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Redetermination of the mean life of the $2p_9$ level in Ne I using cascade analysis

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We report in this letter a confirmation of our recent measurements of the mean lives of the $2p_9$ and $2s_5$ levels in Ne I, which were previously described in this journal.[1] These latest results not only provide improved mean-life estimates, but also verify the validity of our previously presented method of analysis which utilizes analytic relationships between the transition probability of a cascade-repopulated level and the relatively normalized decay curves (RNDC) of all transitions into and out of that level.

The basic relationships employed in the data analysis are developed elsewhere,[1,2] where it is shown that for a cascaded level N with a single decay branch (as is the $2p_9$) the lifetime τ_N can be written

$$\tau_N = \left[\int_{T_I}^{T_F} dt\, I_{NJ} - \sum_k \int_{T_I}^{T_F} dt\, I_{kN}\right] \Big/ [I_{NJ}(T_I) - I_{NJ}(T_F)]. \quad (1)$$

Here, $I_{mn}(t)$ represents the RNDC for the transition $m \rightarrow n$ and the sum on k is over all cascade transitions into level N; J is the single lower level into which level N depopulates; the times $t = T_I$ and $t = T_F$ may be chosen arbitrarily. If all RNDC's occurring in Eq. (1) are measured, the value of τ_N is then obtained from this equation.

In our earlier work, the RNDC's of the $2p_9$ level and 11 of its 12 significant cascades were measured. The cascade from $2s_5$ at 11 180 Å was far beyond the infrared limit of our detector, and could not be measured. Because of this missing RNDC, Eq. (1) cannot be applied directly. Consequently, in our previous report, two observations are invoked. The first is that if a value for τ_N is assumed, Eq. (1) can be inverted to yield the RNDC of the unobserved transition. The second is that a study of available excitation cross sections indicated that cascading into the $2s_5$ level should be small and that the unobserved RNDC should display a very nearly single exponential functional form. We therefore postulated that the actual value of τ_N should be that which gives the reconstructed RNDC that most closely approaches, in the least-squares sense, a single exponential. This allowed us to obtain from Eq. (1) both the $2p_9$ mean life and, through the reconstructed RNDC, the $2s_5$ mean life.

Subsequently, we have extended our detection range to 10 000 Å through the addition of a dry-ice-cooled S-1 ITT FW4034 multiplier phototube. This permitted a direct measurement of the $2s_5$ decay curve through the $2p_{10}$–$1s_5$ transition branch at 9665 Å. Since all transitions from the same upper level have the same shape, this is, to within a normalization constant, the required missing decay curve. The reconstructed RNDC of the previous work and the measured arbitrarily normalized decay curve (ANDC) obtained here are shown in Fig. 1. The curves compare very favorably, thus directly verifying our assumption that $2s_5$ was a single exponential and, more important, confirming the validity of our technique for reconstructing unobserved decay curves. The mean lives are consistent (240 ± 7 ns vs 239 ± 11 ns) and the new measurement provides increased information and accuracy. It is interesting to note that, despite 20 h of running time for the directly measured decay curve, the statistical spread of the reconstructed decay is still somewhat smaller, demonstrating the usefulness of the indirect method for transitions for which detection efficiencies are low.

It is still not possible to use Eq. (1) directly to obtain τ_N because ($2p_9$–$2s_5/2p_{10}$–$2s_5$) branching ratio is not known with sufficient accuracy to determine the normalization constant, ξ, by which the newly measured ANDC should be multiplied before incorporating it into this equation. However, since the choices of T_I and T_F

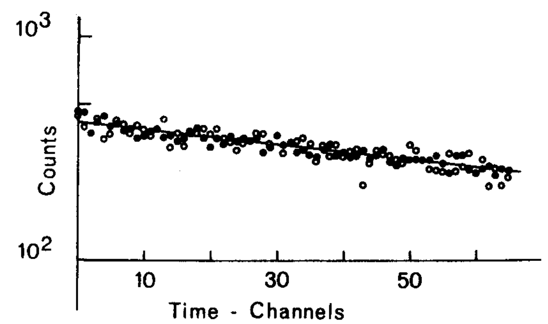

FIG. 1. Intensity decay curve of the $2s_5$ level of Ne I. The time calibration is 1.89 ns/channel. Solid circles represent the reconstructed decay curve of Ref. 1; open circles are the results of the direct measurement presented here. The solid line represents a single exponential decay with $\tau = 240$ ns.

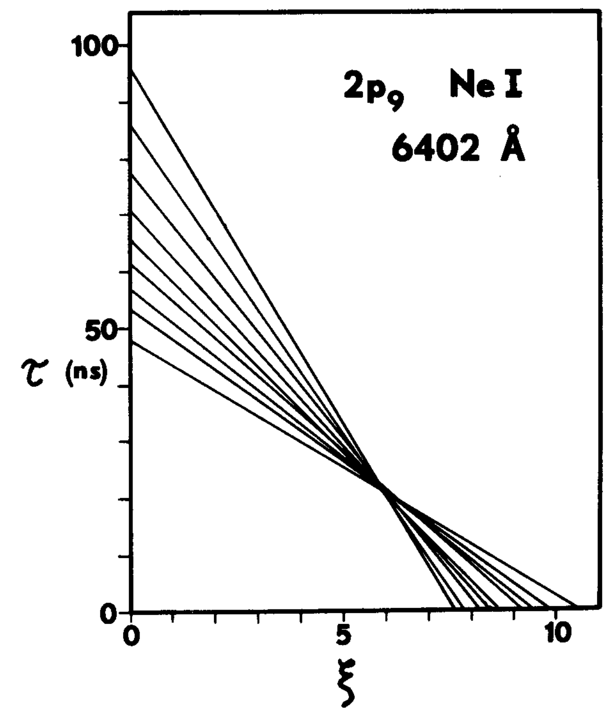

FIG. 2. Parametric ANDC analysis. The mean life of the $2p_9$ level, τ, is plotted as a function of the normalization parameter ξ.

are arbitrary, Eq. (1) actually furnishes a large number of linear relationships between τ_N and ξ of the form

$$\tau_N = a(T_I,T_F) - b(T_I,T_F)\xi, \quad (2)$$

where $a(T_I,T_F)$ is the right-hand side of Eq. (1), with the $2s_5$ term omitted from the k sum, and $b(T_I,T_F)$ is the unnormalized contribution of the ANDC of the $2s_5$ to Eq. (1). Since a and b are determinable from our data, τ_N and ξ can be obtained from the parametric plot shown in Fig. 2, a straightforward extension of the analysis technique applied to a singly cascaded level which was reported earlier.[3] The value obtained for τ_{2p_9} in this manner is in no way subject to assumptions concerning the amount of cascading into the $2s_5$ level and is therefore inherently more accurate than our previous estimate. The mean life of the $2p_9$ level determined in this fashion, 21.7±0.9 ns, is consistent with our previous result of 21.4±0.9 ns. It remains in good agreement with the value obtained by Klose[4] (22.5±0.5 ns) and somewhat higher than the value obtained by Bennett and Kindlmann[5] (19.5±0.6 ns). It is significantly higher than the recent Hanle-effect measurement[6] of Carrington (18.7±0.7 ns).

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