

the available energy in the c.m. system for meson creation will depend on the masses of the interacting particles and not on the final state of the more or less excited nucleus.

We propose to introduce for this primary stage a clustering process similar to this used in the absorption process: the incident nucleon would interact with a nucleon,  $H^2$ ,  $H^3$ ,  $He^4$ ,... depending on either their probability of existence or the possibility that a minimum volume of the nucleus would be involved in large transfers of energy. Without taking account of the internal dynamics which would decrease the figures, thresholds would be obtained with heavy clusters. For effective  $\pi$ -production if we start with  $He^4$  as a safe limit, we get values a little higher than Barkas'. Nuclei showing  $\alpha$ -structure like  $C^{12}$  would give low thresholds. The excitation curve below the pure nucleon-nucleon threshold would give the relative proportions of clusters in  $\sim 10^{-22}$  sec. Extensive statistics of stars emitting  $\pi$ -mesons in light elements at known incident energies would give evidence on this mechanism. With 260-Mev neutrons, the cross section is too low to draw conclusions from our Berkeley plates.

Association at high energies could explain too the high probability of  $(n,d)$  and  $(n,T)$  reactions with or without  $\pi$ -emission.<sup>12</sup>

Finally, we recall<sup>13</sup> that neutron-hydrogen experiments with defined neutron beams, similar to those performed with protons, would give definitive evidence on the di-neutron.

We wish to take this opportunity of thanking warmly Drs. Bradner and Gardner, and Professor Lattes who very kindly have given to our group the possibility of studying some high energy events.

<sup>1</sup> Cartwright, Richman, Whitehead, and Wilcox, *Phys. Rev.* **78**, 823 (1950). V. Z. Peterson, *Phys. Rev.* **79**, 407 (1950).

<sup>2</sup> P. Cüer and M. Morand, *Comptes Rendus* **226**, 649 (1948).

<sup>3</sup> J. Heidemann and L. Leprince-Ringuet, *Comptes Rendus* **226**, 1719 (1948).

<sup>4</sup> D. H. Perkins, *Phil. Mag.* **40**, 601 (1949).

<sup>5</sup> W. Cheston and L. Goldfarb, *Phys. Rev.* **78**, 683 (1950).

<sup>6</sup> Menon, Muirhead, and Rochat, *Phil. Mag.* **41**, 583 (1950).

<sup>7</sup> S. Tamor, *Phys. Rev.* **77**, 412 (1950).

<sup>8</sup> P. Cüer, and L. Van Rossum, *C. R. congrès de Côme* (1949).

<sup>9</sup> W. Horning and L. Baumhoff, *Phys. Rev.* **75**, 378 (1949).

<sup>10</sup> W. G. MacMillan and E. Teller, *Phys. Rev.* **72**, 1 (1947).

<sup>11</sup> W. H. Barkas, *Phys. Rev.* **75**, 1109 (1949).

<sup>12</sup> Cüer, Morand, and Van Rossum, *Comptes Rendus* **228**, 481 (1949).

<sup>13</sup> Morand, Cüer, and Moucharafeyeh, *Comptes Rendus* **226**, 1974 (1948).

## Noise Temperature of a D.C. Gas Discharge Plasma

SHOJI KOJIMA AND KAZUO TAKAYAMA  
Tokyo University of Education, Tokyo, Japan  
September 29, 1950

IN a discharge tube, noise is generated from the cathode fall and the plasma. To pick up the noise of the plasma, a floating probe was inserted near the anode. The fluctuation of the voltage between the probe and the anode was observed by a narrow band amplifier of 14 Mc/sec. The discharge tubes used, of which the diameter is 3 cm and length 7.8 cm, were filled with argon at a pressure of 1 to 3 mm Hg, whereas the tubes filled at higher pressures frequently showed some oscillations.

The noisiness of the plasma is expressed by the noise temperature  $T_n$ , which is defined by the formula

$$\langle e^2 \rangle_{Av} = 4kT_n R,$$

where  $\langle e^2 \rangle_{Av}$  is the mean square voltage fluctuation per cycle and  $R$  is the resistance between the probe and the anode. The mean square voltage was determined by comparison with the shot noise of a diode with the aid of a square law detector. The resistances were deduced from the characteristic curves of the probe.

The measurements were performed at various electron temperatures, varying the applied voltage of the discharge tubes. The electron temperature was more easily determined by the double-probe<sup>1</sup> than the single-probe method. The relations be-

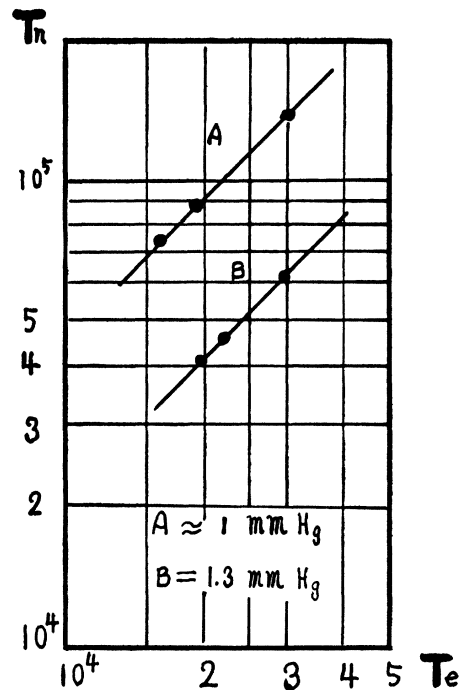


FIG. 1. Relation between the noise temperature  $T_n$  and the electron temperature  $T_e$ .

tween the electron temperature  $T_e$  and the noise temperature  $T_n$  were studied with tubes A and B. The results are shown in Fig. 1. This shows that the noise temperature agrees with the electron temperature as far as orders of magnitude are concerned and that they are in a proportional relation.

The noise of the plasma, as discussed by Parzen and Goldstein,<sup>2</sup> consists of the thermal noise, which depends on the electron temperature, and of the current noise, which depends on the d.c. current. The latter shows a frequency dependence, but the former does not. A preliminary experiment<sup>3</sup> with an amplifier of 600 kc/sec. indicated that the noise temperature at this frequency is nearly equal to that at 14 Mc. Therefore, the observed noise is mainly thermal noise. This explains the approximate agreement between the noise temperature and the electron temperature.

<sup>1</sup> E. O. Johnson and L. Malter, *Phys. Rev.* **76**, 1411 (1949).

<sup>2</sup> P. Parzen and L. Goldstein, *Phys. Rev.* **79**, 190 (1950).

<sup>3</sup> Kojima, Takayama, and Shimanuchi (to be published.)

## Fluorescent Decay of Scintillation Crystals

S. H. LIEBSON, M. E. BISHOP, AND J. O. ELLIOT  
Electricity Division, Naval Research Laboratory, Washington, D. C.  
October 16, 1950

IN order to clarify recent observations of the behavior of organic fluors which scintillate under gamma-ray bombardment, measurements have been made of the decay time of fluorescence under ultraviolet excitation. The technique employed is similar to one suggested by Tumerman<sup>1</sup> and involves a measurement of the phase shift between incident modulated ultraviolet light and the resultant modulated fluorescence of a fluor whose mean lifetime for excited states is  $\tau$ . The decay of excited states is assumed to be of the form  $e^{-t/\tau}$ . The exciting ultraviolet light is modulated by passage through a quartz crystal oscillating at about 5 Mc/sec., the resultant light being modulated at about 10 Mc/sec. It is easily shown that the phase shift is related to the mean lifetime of the fluor by the relation  $\tan\phi = 2\pi f\tau$ , where  $\phi$

TABLE I. Decay times of fluors.

Fluor	Uv decay	Gamma-decay
anthracene	$1.7 \times 10^{-8}$ sec.	$3.0 \times 10^{-8}$ sec.
anthracene ( $-195^\circ\text{C}$ )	0.8	1.3
carbazole	0.7	1.3
chrysene	2.2	2.6
diphenyl acetylene	0.25	0.4
1,4 diphenyl butadiene	0.2	0.6
fluoranthene	4.6	...
fluorene	0.88	...
perylene	1.2	...
phenanthrene	0.52	...
quaterphenyl	0.38	0.7
stilbene	0.31	0.8
terphenyl	1.1	0.6
$\frac{1}{2}\%$ anthracene in benzene	$0.20 \pm 0.05$	...
$\frac{1}{2}\%$ terphenyl in toluene	$0.25 \pm 0.05$	0.2

is the phase shift and  $f$  is the modulating frequency. Measurements of phase shift can be made which correspond to time decays of the order of  $2 \times 10^{-10}$  sec., the principal source of error for these measurements being amplifier noise. The ultraviolet source was a 10 kw carbon arc with transmission filters to limit the spectral range from 2500Å to 3500Å. Table I shows the results of measurements made at room temperature on some fluors together with measurements obtained by means of a pulse technique under gamma-ray bombardment.<sup>2</sup>

The times measured by the pulse technique have been corrected for the decay introduced by the photo-multiplier, estimated at  $4 \times 10^{-9}$  sec. from measurements on dark noise pulses. The accuracy of both sets of measurements was estimated to be about 10 percent. Measurements by the shorted-line technique are in substantial agreement with those of recent investigators.<sup>3-5</sup>

Measurements using modulated ultraviolet light were checked with measurements made by Gaviola,<sup>6</sup> corrected according to Tumerman.<sup>1</sup> For a solution of rhodamine B in water and glycerine, values of  $2.5 \times 10^{-9}$  sec. and  $5.2 \times 10^{-9}$  sec., respectively, were obtained, in agreement within experimental error with Gaviola's results. A grid-controlled x-ray tube operated at 80 kv was modulated at 10 Mc/sec. and used in place of a light source. Measurements on the decay times for stilbene, anthracene, terphenyl, diphenyl acetylene, and a  $\frac{1}{2}$  percent solution of terphenyl in toluene yielded results in good agreement with the ultraviolet excitation decay times. Oscillator strengths based on measurements of absorption spectra for stilbene and 1,4-diphenyl butadiene<sup>7</sup> were calculated as  $3.5 \times 10^{-9}$  sec. and  $3.3 \times 10^{-9}$  sec., respectively, indicating a reasonable if not fortuitous agreement with measurements on ultraviolet decays.

The discrepancies between ultraviolet and gamma-ray excitation cannot be easily resolved. A measurement on a crystal of 0.05 percent anthracene in naphthalene at the anthracene wavelengths gave a mean lifetime in good agreement with the ultraviolet measurements on pure anthracene, indicating that the migration of energy within the crystal does not contribute appreciably to the measured decay time. The temperature dependence of the anthracene fluorescence was again demonstrated under ultraviolet excitation. Of equal interest were the results on a liquid solution of anthracene in benzene which gave a decay time of  $2 \pm 0.5 \times 10^{-9}$  sec., and measurements on terphenyl in toluene which were in agreement with gamma-ray measurements. The measurements under x-ray bombardment were undertaken to obtain correlation with gamma-ray measurements, the agreement with ultraviolet excitation being unexpected.

We would like to express our thanks to Professor L. Zechmeister of the California Institute of Technology for the preparation of 1,4-diphenyl butadiene.

<sup>1</sup> L. A. Tumerman, *J. Phys. U.S.S.R.* **4**, 151 (1941).

<sup>2</sup> Elliot, Liebson, Myers, and Ravilius, *Rev. Sci. Inst.* **21**, 631 (1950).

<sup>3</sup> G. G. Kelley and M. Goodrich, *Phys. Rev.* **77**, 138 (1950).

<sup>4</sup> R. F. Post and N. S. Shiren, *Phys. Rev.* **78**, 80 (1950).

<sup>5</sup> Elliot, Liebson, and Ravilius, *Phys. Rev.* **79**, 393 (1950).

<sup>6</sup> E. Gaviola, *Zeits. f. Physik* **42**, 862 (1927).

<sup>7</sup> R. S. Mulliken and C. A. Rieke, *Rep. Prog. Phys.* **8**, 231 (1941).

## The Thermal Neutron Absorption Cross Section of Silicon\*

C. W. TITTLE

North Texas State College, Denton, Texas

AND

HENRY FAUL

U. S. Geological Survey, Washington, D. C.

July 24, 1950

THE thermal neutron absorption cross section of silicon has been determined experimentally by the method of Frisch, von Halban, and Koch.<sup>1</sup> A Ra- $\alpha$ -Be neutron source was placed in a mixture of pure silica sand and water, large enough to be effectively infinite; and the thermal neutron distribution was measured with indium foils. Counting was done with mica window Geiger-Mueller counters. Correction for the indium resonance was made by determining the activation of the foils when shielded by 0.10 cm of Cd. To correct for the absorption of indium resonance neutrons by Cd, this measured activity was multiplied by the factor 1.13, determined for indium foils of the thickness used (58 mg/cm<sup>2</sup>). Sufficient data were taken to make the space integrals of the thermal neutron density good to 2 percent in the case of the sand-water mixture, 2 percent in one experiment in which the comparison mixture was a heterogeneous lattice consisting of graphite rods and water, and 1 percent in another experiment in which the comparison medium was water. Correction for the depression of the thermal neutron density by the indium foils was made by use of Bothe's formulas.<sup>2</sup>

In these experiments the silicon cross section was compared with the hydrogen cross section for absorption. Correction for other nuclei was made by assuming  $\sigma_a(\text{oxygen}) = 0.0016$  barn and  $\sigma_a(\text{carbon}) = 0.0045$  barn.<sup>3</sup> Impurities were negligible.

From the experiment in which sand-water was compared with carbon-water,

$$\sigma_a(\text{H})/\sigma_a(\text{Si}) = 2.3 \pm 20 \text{ percent.}$$

From the one in which sand-water and water were compared,

$$\sigma_a(\text{H})/\sigma_a(\text{Si}) = 2.0 \pm 15 \text{ percent.}$$

Errors shown are estimated probable errors based on reasonable values of uncertainties in the corrections, concentrations, and space integrals. The weighted average of the two determinations is

$$\sigma_a(\text{H})/\sigma_a(\text{Si}) = 2.1 \pm 12 \text{ percent.}$$

If  $\sigma_a(\text{H})$  is taken to be  $0.313 \pm 0.013$  barn<sup>3</sup> at the standard neutron speed of  $2.2 \times 10^6$  cm/sec.,

$$\sigma_a(\text{Si}) = 0.15 \pm 0.02 \text{ barn.}$$

The calculations have neglected the possibility of resonance absorption in Si. An experiment to search for resonance absorption showed that the resonance escape probability  $p = 1.01$ , i.e., 1.00 within the experimental uncertainty of about 2 percent.

\* The experimental work reported here was done at the Massachusetts Institute of Technology, Cambridge, Massachusetts, in connection with the Nuclear Shielding Project, which is supported by a joint program of the ONR and the BuShips.

<sup>1</sup> Frisch, v. Halban, and Koch, *Kgl. Danske Videnskab. Selskab, Mat.-fys. Medd.* **15** (10), 1 (1938). See also W. J. Whitehouse and G. A. R. Graham, *Can. J. Research* **25A**, 261 (1947).

<sup>2</sup> C. W. Tittle, *Phys. Rev.* **80**, 758 (1950).

<sup>3</sup> M. Ross and J. S. Story, *Physical Society Reports on Progress in Physics* **12**, 291-304 (1948-49).

## The Gamma-Ray Spectrum of Ba<sup>131</sup>

E. L. ZIMMERMAN, E. B. DALE, D. G. THOMAS, AND J. D. KURBATOV

Department of Physics, Ohio State University, Columbus, Ohio

July 10, 1950

THE Ba<sup>131</sup> photo-electron spectrum from a lead radiator has been investigated below 700 kev. A thin lens spectrometer adjusted for two percent resolution was used. The spectrometer calibration constant was 598.9 gauss-cm/amp. This was determined by measuring the *K* and *L* photo-electron peaks of the