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TWO-PHOTON EMISSION FROM THE SINGLET METASTABLE STATE OF SINGLY IONIZED LITHIUM†

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Lipeles, Novick, and Tolk¹ have used coincidence counting techniques to detect the two-photon decay of the metastable $2^2S_{1/2}$ state of singly ionized helium. The theoretical lifetime against two-photon decay is 1.9×10^{-3} sec.² The metastable 2^1S state of singly ionized lithium may be a suitable case for investigation also. The lifetime τ for two-photon decay from a state φ_i of energy E_i to a state φ_f of energy E_f is given by³

$$\frac{1}{\tau} = \frac{1}{2} \int_0^{\nu_{if}} d\nu A(\nu),$$

where $\nu_{if} = (E_i - E_f)/h$ and $A(\nu)d\nu$ is the probability that a photon of frequency ν is emitted in the frequency interval $\nu, \nu + d\nu$. $A(\nu)d\nu$ can be written as the infinite summation

$$A(\nu)d\nu = \frac{1024\pi^6 e^4 \nu^3 \nu'^3}{3h^2 c^6} \left| \langle f | \sum_{j=1}^N z_j | m \rangle \langle m | \sum_{j=1}^N z_j | i \rangle \left(\frac{1}{\nu_{mi} + \nu} + \frac{1}{\nu_{mi} + \nu'} \right) \right|^2 d\nu,$$

where $\nu + \nu' = \nu_{if}$ and z_j is the z coordinate of the j th electron of the N -electron system. If H is the system Hamiltonian and we define χ_i by the equation

$$(H - E_i + h\nu)\chi_i(\nu) + \sum_{j=1}^N z_j \varphi_i = 0, \tag{1}$$

$A(\nu)d\nu$ can be written alternatively as

$$A(\nu)d\nu = \frac{1024\pi^6 e^4 \nu^3 \nu'^3}{3c^6} \left| \langle \varphi_f | \sum_{j=1}^N z_j | \chi_i(\nu) \rangle + \langle \varphi_f | \sum_{j=1}^N z_j | \chi_i(\nu_{if} - \nu) \rangle \right|^2 d\nu.$$

We have solved (1) by minimizing the functional

$$J(\nu) = \langle \chi_i(\nu) | H - E_i + h\nu | \chi_i(\nu) \rangle + 2 \langle \chi_i(\nu) | \sum_{j=1}^N z_j | \varphi_i \rangle$$

adopting for the eigenfunctions of the 2^1S and 1^1S states the variational representations

$$\varphi_i(\vec{r}_1, \vec{r}_1) = \exp\{-(\alpha_i r_1 + \beta_i r_2)\} \sum_{l,m,n} a_{lmn} r_1^l r_2^m r_{12}^n,$$

appropriately normalized and symmetrized, and using as the trial form of $\chi_i(\nu)$

$$\chi_i(\vec{r}_1, \vec{r}_2 | \nu) = \exp\{-(\gamma r_1 + \delta r_2)\} \times \sum_{l,m,n} b_{lmn}(\nu) r_1^l r_2^m r_{12}^n Y_1^0(\hat{r}_1) Y_0^0(\hat{r}_2)$$

appropriately symmetrized.

Up to 50 terms were included in φ_i , φ_f , and χ_i . The results show that the emitted photons have a continuous distribution broadly peaked at about 30 eV. The calculated lifetime against two-photon decay is 5.15×10^{-4} sec, though there remains some uncertainty in the third significant figure.

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INFLUENCE OF He⁴ ON EXCHANGE-LATTICE RELAXATION IN SOLID He³

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Previous papers have reported approximate agreement¹⁻³ between experimental determinations of the exchange-lattice equilibrium time in solid He³ and the theory of Griffiths.⁴ We have made measurements at molar volume 19.97 ± 0.03 cc in the temperature range 0.4 to 0.6°K which show that this agreement was fortuitous and that the equilibrium time is strongly dependent on the He⁴ content of the sample. Our results demonstrate an extra relaxation process with a rate proportional to He⁴ concentration and a temperature variation between T^8 and T^9 .

The results will be considered with reference to the "three bath model" proposed for solid He³ by Garwin and Landesman.⁵ In this region of temperature, however, the measured Zeeman-exchange relaxation times^{1,2,6} are always at least an order of magnitude smaller than the observed Zeeman-lattice relaxation times, so the Zeeman and exchange systems may be considered as intimately coupled. In the bcc phase under these conditions it has been shown¹ that the signal recovery time T_1 should be given by

$$T_1 = \tau_{XL} \{1 + F^2/(3J^2)\}, \quad (1)$$

where τ_{XL} is the exchange-lattice relaxation time, F is the Zeeman frequency, and J is the exchange frequency.

In the present experiments T_1 has been measured at various frequencies between 1.27 and 4.5 MHz for samples of He³ containing different amounts of He⁴. For each sample, values of T_1 at some fixed temperature are plotted against F^2 ; the results are compatible with Eq. (1), and we deduce that $J=0.97$ MHz fits each sample.⁷ This result has been used to derive τ_{XL} values from the measured values of T_1 . It should be noted that all signals after saturation followed a normal exponential recovery with time.

Three processes, whose transition probabilities may be assumed to add, are expected to couple the exchange system to the lattice giving

$$(\tau_{XL})^{-1} = \eta_D + \eta_{SP} + \eta_{TP}, \quad (2)$$

where η_D , η_{SP} , and η_{TP} are the rates for a diffusion-induced process, a single-phonon process, and a two-phonon process, respectively.

The diffusion process has been considered by Richards.⁸ For the bcc phase his result