

Radiative Lifetimes of Some Ultraviolet Transitions of N I and N II¹

Wm. Hayden Smith, J. Bromander, L. J. Curtis,² and R. Buchta

Princeton University Observatory, Princeton, New Jersey, and Research Institute for Physics, Stockholm, Sweden

Received November 16, 1970

Abstract

Radiative lifetimes of some ultraviolet transitions of N I and N II. Wm. Hayden Smith (Princeton University Observatory), J. Bromander, L. J. Curtis and R. Buchta (Research Institute for Physics, Stockholm, Sweden). *Physica Scripta (Sweden) 2, 211–212, 1970.*

Beam-foil studies of the prominent transitions of N I and N II below 1 200 Å have yielded accurate lifetimes and oscillator strengths. The lifetime of the N II transition at 916 Å ($2s^22p^3P-2s2p^3P$) was found to have a lifetime of 0.82 ns. These studies are discussed in relation with the results of other laboratories.

1. Introduction

The present research was undertaken to attempt to resolve the apparent difference between the measured lifetime of the N II transition at 916 Å ($2s^22p^3P-2s2p^3P$) as measured by Heroux [1] in a beam-foil experiment and Hesser and Lutz [2] in a phase shift experiment. Heroux found a lifetime of 0.96 ± 0.05 ns, while Hesser and Lutz found a lifetime of 0.4 ± 0.2 ns, with cascading represented by a lifetime of 17 ns. It was suggested by Hesser and Lutz that the discrepancy between the results of the two investigations arose from the neglect of cascading by Heroux. It was to test this possibility, and to obtain lifetime results for other transitions in low charge states of nitrogen that the present study was carried out.

2. Experimental

We have applied the standard beam-foil technique using a low energy isotope separator as an accelerator. 112 keV N⁺⁺ ions were excited by a 10 μg/cm² carbon foil, and spectra were studied in the wavelength range 650–1 200 Å. The majority of the recorded lines belong to N I and N II and only a few persistent transitions in N III were observed.

The spectroscopic equipment consisted of a 1-m normal incidence vacuum monochromator with a Bendix Channeltron multiplier as a photon detector.

To measure the velocity of the beam particles after the foil we used an electrostatic energy analyzer. At 112 keV incident energy the velocity after the foil turned out to be 1.16 mm/ns ± 4%, the uncertainty being mainly due to differences in the foil thicknesses.

¹ This research was supported in part by the Swedish Natural Science Research Council, and by the National Aeronautics and Space Administration.

² Permanent address: University of Toledo, Department of Physics.

The decay curves were obtained by counting photons for times corresponding to equal amounts of charge in the Faraday cup for each position downstream from the foil. The sums of several independent runs were then analyzed with a least squares computer routine which fitted one or two exponentials and a time independent background to the experimental points. Many of the transitions were studied both in the first and second order. The error limits quoted in Table I are a combination of the RMS errors of the fitted parameters and the error in the velocity determination.

Results

The results of this work under the conditions specified in the experimental section of this note are listed in Table I. We find quite good agreement with earlier experimental studies for the 672 and 1 085 Å transitions of N II and the 1 135 Å transition of N I, but are at variance with certain studies for the other transitions as will now be detailed.

The transition at 916 Å is a resonance transition in the nitrogen ion that can be observed in the interstellar medium, and thus is of value in the determination of the abundance and charge state distribution of nitrogen in space. The study of Heroux [1] gave a lifetime of 0.96 ns for this transition and stated that the decay curve was a single exponential. Hesser and Lutz [2] on the other hand found a lifetime of 0.4 ns and the presence of cascading.

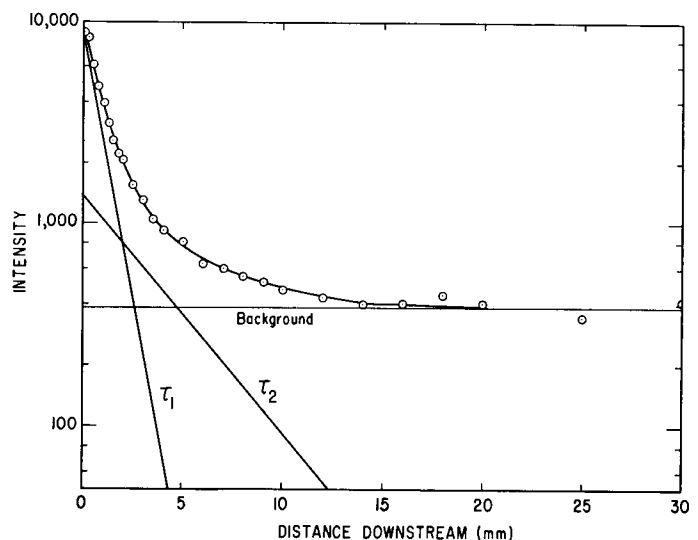


Fig. 1. Observed decay of the N II transition at 776 Å. Circles represent the experimental points. Solid lines represent the fitted exponentials and the background.

Table I. *Lifetimes of levels in N I and N II*

(a) ref. 5, phase shift; (b) ref. 1, beam-foil; (c) ref. 6, beam-foil; (d) ref. 2, phase-shift; (e) ref. 4, compilation of best values; (f) ref. 3, many electron theory

Spectrum	Wavelength (Å)	Combination	Lifetime (ns)			Other values (ns)						<i>f</i> -value this expt.
			Upper level	Cascade	$R(0)^a$	a	b	c	d	e	f	
N II	672	$2s^2 2p^3 P - 2p^3 s^3 P$	1.08 ± 0.09	11.0 ± 0.9	0.23		1.01 ± 0.15	0.9 ± 0.9	0.9 ± 0.2	0.77		0.063 ± 0.004
N II	776	$2s^2 2p^2 1D - 2s 2p^3 1D$	0.70 ± 0.07	3.8 ± 0.8	0.09				0.0 ± 0.2	0.20	0.282	0.129 ± 0.013
N II	916	$2s^2 2p^2 3P - 2s 2p^3 3P$	0.82 ± 0.06	5.5 ± 1.2	0.25		0.96 ± 0.05		0.4 ± 0.2	0.56	0.86	0.153 ± 0.011
N II	1 085	$2s^2 2p^2 3P - 2s 2p^3 3D$	2.92 ± 0.17	—	—	2.7 ± 0.3	2.92 ± 0.15	2.8 ± 0.2		1.75	2.88	0.107 ± 0.006
N I	1 135	$2s^2 2p^3 1S - 2s 2p^4 p$	7.4 ± 0.4	—	—	7.2 ± 0.7		7.0 ± 0.2		4.3	3.62	0.078 ± 0.004

^a Replenishment ratio, defined in ref. 7 as $R(0) = (1 - \tau_1/\tau_2)/(1 + C_1/C_2)$, where C_1/C_2 is the ratio of the two exponential decay intercepts at time zero.

We have remeasured the upper state lifetime of this transition and found a value of 0.82 ± 0.06 ns with a cascading that is describable with a lifetime of 11 ns. Thus, we find a lifetime that is in fair agreement with that of Heroux, and probably would be in excellent agreement if the decay curves in that study had been carried out to a greater number of mean lives before cutoff, and then analyzed for cascades. The recent calculation of Westhaus and Sinanoğlu [3] gives a predicted lifetime in very good agreement with our result and is considerably superior in accuracy to the results quoted by Wiese et al. [4]. In order to understand the discrepancy with Hesser and Lutz, we can only suggest that the spectral overlap with the $p' - X$ transition of N_2 which was exhibited in their spectra may have influenced their analysis, which assumed only a cascade and no overlapping of emissions from other sources.

The N II transition at 776 Å ($2s^2 2p^2 1D - 2s 2p^3 1D$) was found to have a decay curve (Fig. 1) that is well fitted by a main lifetime of 0.70 ± 0.07 ns with a 3.8 ns cascade. This result is very different from that of Hesser and Lutz, the only experimental result available in the literature. They found a cascade-free lifetime of $0.0^{+0.2}_{-0.0}$ ns which was in fair agreement with the calculations quoted by Wiese et al. [4] and Westhaus and Sinanoğlu [3]. Our data give no evidence for a decay as short as that found by Hesser and Lutz, as shown by Fig. 1. It is possible that a decay much less than 0.2 ns would have been missed in our experiment, although a lifetime of 0.2 to 0.3 ns would have been detected. In order to determine whether the decay measured here is the main decay or a cascade decay, as would be implied by Hesser and Lutz' results, in which case the lifetime must be much less than 0.2 ns, requires a higher time resolution than can be obtained at the beam velocities used here.

Acknowledgements

The authors wish to thank H. G. Berry for helpful discussions and placing the unpublished N I and N II results from ref. 6 at our disposal.

References

1. Heroux, L., Phys. Rev. **153**, 156 (1967).
2. Hesser, J. E. and Lutz, B. L., J. Opt. Soc. Am. **58**, 1513 (1968).
3. Westhaus, P. and Sinanoğlu, O., Phys. Rev. **183**, 56 (1969).
4. Wiese, W. L., Smith, M. W. and Glennon, B. M., Atomic Transition Probabilities vol. I, NSRDS-NBS4. US Government Printing Office, Washington, D.C., 1966.
5. Lawrence, G. M. and Savage, B. D., Phys. Rev. **141**, 67 (1966).
6. Berry, H. G., Bickel, W. S., Bashkin, S., Desesquelles, J. and Schectman, R., to be published.
7. Curtis, L. J., Berry, H. G. and Bromander, J., Physica Scripta (in press).

Research Institute for Physics
Roslagsvägen 100
S-104 05 Stockholm 50, Sweden