

There is yet another way of obtaining active molecules, namely, pre-exposure of the molecular beam to auxiliary high frequency fields which induce resonance transitions between different levels of the molecules. In Fig. 1 and Fig. 2 we illustrate the possible variants which utilize an exciting irradiation of frequency  $\nu_{ex}$  for populating the upper level in order to obtain a scheme of self-excitation with the frequency  $\nu_g$ .

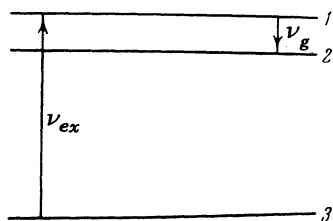


Fig. 1

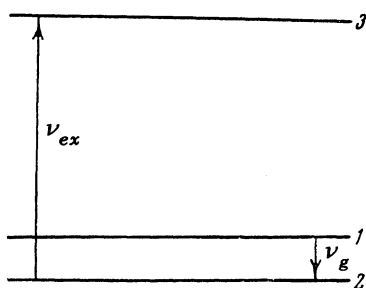


Fig. 2

In one case, illustrated by Fig. 1, active molecules in level 1 are obtained at the expense of molecules in level 3 through transitions induced by the high frequency field. If the high frequency field possesses sufficient energy, so that the effect nears saturation, then the number of active molecules equals

$$\frac{1}{2}(N_3 - N_1) + N_1 - N_2, \quad (1)$$

where  $N_i$  is the number in the  $i$ th level.

The number of active molecules in level 1 increases with an increase of the energy difference between the first and third level relative to the energy difference between the first and the second levels. One must consider that the number of molecules in the levels is determined, in the case of thermodynamic equilibrium, by the Boltzmann factor.

$$N_i \sim e^{-E_i/kT}, \quad (2)$$

where  $E_i$  is the energy of the  $i$ th level and  $T$  is the absolute temperature of the molecular beam.

These considerations are valid for the case illustrated in Fig. 2. Here, however, instead of an increase of the number of molecules in level 1, we have a decrease of the number in level 2. The number of active molecules equals, in this case,

$$\frac{1}{2}(N_2 - N_3) + N_1 - N_2. \quad (3)$$

The method presented herein can be used, for example, in the following cases.

1) Level 1 and 2 appear as neighboring rotational levels belonging to one and the same vibrational state of the molecule, with level 3 belonging to a neighboring vibrational state. In this case the rotational quantum number of this level (level 3) differs from that of level 1 and 2 by  $\Delta J = 0, \pm 1$ .

It is convenient to use the transitions between the vibrational levels for which  $\Delta J = \pm 1$ , since this case does not impose too strict a requirement for the exciting irradiation to be monochromatic. Since transitions between vibrational levels fall in the infra-red region of the spectrum for most molecules, the exciting irradiation must belong to this frequency range. However, infra-red thermal sources in existence at the present time have insufficient power to produce a saturation effect.

2) Levels 1, 2, and 3 are rotational levels of the molecule with asymmetric rotational momentum.

3) Levels 1 and 2 are hyperfine structures belonging to a given rotational state, and level 3 is a hyperfine level of a neighboring rotational level.

4) Levels 1 and 2 are specified by an inversion doublet belonging to a rotational level, and level 3 is one of the inversion levels of a neighboring rotational state.

The method presented here can be used to obtain a sufficient number of active molecules for the purpose of constructing a low frequency molecular oscillator.

Translated by A. Skumanich  
41

<sup>1</sup> N. G. Basov and A. M. Prokhorov, J. Exper. Theoret. Phys. USSR 27, 282 (1954)

<sup>2</sup> C. N. Townes et al, Phys. Rev. 95, 282 (1954)

## Luminescence of Organic Scintillators

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(Submitted to JETP editor September 8, 1954)

J. Exper. Theoret. Phys. 28, 251-252 (February, 1955)

**D**ESPITE a number of attempts in this direction, so far no satisfactory explanation has been offered for the low light energy output of organic

scintillators irradiated by slow electrons,  $\alpha$ - particles and other slow charged particles<sup>1-3</sup>. In seeking a new approach to the problem, we have investigated the influence of the temperature and the nature of the surrounding gaseous medium on the scintillation output.

Below we give the results of our study of the luminescence output of plastic scintillators, prepared by polymerization of a 1.5% solution of 1,1,4,4- tetraphenyl-1, 3-butadiene in purified styrene (polymerization at high temperature and high pressure in the absence of a catalyzer and plasticizer). The scintillator was excited either by  $\gamma$ -rays from  $\text{Co}^{60}$  source or by  $\alpha$ -particles from polonium. The luminosity was determined according to the mean current output of a FEIu-19 photomultiplier. The light was conducted from the scintillator to the photocathode of the multiplier by means of a polymethylmetacrylate rod, 280 mm long, enclosed in a textolite tube. With this arrangement the temperature of the photomultiplier remained virtually constant during the tests.

TABLE

Temperature dependence of the persistent luminescence (afterglow) of a plastic scintillator

Temperature °C	Photomultiplier current 15 sec after end of excitation	
	by $\gamma$ -rays	by $\alpha$ -particles
-115	1.8	—
-121	6.0	—
-137	10.0	—
-150	17	1.7
-167	19	7.8
-188	22	13.2

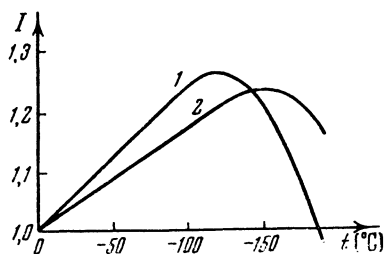


Fig. 1. Temperature dependence of the luminous intensity,  $I$ , of a plastic scintillator: 1- excited by  $\gamma$ -rays from a  $\text{Co}^{60}$  source; 2- excited by  $\alpha$ -particles from a polonium source. Curves adjusted to coincide at 0°C.

Our data on the temperature dependence of luminescence for plastic scintillators Fig. 1, differ from those in scientific literature<sup>2,4</sup>, particularly in that we observed a decrease in luminescence at lower temperatures. This decrease is

accompanied by the appearance of a persistent luminescence (afterglow), the initial intensity of which increases, as the temperature at which the scintillator is excited is reduced (see Table above). The attenuation of the persistent luminescence (afterglow) at three different temperatures, plotted to a semilogarithmic scale, is shown in Fig. 2. It will readily be seen that the attenuation law in the given time interval is not exponential<sup>5,6</sup> and that the extinction time is long.

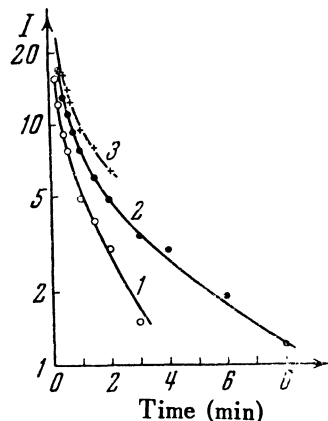


Fig. 2. Attenuation of persistent luminescence (afterglow) of a plastic scintillator, irradiated for 2 minutes by  $\gamma$ -rays from a  $\text{Co}^{60}$  source at the following temperatures: 1)-129°C, 2)-174°C, 3)-188°C.

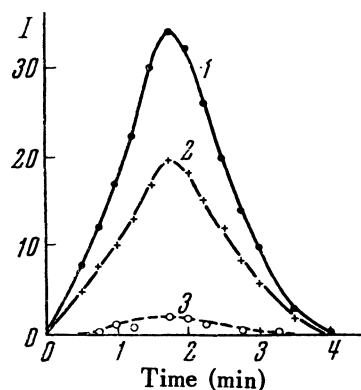


Fig. 3. Thermoluminescence of a plastic scintillator, excited at about -190°C by  $\gamma$ -rays from a  $\text{Co}^{60}$  source for 4 min (1), 2 min (2) and by  $\alpha$ -particles from a polonium source for 2 min (3). Indicated times are from beginning of heating, [following extinction].

In some of our experiments the scintillator was rapidly heated after extinction of the afterglow: further light emission - thermoluminescence - was observed. The results of one such experiment are

shown in Fig. 3. The luminous intensity in Figs. 2 and 3 and in the table is given in the same units. The short term [initial response] luminescence at 0°C with the scintillator excited by  $\alpha$ -particles or  $\gamma$ -rays amounts to about 2500 such units.

The experimental results not only prove the existence of persistent luminescence (afterglow) and thermoluminescence for organic plastic scintillators excited at low temperatures by ionizing radiation, but also demonstrate that there are quantitative differences in the nature of the luminosity effects with  $\alpha$ - as against  $\gamma$ -excitation. With  $\alpha$ -excitation the decrease in short-term luminescence begins at a lower temperature than with  $\gamma$ -excitation and the afterglow intensity is appreciably lower. Thermoluminescence with  $\alpha$ -particle excitation is relatively weak, particularly if we take into account the fact that the energy absorbed by the plastic scintillator with  $\alpha$ -excitation exceeded the energy input with  $\gamma$ -ray excitation by a factor of 10. A possible reason for the difference is appreciable local heating of the scintillator in the  $\alpha$ -particle track.

In any case it is obvious that temperature effects must be duly taken into account in any attempt to explain the dependence of the scintillation output on the speed and charge of the exciting particles.

Translated by E. Rosen  
43

<sup>1</sup> J. B. Birks, *Scintillation Counters*, London, 1953

<sup>2</sup> S. C. Curran, *Luminescence and the Scintillation Counter*, London, 1953.

<sup>3</sup> G. F. Wright, *Phys. Rev* **91**, 1282 (1953)

<sup>4</sup> Survey in *Nucleonics* **10**, 32 (No. 3, 1952)

<sup>5</sup> V. A. Levshin, *Photoluminescence of Liquid and Solid Substances*, Moscow, 1951

<sup>6</sup> V. A. Iastrebov, *J. Exper. Theoret. Phys. USSR* **21**, 164 (1951); *Doklady Akad. Nauk SSSR* **90**, 1015 (1953)

## F-Centers in Silver Halide Crystals

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(Submitted to JETP editor September 16, 1954)

*J. Exper. Theoret. Phys. USSR* **28**,  
252-253 (February, 1954)

IN a recently published article Grenishin<sup>1</sup> asserts that the absorption bands of AgBr at  $\lambda = 420-430$   $\mu\mu$  (studied first by the writer in collaboration with Putseiko<sup>2</sup> and subsequently by the writer<sup>3,4</sup> alone) are in no way connected with the presence, in the silver halide crystals, of *F*-centers, similar to the *F*-centers found in the halides of alkali metals. By way of proof Grenishin cites the presumed temperature independence of the half-width of the absorption bands and the absence of vacant lattice sites in silver halides.

The first statement is erroneous: Grenishin used data taken from our report on experiments in which the temperature was varied only in a narrow interval. Experiments carried out by the writer in collaboration with Shimanskii<sup>5</sup> showed that when the temperature of AgBr is changed from 90-100°C to 350°C the half-width increases, on the average, by a factor of 1.6-1.7 and in the case of heating to 408°C, by a factor of 1.8-1.9. Heating of an AgCl crystal also leads to a 1.6-fold increase in the half-width of the absorption band. This is clearly illustrated by the data listed in the table below\*.

It will be seen from the table that the variation of the half-width of the *F*-center absorption band with the temperature is of the same order as for the halides of alkali metals<sup>6</sup>.

As for the second statement, it is true that no vacant halide ion sites (such as occur in alkali metal halides) are formed by the mechanism of Schottky in silver halides. However, this is no proof that *F*-centers cannot form by the mechanism of de Boer. The writer has suggested a possible mechanism of the formation of *F*-centers in silver halides. By virtue of the close packing of the crystal lattice and the partially homeopolar nature of the bonds there is a certain probability of the transfer of an electron from the halide ion to the one of the six neighboring silver ions, with the subsequent escape of a halide atom and the formation of an *F*-center in its place. The activation energy for the process is approximately 0.15 eV<sup>5</sup>. Due to the low value of this activation energy the *F*-center absorption band overlaps the intrinsic absorption band. With different ratios of the intensity of the two bands,

Half-width in eV

Temperature in °C	Crystals						
	AgBr						AgCl
	№ 1	№ 2	№ 3	№ 4	№ 5	№ 6	
90	0.22	0.42	0.24	0.46	0.23	0.34	0.22
350	—	0.60	0.44	0.57	0.35	0.57	0.35
408	0.47	0.76	—	0.87	0.42	—	—