Reabsorption of the 2138-A line can considerably reduce this ratio, but a rough estimate shows that this ratio remains ~ 1.

The ratio of the numbers of excitations, α_i/α_k, if we assume that the excitation occurs only because of electronic collisions, should be less than unity, but under the conditions we are considering there is a mechanism for selective excitation of the 4^1D_2 level which consists of the following: An atom of mercury has a 7^3S_1 level whose energy of excitation is only 133 cm^{-1} lower than the energy of the excited 4^1D_2 level of the zinc atom; i.e., the difference between the energies is of the order of the average energy of thermal motion of the atoms at room temperature. Therefore, we have very effective resonance collisions of the second kind between excited mercury atoms (7^3S_1) and unexcited zinc atoms, as a result of which there will occur an excitation of zinc atoms to the 4^1D_2 level. The number of mercury atoms in the discharge is very much greater than the number of zinc atoms, which guarantees a transfer of energy through collisions of the second kind.

It seems to us that this mechanism of excitation of approaching atoms by resonance collisions of the second kind in a gas discharge mixture can be extremely effective for producing a medium with a negative absorption coefficient. It seems that one can find a considerable number of examples of mixtures of atoms with nearby energy levels and with an asymmetry in the transfer of excitation by inelastic collisions of the second kind.

As an example, we may point to the mixture of cadmium and zinc atoms in which, in the diagram of energy terms, the interaction of the 5^3S_1 HgI and the 6^1S_0 CdI terms should produce a medium with a negative absorption coefficient for the infrared transition with $\lambda = 10394.7$ A and for the visible transition with $\lambda = 4413.06$ A.

The authors express their sincere gratitude to V. A. Fabrikant for valuable advice and useful discussion of the work.

[1] A. Einstein, Verh. Deutsch. Phys. Ges. **8**, 318 (1916).

[2] V. A. Fabrikant, Тр. ВЭИ (Trans. All-Union Electr. Inst.) No. 41, 236 (1940).

[3] N. G. Basov and A. M. Prokhorov, Doklady Akad. Nauk S.S.R. **101**, 47 (1955).

[4] Gordon, Zeiger, and Townes, Phys. Rev. **95**, 282 (1954).

[5] R. A. Butaeva and V. A. Fabrikant, Исследование по экспериментальной и теоретической физике (памяти Г. С. Ландсберга) [Investigations in Experimental and Theoretical Physics (in memoriam G. S. Landsberg)], U.S.S.R. Acad. Sci. Press, 1959, pages 62-70.

[6] A. L. Schawlow and C. H. Townes, Phys. Rev. **112**, 1940 (1958). A. Javan, Phys. Rev. Letters **3**, 87 (1959). J. Weber, Revs. Modern Phys. **31**, 681 (1959). Condell, Van Gunten, and Bennett, JOSA **50**, 184 (1960). S. G. Rautian and I. I. Sobel'man, JETP **39**, 217 (1960), Soviet Phys. JETP **12**, 000 (1961).

[7] Ablekov, Zaĭtsev, and Pesin, Приборы и техника эксперимента (Instrum. and Exp. Techniques) 1960 (in press).

[8] C. Allen, Astrophysical Quantities, London, Athlone Press, 1955.

Translated by M. Hamermesh
161

NUCLEAR ZEEMAN EFFECT IN Sn^{119}

N. N. DELYAGIN, V. S. SHPINEL', V. A. BRYUKHANOV, and B. ZVENGLINSKIĬ

Moscow State University

Submitted to JETP editor July 4, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **39**, 894-896 (September, 1960)

THE resonance absorption of 23.8-kev γ quanta by Sn^{119} nuclei, resulting from the emission and absorption of γ quanta without energy loss to recoil (Mössbauer effect[1]), has been observed earlier by Alikhanov and Lyubimov[2] and by Barloutaud et al.[3] Alikhanov and Lyubimov studied, in particular, the influence of an external magnetic field on the magnitude of the resonance absorption effect. In our previous work[4] we measured the dependence of the resonant absorption of 23.8-kev γ quanta emitted in the decay of Sn^{119m} on the velocity of the source with respect to the absorber; we detected a hyperfine structure of the γ rays due to the splitting of the excited state of the Sn^{119} nucleus in the electric field of the white tin crystal.

In the present work we have investigated the dependence of the resonance absorption of 23.8-kev γ quanta by Sn^{119} nuclei on the source velocity under conditions where the absorber is in an external constant magnetic field. In this case, there is a Zeeman splitting of the absorption line, and one observes in the absorption spectrum a

hyperfine structure which enables one to determine the magnetic moment of the 23.8-kev excited state of Sn^{119}. The source of γ quanta was a foil of white metallic tin (94% Sn^{118} isotope), irradiated with thermal neutrons in a reactor.

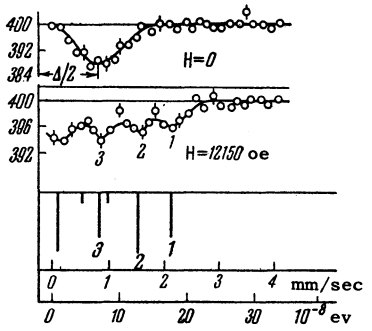
It is not advisable to use metallic tin as the absorber in this case: If we have electric quadrupole and magnetic interactions of comparable magnitude, the hyperfine structure of the level will depend on the relative orientation of the magnetic field and the axis of the electric field gradient. Therefore, a unique interpretation of the results of the measurements (for a polycrystalline absorber) will become difficult.

In our experiment we used $SnNb_3$ alloy as absorber. As we have shown earlier,[4] there is no quadrupole splitting of the 23.8-kev level in a $SnNb_3$ crystal, and therefore, in a constant magnetic field, the hyperfine structure of the absorption line has the simple Zeeman form. The measurements were made with the source and absorber cooled to liquid nitrogen temperature. The experimental apparatus enabling us simultaneously to measure the whole absorption spectrum over a given interval of source velocity was described briefly earlier.[4] The absorber (20 mg/cm^2 of $SnNb_3$) was placed between the poles of a magnet which produced over the region of the absorber a constant homogeneous magnetic field of 12,150 oe. The measurements were made alternately with magnetic field and without field.

In the magnetic field the ground state of the Sn^{119} nucleus (spin $\frac{1}{2}$) splits into two sub-levels, and the excited state (spin $\frac{3}{2}$) into four sub-levels. Between the sub-levels of the excited and ground states six different M1 transitions are possible; as we change the velocity of the source, there occur successive overlappings of the six absorption lines with the two lines of the radiation (the hyperfine structure caused by the quadrupole interaction in the white tin crystal). Thus in the measured absorption spectrum one should observe twelve lines (over the whole range of positive and negative source velocities).

The form of the absorption spectrum will depend on the absolute values of the magnetic moments of the ground (μ_0) and excited (μ) states of the Sn^{119} nucleus, on the relative sign of these moments, and on the size of the quadrupole splitting Δ of the excited state in the tin crystal. The magnetic moment of the ground state of Sn^{119} is known to be -1.05 nuclear magnetons.[5]

The results of the measurements are shown in the figure (the ordinates give the counting rate in arbitrary units, and the abscissa the source velocity in mm/sec, or the corresponding energy shift in ev). Since the counting rate for negative values of the velocity did not differ within the limits of experimental error from the counting rate for positive velocities, we show on the figure only the half of the absorption spectrum for positive velocities. In the upper half of the figure is shown the absorption spectrum in the absence of the magnetic field, analogous to that obtained by us previously.[4] From this spectrum we again determined the separation Δ between the components of the hyperfine structure in the tin crystal; we obtained the value $(1.2 \pm 0.2) \times 10^{-7}$ ev, which is in good agreement with the value obtained previously.[4]



The absorption spectrum obtained when a magnetic field of 12,150 oe is applied to the absorber is shown in the middle part of the figure. Since the size of the magnetic splitting is comparable with the natural line width, not all of the lines in the spectrum are resolved, but this does not prevent a unique interpretation of the result. The position of the farthest absorption maximum (shown in the figure by the number 1) corresponds to an energy shift equal to $\mu H + \mu_0 H + \Delta/2$, if the signs of the magnetic moments of ground and excited state are opposite, and $\mu H - \mu_0 H + \Delta/2$ if these signs are the same (in the formulas, μ and μ_0 are the absolute values of the magnetic moments).

The overall appearance of the absorption spectrum enables us to make a choice between these two possibilities, since the experimental data agree with the theoretical computations of the absorption spectrum only for the case of opposite signs of μ and μ_0 (positive sign of μ). The computed absorption spectrum is shown in the lower part of the figure (disregarding the natural line width; the heights of the lines are proportional to their intensities). Thus, to determine the value of μ it is sufficient in principle to determine the position of just the single extreme absorption maximum.

Knowing the position of the three maxima

(1, 2, and 3 in the figure), we can independently determine, in addition to the value of μ, the values of the quantities Δ and μ_0, which is an additional check of the validity of the interpretation of the measured absorption spectrum. Thus, for the value of Δ we obtained $(1.9 \pm 0.2) \times 10^{-7}$ ev, which is in good agreement with the value obtained from the absorption spectrum in the absence of a magnetic field, and the value of μ_0 was found to be $-(1.1 \pm 0.3)$ nuclear magnetons in agreement with the available data. For the magnetic moment of the 23.8-kev excited state of Sn^{119} we found a value $\mu = +(1.9 \pm 0.4)$ nuclear magnetons. This value considerably exceeds the value predicted by the single-particle model (Schmidt lines), which shows that the 23.8-kev level in Sn^{119} in not a pure single-particle level. Such a conclusion is confirmed by the fact that the M1 transition with energy 23.8-kev is l-forbidden.

[1] R. L. Mössbauer, Z. Physik **151**, 124 (1959).

[2] A. I. Alikhanov and V. A. Lyubimov, Izv. Akad. Nauk S.S.S.R., Ser. Fiz. **24**, No. 9 (1960), Columbia Tech. Transl., in press.

[3] Barloutaud, Cotton, Picou, and Quidort, Compt. rend. **250**, 319 (1960). Barloutaud, Picou, and Tzara, Compt. rend. **250**, 2705 (1960).

[4] Delyagin, Shpinel', Bryukhanov, and Zvenglinskiĭ, JETP **39**, 220 (1960), Soviet Phys. JETP **12**, 159 (1961).

[5] N. F. Ramsey, in Experimental Nuclear Physics, ed. E. Segrè, John Wiley, 1953.

Translated by M. Hamermesh
162

THE DETERMINATION OF THE COEFFICIENTS OF DIFFUSION AND OF HEAT CONDUCTIVITY OF WEAK SOLUTION OF He^3 *IN HELIUM II*

T. P. PTUKHA

Institute for Physics Problems, Academy of Sciences, U.S.S.R.

Submitted to JETP editor July 13, 1960

J. Exptl. Theoret. Phys. (U.S.S.R.) **39**, 896-898 (September, 1960)

IF one wall of a reservoir containing a weak mixture of the isotopes He^3-He^4 is kept cold while heat is given out at the other, He^3 will be carried along by the thermal excitations and accumulate at the cold end. Diffusion and heat conductivity will cause a concentration gradient and a temperature gradient ∇T. By measuring the temperature gradient in the direction of the heat current in the steady state, and knowing the magnitude of this heat current, we can find the effective heat conductivity, κ_{eff}, which characterizes the processes of diffusion, thermal diffusion, and heat conductivity in the mixture.

To measure ∇T, four 35-μ phosphor-bronze wire resistance thermometers were used. The thermometers were made in such a way that their coils lay in one plane. The heat current was produced by a constantan heater with bifilar winding in the form of a flat disk. The lowest temperatures were obtained by pumping off He^3 vapor. The temperature of the He^3 bath was controlled by a temperature regulator[1] and kept constant to 10^{-4} °K.

Figure 1 shows the dependence of κ_{eff} on T. The circles and crosses correspond to results obtained with two different devices. The theoretical curves (dashed) calculated by Khalatnikov and Zharkov[2] are shown for comparison.

They determined the unknown constant for the interaction of an impurity with a roton, which is necessary for this calculation, from the experimental value of the diffusion coefficient found by Beenakker et al.[3] at T = 1.5° K. The existence of a minimum in the $\kappa_{eff}(T)$ curve indicates the existence of two heat transfer mechanisms in weak He^3-He^4 mixtures: heat transport due to the motion of thermal excitations, limited by the presence of He^3 (He^3 acts as a resistance to the propagation of heat), and heat transport by thermal conductivity (the diffusion of thermal excitations).

Values of the diffusion coefficient D in the temperature range from the λ point to T = 1.5° K were derived from the values of κ_{eff} for a concentration C = 0.1%. The results are shown in Fig. 2. The theoretical curve obtained from the equation[2]

$$D = \frac{kTt_{ip}}{m_3}\left(\frac{\rho_{n_0}}{\rho_n}\right)^2, \qquad (1)$$

is shown for comparison. Here k is Boltzmann's constant, ρ_{n_0} is the part of the normal density (ρ_n) of the mixture associated with the thermal excitations, and t_{ip} is the time characterizing the scattering of an impurity on a roton.

To determine t_{ip}, we normalized κ_{eff} to the experimental value at T = 1.6° K. The experimental values of the diffusion coefficient, taken from