MEASUREMENT OF THE 6 $^2S_{1/2}$ STATE LIFETIME OF In I BY THE HANLE EFFECT*

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The lifetime of $6^2S_{1/2}$ first excited level in In I has been measured in an atomic beam by the Hanle effect method and the result obtained is $\tau = (7.2 \pm 0.3)$ ns.

The resonance dependence of fluorescent light on the static magnetic field swept around the zero value is well known as the Hanle effect — a particular case of a general level-crossing phenomenon. The absolute value of an excited level lifetime may be obtained from the width of a resonance curve with a great accuracy. The formula describing the rate at which light with polarization $\hat{e}'$ is emitted from the crossed levels excited by the light with polarization $\hat{e}$ was derived by Breit [1] and then generalized by Franken [2]. One may write this relation in the form:

$$R = \sum_{MM'} \frac{F_{MM'}G_{M'M}}{\Gamma - i(E_M - E_{M'})/\hbar}, \tag{1}$$

where Γ — natural width of an excited level, E_M and $E_{M'}$ — energies of excited state Zeeman sublevels having the magnetic quantum numbers M and M'

$$F_{MM'} = \sum_m \langle \gamma M | \hat{e} \cdot \hat{D} | \gamma' m \rangle \langle m \gamma' | \hat{e}^* \cdot \hat{D} | \gamma M' \rangle$$

and

$$G_{M'M} = \sum_{m'} \langle \gamma M' | \hat{e}' \cdot \hat{D} | \gamma' m' \rangle \langle m' \gamma' | \hat{e}'^* \cdot \hat{D} | \gamma M \rangle,$$

where $\langle \gamma M | \hat{e} \cdot \hat{D} | \gamma' m \rangle$ is the probability amplitude of an electric dipole transition between two states with magnetic quantum numbers of an excited state M and a ground state m, respectively, (γ and γ' denote all the other quantum numbers corresponding to these states).

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We may, from this formula, evaluate the amplitude and shape of the Hanle signal. The former depends on characteristics of an investigated atomic level and on the directions of exciting and fluorescence light beams. The latter is related to the kind of crossing. For the crossing with $|\Delta M| = |M-M'| = 1$ the $F_{MM'}G_{M'M}$ product is imaginary then the signal is a dispersion curve; for $|\Delta M| = 2$ that product is real and the signal is lorenzian.

We investigated the Hanle effect signal in a particular case of the $6\,^2S_{1/2}$ first excited level of In I. Its electronic angular momentum is $J = 1/2$, therefore, according to Lurio and Gallagher [3] evidence, the only possible crossing which can be observed is the one with $|\Delta M| = 1$ and, moreover, the exciting and fluorescence light should be circularly polarized. This level has two hfs sublevels with $F = 5, 4$ (nuclear angular momentum of ^{115}In is $I = 9/2$) the Lande factors of these sublevels under the assumption of L–S coupling are 1/5 and $-1/5$, respectively. The amplitude of the Hanle signal in that case is very low and is 5% of a total fluorescence signal (diagonal elements sum in Eq. (1)).

The geometry of the reported experiment is shown in Fig. 1. The light from the resonance hollow cathode lamp was directed perpendicularly to a static magnetic field

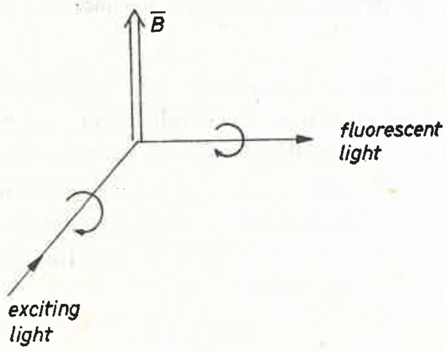

Fig. 1. Geometry of the experiment. The circular polarization of light beams is indicated

produced by Helmholtz coils. It excited indium atoms inside the atomic beam apparatus, the atomic beam Doppler profile was very wide to avoid the scanning effect [4], and then the photomultiplier EMI 9524 S detected the fluorescence light in a direction that was simultaneously perpendicular to both previous ones. The output signal from a photomultiplier was measured by a lock-in nanovoltmeter UNIPAN 232 B which was connected to an averaging system especially constructed for this experiment. It was used in order to improve a signal to noise ratio. The stability of a total fluorescent signal was controlled by a recorder measuring the dc part of the photomultiplier output signal. The modulation of the signal necessary for lock-in detection was obtained due to a rotating polarizer which gave the modulation of the circular polarization of the exciting light beam. We chose that kind of modulation to avoid distorting the signal which was present when the magnetic field modulation was used [4]. The block scheme of the experimental set-up is shown in Fig. 2.

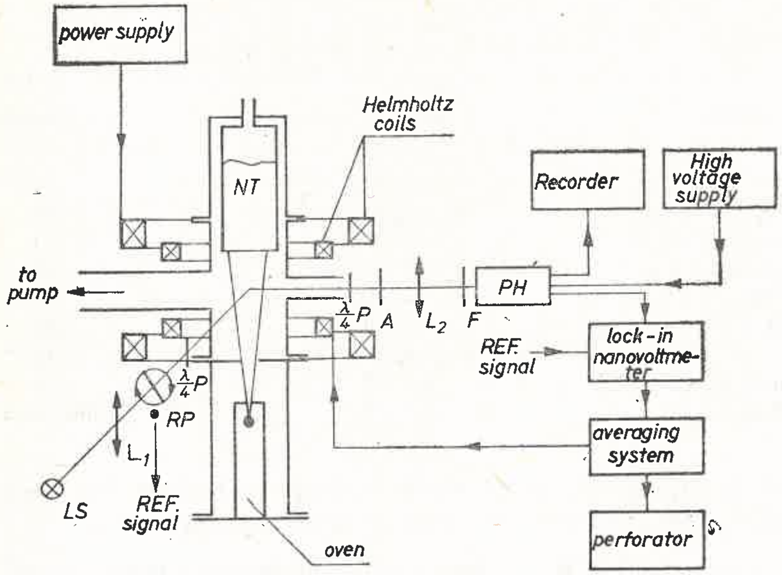

Fig. 2. Experimental set-up. LS — hollow cathode lamp, L_1, L_2 — lenses, RP — rotating linear polarizer, A — linear analyzer, $\lambda/4$ P — $\lambda/4$ plates for $\lambda = 4102$ Å and $\lambda = 4511$ Å, F — interference filter for $\lambda = 4511$ Å, PH — photomultiplier

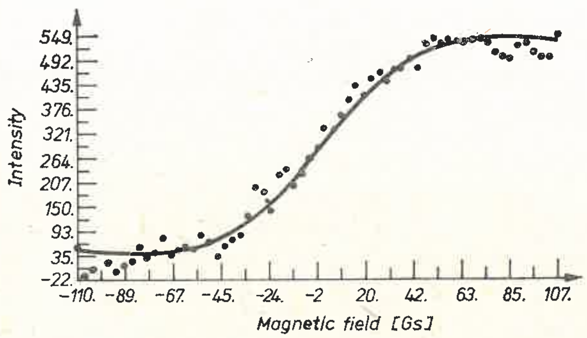

Fig. 3. Experimental result. Dots denote experimental points obtained as a result of 60 sweeps averaging. Solid line is the dispersion curve fitted by least squares method

A typical experimental result is presented in Fig. 3. This curve was obtained as a result of averaging 60 sweeps in the magnetic field range from -110 Gs to $+110$ Gs. The measured lifetime is $\tau = (7.2 \pm 0.3)$ ns. It was computed from the theoretical curve that

TABLE I

The lowest S-state lifetime of In I

Method	Lifetime in [ns]	References
Hook	6.3 ± 0.8	[5]
Phase shift	8.5 ± 0.1	[6]
Atomic-beam absorption	8.35 ± 1.2	[7]
Phase shift	7.5 ± 0.3	[8]
Hanle effect	7.0 ± 0.3	[4]
Beam foil	7.5 ± 0.7	[9]
Theory	6.46	[10]
Exponential decay	7.4 ± 0.3	[11]
Hanle effect	7.2 ± 0.3	this paper

was fitted to the experimental points by the least squares method. This result is in very good agreement with lifetime values obtained earlier by other authors.

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