusion coefficient

As can be seen in fig. 4 the agreement of the present data at 295 K is good, whereas at 77 K the present value is 25% larger than previous results. From potential curve considerations, showing a large insensibility of D on the shape and parameter values of the ($^3P_2$ - ^1S_o) interaction, this deviation is not disquieting.

De-excitation rate

Experimental (1,5,6,10) and theoretical (11) results on A are shown in fig. 5. The present result at 295 K is 50% smaller than previous data, but in good agreement with the theory of Cohen et al (11).

Three-body collision coefficient

The present results on γ at 77 and 300 K are in good agreement with previous experiments. The activation energy for this process is calculated to be 0.032 eV, in conformity with (12) and (13).

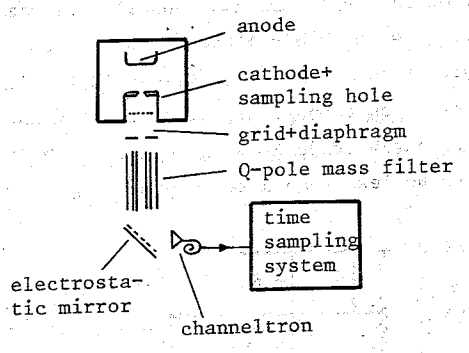

Fig 2: Experimental setup and measuring system.

Acknowledgements

The authors thank L.A.W.Gaykema and M.J.P.Vetjens for their valuable contributions and D.C.Schram and A.A.Kruithof for helpful discussions.

References

(1) Phelps A.V., Phys. Rev. 114 (1011) 1959.
(2) Phelps A.V. et al,Phys. Rev. 89 (1202) 1953.
(3) Dixon J.R. et al, Phys. Rev. 107 (118) 1957.
(4) Grant J.R. et al, Phys. Rev. 90 (59) 1953.
(5) Steenhuysen L.W.G. et al, Proc. XIII ICPIG Berlin p. 37, 1977.
(6) Leichner P.K. et al, Phys. Rev. A12 (2501) 1975.
(7) Metaxas A.C. et al, J. Phys. D5 (1077) 1972.
(8) Grant F.A., Phys. Rev. 84 (844) 1951.
(9) Molnar J.P., Phys. Rev. 83 (945) 1951.
(10) Biondi M.A., Phys. Rev. 88 (660) 1952.
(11) Cohen J.S. et al, Phys. Rev. A17 (1343) 1978.
(12) Cohen J.S. et al, J. Chem. Phys. 61 (3230) 1974.
(13) Gritsyna V.V., Opt. Comm. 10 (320) 1974.

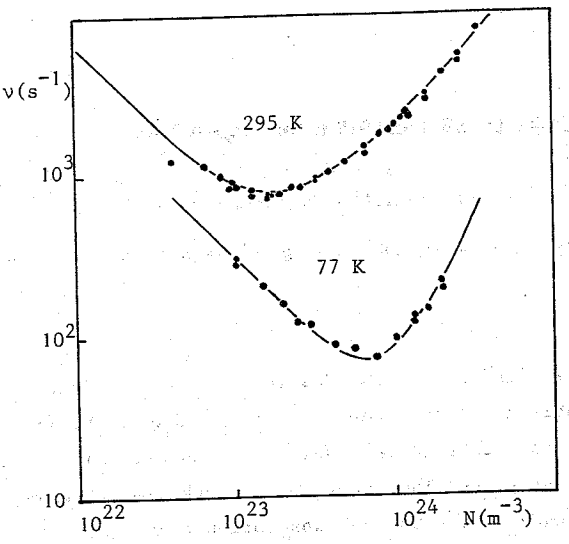

Fig 3: Decay frequency of Ne($^3P_2$) vs. gas density at 77 and 295 K solid curve: least square fit of eq.1

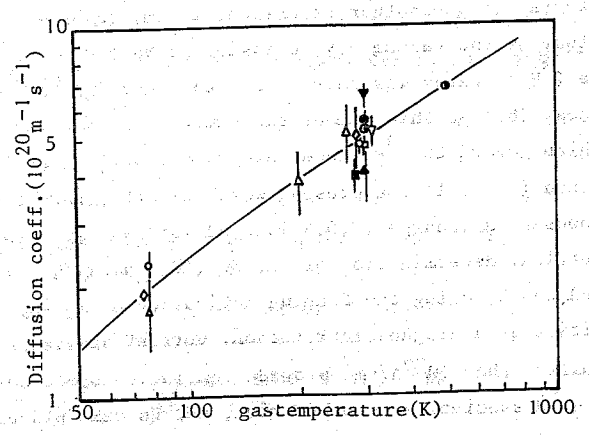

Fig 4: Diffusion coefficient vs. gas temperature. 1(●),4(Δ),5(□),7(▽),3(●),8(▲), 9(■),10(▼),2(◇),present(○). Solid curve:theory with 16/6-potential.

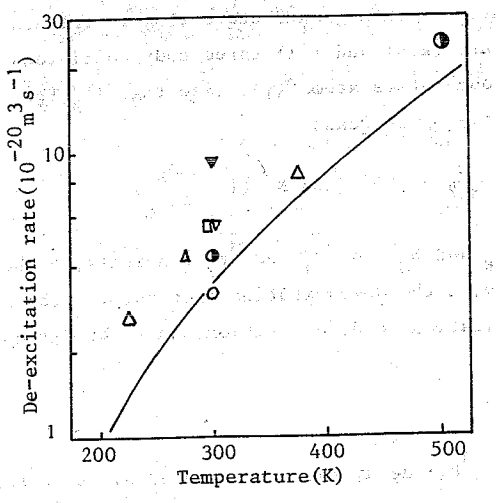

Fig 5: De-excitation rate vs. gas temperature. 1(◑),4(Δ),10(▼),5(□), 6(▽),present(○). solid curve: theory/12/.