Substance	T, °K	$10^3 T_1$, sec	$10^3 T_2$, sec	ΔH, oe	$10^2 \cdot D$, cm²/sec	Q, joule/mole	Notes
H_2	90	2	1.4	0.2	2.7	590	Monomolecular layer
	77	5	1.3	0.2	2.4		
	20.4	10	0.1	2			
	20.4	20	8	0.03	$2 \cdot 10^{-2}$		Liquid film
H_2	14_{liq}	200	200	10^{-3}			In free state according to data of reference 6.
	14_{sol}		2.3	0.1	0.1	1200	
	11		0.23	1.0			
CH_4	290	20	1.9		4	760	Monomolecular layer
	90	8	2.1		2.5		
	77	7	2.6		2.1		
H_2O	290	1	0.7				10 Steam pressure
		2	0.7				20 over charcoal
		10	5				70 in mm Hg
		15	6				170
		3000	2000				In free state

to Bloom's data[6] hydrogen has an absorption line of 0.1 oe width only near its freezing point (liquid hydrogen gives a line width of 10^{-3} oe). It should be pointed out that at a temperature in the neighborhood of 25° K the n.m.r. line width in hydrogen adsorbed on charcoal increases to 2 oe. It is of definite interest to make an estimate of the coefficient of internal friction for water. According to n.m.r. data the viscosity of water in the adsorbed state increases by more than an order of magnitude.

Thus, an analysis of the results of this investigation shows that physical properties of adsorbed gases can be successfully studied by the n.m.r. method which significantly extends the range of possibilities in the study of molecular physics.

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251

OBSERVATION OF SPONTANEOUS COHERENT RADIATION OF A FERRITE IN A RESONATOR

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In recent years there have been published a number of researches related to spontaneous coherent radiation of electron spin systems in the microwave range. In the majority of cases,[1-3] generation is accomplished by use of paramagnetics that possess, at liquid-helium temperatures, very long spin-lattice relaxation times (from milliseconds to minutes). Such a choice is not fortuitous, for the duration of the relaxation processes determines the time scale of the experiment. With long relaxation times, it is easy to excite the spin system by the method of adiabatic rapid passage or with the aid of 180° pulses. A similar method (a 45° pulse) has been successfully applied also to the excitation of organic free radicals[4] possessing relaxation times from 0.03 to 0.1 μsec.

For the overwhelming majority of ferrites, the relaxation times τ, estimated from the width of the ferromagnetic resonance line, are much smaller than the figures mentioned. This circumstance substantially complicates the technical application of the indicated method for excitation of ferrites. Furthermore there is a difficulty in principle, in that τ is of the order of magnitude of, or less than, the time constant of the apparatus. Therefore we used a somewhat different principle, consisting of this: that the resonance excitation of the ferrite is carried out at a frequency ν_1 different from the frequency ν_2 of spontaneous radiation.* The acts of excitation and radiation are separated by a time interval $t_2 - t_1$, during which the external magnetic field is changed from the value $H_1 = 2\pi\nu_1/\gamma$ to $H_2 = 2\pi\nu_2/\gamma$, where γ is the gyromagnetic ratio for the electron. In order that the precession of the magnetic moment of the ferrite may not become practically extinguished during the time $t_2 - t_1$, this interval must not greatly exceed τ.

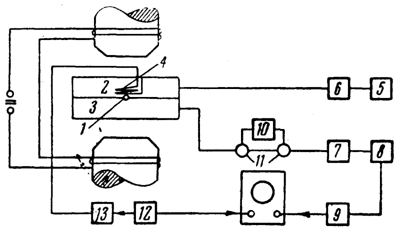

FIG. 1. Block diagram of the experimental arrangement: 1, ferrite; 2 and 3, resonators; 4, pulse coil; 5, generator; 6 and 7, attenuators; 8, detector; 9, broadband amplifier; 10, resonator-filter; 11, waveguide switches; 12, synchronizer; 13, thyratron current-pulse generator.

A block diagram of the experimental arrangement is shown in Fig. 1. The ferrite 1 is fastened in an opening in the common wall of the rectangular resonators 2 and 3. The dimensions of the resonators correspond to the TE_{012} mode; the fastening point of the ferrite coincides with an antinode of the magnetic field of each. The resonator block is placed between the poles of an electromagnet. Resonator 2, designed to excite precession in the ferrite, is connected by means of a waveguide with generator 5 and tuned to its frequency ν_1. The resonator Q is approximately 300; the excitation power is of the order of a few watts. By means of the two-winding coil 4, located inside resonator 2, there is produced a pulsed magnetic field parallel to the constant field H_0 of the electromagnet. The change of the total field with time is shown in Fig. 2. For $|H - H_1| \lesssim \Delta H$, where ΔH is the half width of the resonance line of the ferrite, the ferrite interacts with the high-frequency field in 2, and there is excited a precession of the magnetic moment, with precession angle θ. In the succeeding interval of time, the precession frequency does not coincide with the characteristic frequencies of the resonators ($\nu_1 < \nu < \nu_2$), and the angle θ decreases under the influence of relaxation processes alone:

$$\theta = \theta_0 \exp\{-(t - t_1)/\tau\}. \tag{1}$$

When, finally, H passes through the values $|H - H_2| \lesssim 2\pi\Delta\nu_2/2\gamma$ ($\Delta\nu_2$ = tuning band of the resonator 3

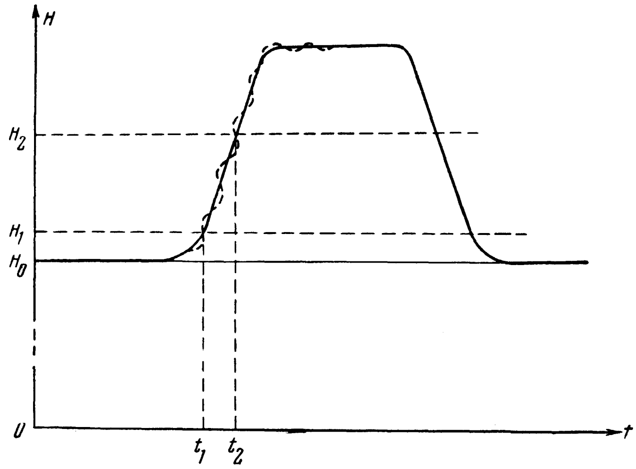

FIG. 2. Change of magnetic field with time.

to frequency ν_2), the ferrite radiates a short pulse. This pulse is further detected, amplified by the broadband amplifier 9, and observed with the aid of a fast oscillograph.

In the experiment, the excitation frequency used was $\nu_1 = 8900$ Mcs. The electromagnet field H was kept equal to 3050 oe, with the value of the pulsed field 700 oe. The frequency could be varied over the range 9000 to 9800 Mcs by adjustment of the resonator 3. In order that the antinode of the field might not move with respect to the ferrite in this process, the adjustment was made by simultaneous and symmetrical movement of two pistons. The slope of the pulse front, $dH/dt = 3 \times 10^{10}$ oe/sec, insured over the range of adjustment mentioned a value $t_2 - t_1 = (3 \text{ to } 15) \times 10^{-9}$ sec.

The process of coherent radiation of a spin system placed in a resonator has been described by Faĭn.[5] He considered, in particular, the case of a resonator tuned to the characteristic frequency of the system, when the radiation field is absent at the initial instant. In our case the precession frequency changes continuously, and radiation occurs when $|\nu - \nu_2| \lesssim \nu_2/2$. However, it is possible to estimate the radiated energy and power by using Faĭn's results, if one replaces the actual process of frequency change by a step change and assumes the frequency to be constant during the radiation process. The duration of the act of radiation, Δt_2, is easily determined from knowledge of dH/dt and $\Delta\nu_2$. The time of complete transfer of the energy of the ferrite into radiation, estimated by formula (56) of Faĭn's paper for the specimens used, was of order 10^{-8} sec, whereas $\Delta t_2 \sim 10^{-9}$sec. Consequently, in our experiment the ferrite is able to radiate only a part of its energy. For this case, the formula mentioned can be simplified, and we get for the power in the pulse the simple expression

$$P = \mathrm{const}\cdot \Delta t_2 \theta_0^2 \exp\{-2(t_2 - t_1)/\tau\}. \qquad (2)$$

From formula (2) the possibility is evident of directly determining the relaxation time τ within the framework of the experiment described. Actually, a change of ν_2 by adjustment of resonator 3 is equivalent to a change of t_2. If meanwhile Δt_2 is constant [$H(t)$ a linear function and $\Delta\nu_2$ a constant], then

$$\ln(P'/P'') = 2(t_2'' - t_2')/\tau, \quad \tau = 2(t_2'' - t_2')/\ln(P'/P''). \qquad (3)$$

All the quantities in the right member of (3) are found from the experiment.

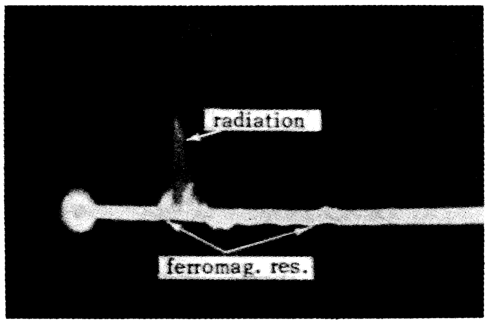

FIG. 3. Signals due to radiation and to ferromagnetic resonance on the oscillograph screen.

Figure 3 shows a photograph of the picture on the oscillograph screen. The large pulse is caused by the radiation at $H = H_2$, and the two small ones by ferromagnetic resonance at $H = H_1$. The correctness of this interpertation was confirmed by special checks. In the first place, it was established that the carrier frequency of the large pulse coincided with ν_2 and of the smaller with ν_1. For this purpose, there was connected in the line, in front of the detector, the adjustable resonator-filter 10. In the second place, it was shown that the radiation pulse was absent in all cases in which the magnetic field did not reach the value H_2. In the third place, the dependence of the size of the radiated pulse on Δt_2 was verified qualitatively. The fact is that the slope of the pulse front of the magnetic field was slightly oscillatory, as is shown by the dashed curve in Fig. 2. Consequently the interval Δt_2 should also oscillate with change of t_2, and the dependence $P(t)$ expressed by formula (2) ceases to be purely exponential. On the experimentally obtained graphs of $P(t)$, the corresponding fluctuations are clearly indicated; this, unfortunately, greatly complicates the determination of the relaxation time.

The specimens used in this research were of yttrium iron garnet, of diameter from 0.5 to 1.0 mm, with polished surface of spherical form.

In closing, we wish to express our deep gratitude to A. G. Gurevich, G. A. Smolenskiĭ, and K. P. Belov, who kindly provided the ferrite specimens; to A. M. Leonov, who took an active part in the construction of the apparatus; and to V. M. Faĭn for valuable advice.

*A similar idea was used in the work of Hoskins,[6] where an experiment with ruby is described.

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252

FORMATION OF PIONS IN πN COLLISIONS

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THE model of Lindenbaum and Sternheimer[3] offers only a qualitative explanation for the observed momentum distribution of π mesons from the reaction $\pi + N \rightarrow 2\pi + N$ at kinetic energies 1.0 and 1.4 Bev (in the laboratory frame of reference). According to this model, the meson arises from the formation of an isobaric state ($T = 3/2$, $J = 3/2$, $l = 1$) with finite width. On the other hand, Fermi's statistical theory does not explain these distributions, while within the framework of this theory a calculation of the isobars, as particles of mass $M = 1.32$ nucleon masses, also leads to only qualitative agreement with experiment. Rus'kin[5] has attempted to improve the agreement by taking into account a resonance $\pi\pi$ interaction, a new particle Π being introduced, with mass $M = 0.47$ nucleon masses, which decays into two π mesons. We have made analogous calculations, which do in-