Remeasurement of the Mg $^3P_1$-state lifetime*

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The lifetime of the metastable $^3P_1$ state of Mg has been remeasured by a dye-laser excitation technique. The metastable state was populated by an intense pulse of 4571-Å radiation from a flashlamp-pumped dye laser, and the decay of the population was monitored by observing the absorption of 5173-Å resonance radiation from a Mg discharge lamp. The measured value for the $^3P_1$ lifetime is 4.5 ± 0.5 msec.

In a previous paper,[1] we reported a measurement of the lifetime of the $^3P_1$ metastable state of Mg. Our value of 2.2 ± 0.2 msec was in good agreement with published experimental results,[2] but in disagreement with several theoretical calculations[3] which predicted a lifetime of ~4 msec.

Subsequently, we measured the $^3P_1$ lifetime in Ca,[4] and our result was in excellent agreement with recent theoretical calculations as well as with previous experiments. Because the calculation for Mg is expected to be as reliable as the calculation for Ca, the discrepancy between our value for the Mg lifetime and the theoretical predictions was disturbing. Despite the care taken in our original experiment to eliminate quenching of the metastable state by contaminants in the sample, the fact that our value was shorter than the theoretical lifetime suggested that contamination might be the source of the discrepancy. This view was reinforced by the agreement between our experiment and theory in the case of Ca, where the experiment is less sensitive to quenching. Therefore, we decided to remeasure the Mg lifetime.

We report here the results of our remeasurement. A block diagram of the apparatus is shown in Fig. 1. The basic experimental technique is described in Ref. 1. Large numbers of Mg atoms were excited to the $^3P_1$ level by passing an intense 0.5-μsec pulse of 4571-Å radiation from a dye laser through a tantalum-lined quartz absorption cell containing Mg vapor and an inert buffer gas. The number of atoms in the $^3P_1$ state was monitored as a function of time by observing the absorption by the metastables of 5173-Å Mg resonance radiation. In the original experiment, oscilloscope traces of the absorption signals were photographed and analyzed. In the present experiment, we recorded, stored, and analyzed the signals with a PDP-Lab 8E signal averaging system.

In our first Mg experiment, the observed lifetime was independent of buffer-gas pressure, clearly indicating that quenching by impurities in the buffer gas was not a problem. This is not surprising because the Mg vapor is an excellent getter. We tested the gettering properties of the Mg by introducing small quantities of air into the sample. We observed a strong quenching effect, which disappeared in a matter of minutes as the air was gettered. For this reason, we anticipatec that the most likely source of impurities which could continuously quench the metastables was the residual outgassing of the tantalum liner.

In the original experiment we had outgassed the tantalum at 850°C until the vacuum reached 2×10^{-6} Torr before admitting gas and running at 500°C. In the present experiment we outgassed the tantalum at 1050°C until the vacuum reached 9×10^{-8} Torr, the point at which we no longer gained by continued heating. This resulted in an increase in the observed lifetime of approximately a factor of 2. Because of the longer observed lifetime, diffusion of the Mg metastables to the wall became an observable effect; so we increased the diameter of our cells from 2.5 to 5.0 cm to minimize the effect of wall quenching.

In order to check for possible systematic error inherent in the absorption monitoring technique (nonlinear absorption), in some runs we monitored the decay of the metastables by observing the fluorescence from the $^3P_1$ state. The fluorescence measurements were in complete

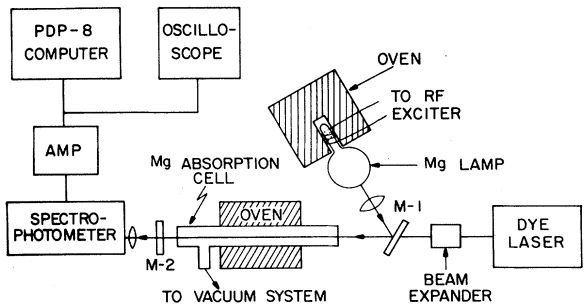

Fig. 1. A block diagram of the apparatus.

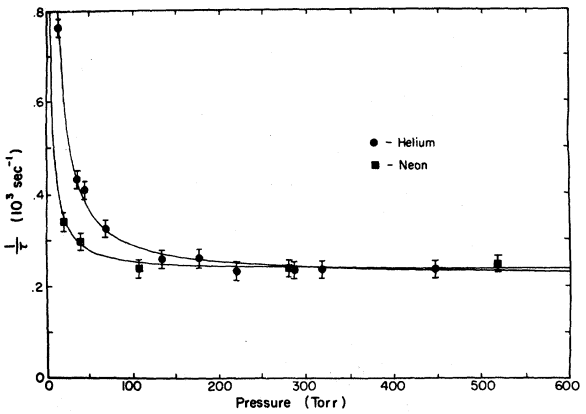

Fig. 2. Observed reciprocal lifetime of the Mg $^3P_1$ state as a function of buffer-gas pressure. Each point represents the average of a minimum of 40 absorption signals.

agreement with the absorption measurements. There was no observed dependence on the Mg density, which we varied by more than an order of magnitude, indicating that radiation trapping was not a problem.

The results of our measurements as a function of buffer-gas pressure for He and Ne are shown in Fig. 2. There was no indication of quenching by the buffer-gas atoms, although the effect of wall quenching with decreasing gas pressure is clearly evident. To take diffusion into account, we extrapolated to infinite buffer-gas pressure assuming a simple $1/P$ pressure dependence. Our extrapolated values for He and Ne are 4.3 and 4.7 msec, respectively. We quote for our remeasured value of the Mg lifetime 4.5 ± 0.5 msec. We attribute the difference between the present results and our previous measurements to quenching by unknown contaminants in the original samples.

TABLE I. A summary of recent theoretical and experimental values for the Mg $^3P_1$ lifetime.

Author	Theory τ (msec)	Expt[a] τ (msec)
Garstang (Ref. 3)	4.2	
Victor and Laughlin (Ref. 3)	4.6	
Mitchell (Ref. 6)		3.8 ± 1.2
Boldt (Ref. 2)		1.9 ± 0.4
Strumia *et al.* (Ref. 5)		1.8 ± 0.2
This experiment		4.5 ± 0.5

Because of our inability to monitor contamination independently, our value must be considered to be a lower limit to the $^3P_1$ lifetime, where the quoted error represents our estimate of nonsystematic error. There were a number of indications, however, that we did successfully eliminate quenching as a source of error. First of all, the density of contaminants coming from the walls should be strongly temperature dependent, but the temperature of the cell could be varied between 440 and 640°C, with no measurable decrease in the observed lifetime. Secondly, a reduction by more than an order of magnitude of the outgassing of the tantalum at 1050 °C during the sample preparation only increased the observed lifetime by a factor of 2. Thirdly, we obtained reproducible results from a number of samples.

Our remeasured value of the $^3P_1$ lifetime is compared in Table I with other recent measurements and theoretical calculations. It is the first published value which is in substantial agreement with theoretical predictions.

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