Measurement of the $^3P_1$ lifetime in Sr†

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The lifetime of the $^3P_1$ state of Sr has been measured by observing the intensity of the $5s^2\,{}^1S_0 - 5s5p\,{}^3P_1$ fluorescence as a function of time, following the excitation of the $^3P_1$ state by a 1-μsec pulse from a flashlamp-pumped dye laser. The measured value of the $^3P_1$ lifetime is 21 ± 1 μsec.

As part of our on-going program to determine the lifetimes of atomic states which are of astrophysical interest, we have measured the lifetime of the $^3P_1$ state in Sr. Previous experiments[1-5] by other investigators have yielded disparate results.

A block diagram of the apparatus used in this experiment is shown in Fig. 1. The technique used in the present experiment differs from that used in our previous experimental determinations[6,7] of the $^3P_1$ lifetimes in Ca and Mg. A 1-μsec pulse from a flashlamp-pumped dye laser excited Sr atoms to the $^3P_1$ level, and the lifetime was determined by observing, with a photomultiplier tube, the 6893-Å fluorescent intensity as a function of time. The signal was displayed and stored for analysis on a storage oscilloscope.

A suitable density of Sr atoms was produced by heating Sr metal in a quartz fluorescence cell lined with tantalum foil. The tantalum prevented the hot Sr vapor from reacting with the cell walls. The windows of the cell were outside the oven and the Sr vapor was prevented from reaching the windows by an inert buffer gas. The cell was connected to a vacuum-gas handling system. Each cell was typically baked out under vacuum at 950 °C until the background pressure reached 2×10^{-7} Torr. Then the cell was opened to air, Sr metal was introduced and the cell was reconnected to the vacuum system. A buffer gas was introduced and the cell was heated again to 800 °C until the Sr melted. The cell was then cooled, the contaminated gas was pumped out, and fresh gas was admitted to the cell. Runs were made in the temperature range 370–460 °C.

The observed lifetime as a function of He pressure is shown in Fig. 2 for Sr vapor pressures of $\sim3\times10^{-5}$ and $\sim8\times10^{-5}$ Torr. These data have been corrected for the effect of the mixing[6] of the $^3P_2$, $^3P_1$, and $^3P_0$ populations by collisions with the buffer gas. These data show no evidence of error due to buffer-gas quenching or diffusion to the walls. In addition, data taken in numerous runs at various temperatures showed no indication of quenching by outgassing impurities.

Figure 2 shows no systematic increase in the observed lifetime with increasing Sr density, indicating that radiation trapping was not a source of error. The onset of radiation trapping was not observed until the density of Sr was increased by an order of magnitude to $\sim7\times10^{-4}$ Torr, at which point the observed lifetime increased by ~10%. The data taken at a Sr density of $\sim7\times10^{-4}$ Torr are not shown. We therefore conclude that radiation trapping is not a source of error in the data shown in Fig. 2.

A least-squares fit of the data in Fig. 2 to a straight line yielded a zero-pressure intercept of 21.0 μsec. A straight average of the measured lifetimes, ignoring any possible buffer-gas pressure dependence, also gave 21.0 μsec. From this

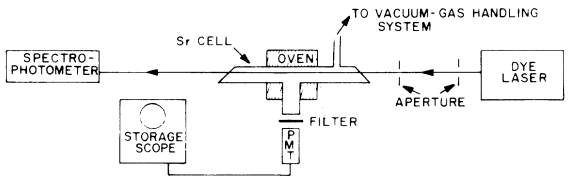

FIG. 1. Block diagram of the apparatus.

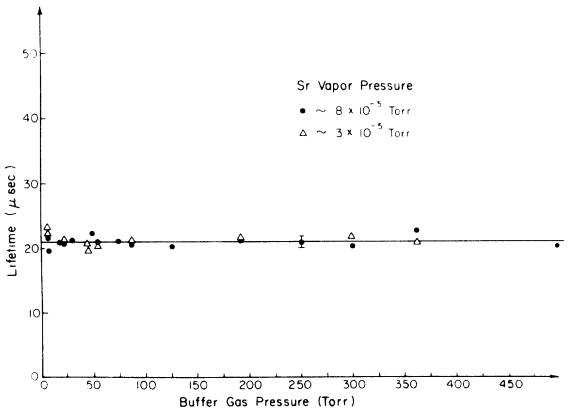

FIG. 2. Lifetime of the $^3P_1$ state of Sr as a function of He buffer-gas pressure at two different Sr vapor pressures. The horizontal line is a linear least-squares fit to the data.

TABLE I. Summary of recent theoretical and experimental values for the Sr $^3P_1$ lifetime.

Method	Lifetime (μsec)	References
Hook method	25	1
Emission spectrum	16.4(3)	2
Atomic beam	74(28)	3
Double resonance	21(3)	4
Double resonance	6.4(6)	5
Theory	19.9	8
Theory	14.5	9
Laser excitation	21(1)	This expt.

we conclude that the $^3P_1$ lifetime is 21 ± 1 μsec, where the quoted uncertainty represents the standard deviation of all measurements, independent of pressure.

Table I is a summary of the most recent experimental and theoretical determination of the Sr $^3P_1$-state lifetime. Our results are in excellent agreement with the theoretical prediction of Luc-Koenig[8] and the experimental value of Ma *et al.*[4] Our measurements of the $^3P_1$-state lifetimes in Mg, Ca, and Sr are all in excellent agreement with the calculated values for these lifetimes.

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