the influence of an applied field could be observed only when the size of the colloid particles was adequate.

The fine division of domains thus observed is to be attributed to the random distribution of strains under the condition that $K_1 < (3/2)\lambda E\epsilon$, where λ means the saturation value of magnetostriction, E the Young's modulus and ϵ the strain. There is evidence that the strain is caused by the random generation of d.o. For, if we substitute into the above expression $\lambda = 5\times10^{-6}$, $E = 2\times10^{12}$ dyne/cm^2 and $\epsilon = 1.7\times10^{-4}$, the strain of d.o., we get 2.5×10^3 ergs/cc, which is nearly equal to the actual value of K_1 when the transition of patterns took place.

The fine domain structure described above might, under proper conditions, give rise to high μ, as will be discussed along the following lines: (1) The crooked boundaries in this structure might continuously decrease their area in the process of magnetization, and the resulting decrease of exchange energy could play a role in promoting the magnetization. The exchange energy stored in the demagnetized state was estimated at *ca* 10^2 ergs/cc if we assume a distribution of spin-direction with a period of 0.01 mm. If, therefore, the d.o. were destroyed so much by further disordering that $\lambda E\epsilon$ decreases to 10^2 ergs/cc, magnetization would take place without any external work. This means a high mobility of the boundaries. (2) The influence of inclusions or lattice defects would be nothing but a local one in this structure, without any essential effect on the magnetization as a whole. (3) The contribution to μ_a will be proportional to the total area of the boundaries, which seems to be very large in this structure as compared to usual domain structure.

Too severe disordering will destroy the fine domain structure so as to decrease the exchange energy, again decreasing μ_a. It is experimentally known that the maximum μ_a is attained by a proper rate of quenching for permalloy[5] and by proper prolonged annealing for Mo-permalloy.[6] These treatments are interpreted as means of attaining proper values of the strain.

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Activation of LiI Crystal Phosphors*

W. Bernstein and A. W. Schardt
Brookhaven National Laboratory, Upton, New York
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LITHIUM iodide crystals have been grown[1,2] with different activators and tested for pulse height and resolution with thermal neutrons from the BNL reactor. A collimated beam $\frac{1}{8}$ in. in diameter was used for exploring different parts of the crystals. A $\frac{7}{8}$ in. diameter uniform beam was available for testing over-all response. The crystals, wet with Nujol, were placed on a 5819 photomultiplier inside a $\frac{1}{32}$ in. thick diffuse reflector made from titanium oxide in lucite. The electronics used were essentially the same as described previously.[3] The pulse height has been measured in terms of the gamma-ray energy necessary to produce a photoelectric line at the same pulse height in a standard[3] NaI(Tl) crystal.

In general, single crystals $\frac{5}{8}$-in. diameter and $2\frac{1}{2}$ in. long were grown; then cleaved into one centimeter thick sections. These pieces were cleaved into small (2 mm) cubes if the pulse-height distribution was very nonuniform. Crystals grown at 4 in. per day with an excess of TlI activator (0.5 percent by weight) were clear and colorless with a thin layer of thallous iodide around the outside of the crystal. Spectroscopic analysis[4] of a typical piece from the tip of the crystal gave 0.008 percent by weight of TlI; at the top 0.013 percent was found. The pulse heights from these pieces were in the ratio of 1:2. Two regions of pulse height were

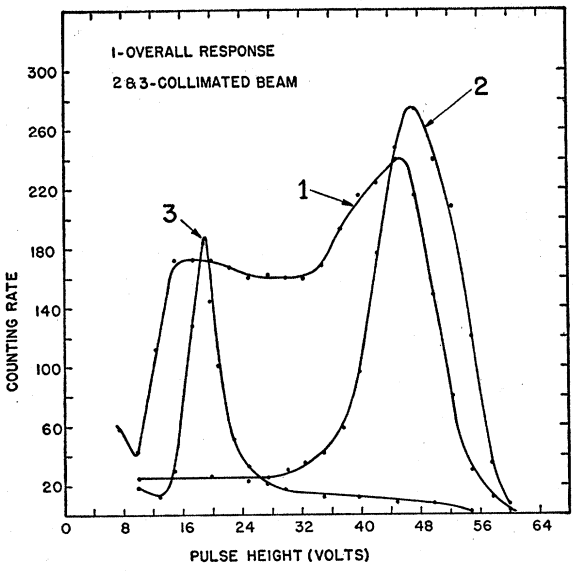

FIG. 1. LiI(Tl) $\frac{3}{4}$ in. $\times\frac{1}{2}$ in. $\times\frac{1}{2}$ in. crystal irradiated with thermal neutrons. (1) Response of whole crystal in uniform beam. (2 and 3) $\frac{1}{8}$ in. beam at characteristic spots in crystal.

favored, 120 to 180 kev, and 300 to 450 kev, NaI(Tl) equivalent. In general pieces of the order of 2 mm^3 gave the resolution found for the equivalent pulse height in NaI. However, larger pieces had either two peaks or a very broad distribution in pulse height (Fig. 1). Exploration with the collimated neutron beam showed that the transition between the two regions occurs within less than $\frac{1}{8}$ inch. Attempts to grow uniformly activated crystals by using growing speeds from 1.7 in. to 7 in. per day were unsuccessful.

From the above it is evident that the pulse height is a function of thallium concentration. Similar variations in thallium concentration were also found by Harshaw[5] in NaI(Tl) crystals (0.1 to 0.5 percent). However, in that case the pulse height was not affected. It seems that the amount of thallium entering the LiI lattice is insufficient for complete activation. A search is being made for other activators which can enter the crystal in sufficient amounts. So far, indium, tin, and silver have been tried. Reagent grade chemicals were used, but small impurities may have an unexpected effect.

LiI(In) behaved very much like LiI(Tl); most of the activator was expelled from the lattice. On neutron irradiation two peaks were found corresponding to 45 and 80 kev. The fluorescence band is a whitish orange and does not match the 5819 spectral response.

A crystal grown with 0.15 percent by weight $SnCl_2\cdot2H_2O$ activator was transparent yellow at the tip, becoming more and more opaque yellow toward the top. All but the most opaque part gave a uniform pulse height of 197 kev, and the resolution found with NaI(Tl) for that pulse height (14.5 percent). The decay time is almost the same as that of LiI(Tl). The fluorescence band is in the green.

A crystal grown with 0.3 percent AgI activator was colorless and transparent at the tip, gradually becoming cloudy toward the top. All the activator went into the crystal, since no AgI was found on the surface. The pulse height was the equivalent of 210 kev. Different sections of the crystal showed a pulse-height variation of 20 percent. The fluorescence band is greenish yellow.

The results with the tin activator looked sufficiently promising to grow a larger crystal. A $1\frac{1}{2}$ in. ampule was used and 0.05 percent by weight $SnCl_2\cdot2H_2O$ was added. Five parallel crystals starting at the tip grew from this melt. The tip was transparent and slightly yellow; the top was cloudy. Pieces approximately $1\times\frac{3}{4}\times\frac{3}{8}$ inches gave a resolution between 13.7 percent and 16.5 percent, and a pulse height equivalent to 250 kev (Fig. 2). The

pulse height between different pieces varied by less than 10 percent. The proportionality between energy and pulse height was checked within 6 percent by using Cs^{137} gamma-rays (Fig. 2).

From this it is evident that large LiI(Sn) crystals can be grown which give good resolution and pulse height. This makes it possible to build relatively small detectors with high efficiency for thermal and epithermal neutrons. The resolution makes it also possible to use these crystals for rough neutron-energy measurements in the region where the $Li^6(n, \alpha)He^3$ cross section is large enough (~1 barn).

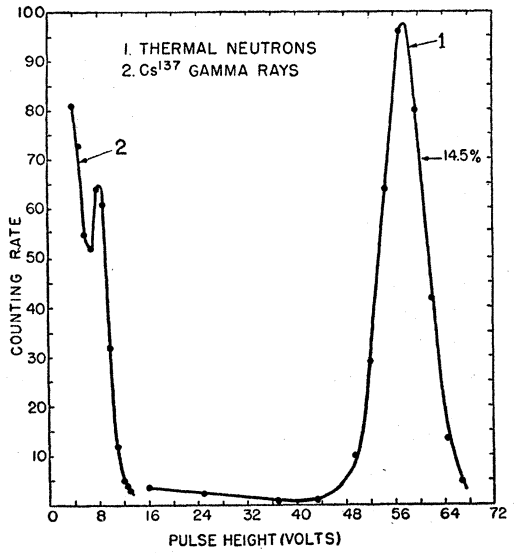

FIG. 2. LiI(Sn) 1 in. × ¾ in. × ¾ in. crystal response. (1) irradiated with thermal neutrons; (2) Cs^{137} gamma-rays.

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The Graphs for the Kernel of the Bethe-Salpeter Equation

C. A. HURST
Trinity College, University of Cambridge, Cambridge, England
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IN view of the recent discussions of Bethe and Salpeter[1] and Low and Gell-mann[2] on the derivation of an integral equation for describing bound states in field theory, it is of interest to see whether this kernel is likely to show any irregular type of convergence. Although it is the intention of these authors to escape some of the limitations of perturbation expansions, particularly when dealing with problems concerning bound states, it has not been found possible to obtain a tractable equation in a closed form, so that the kernel can only be employed in the form of a power series expansion in the coupling constant.

The kernel for the two-particle scattering process is composed of "irreducible" parts. These parts are such that it is not possible, by cutting the two spinor lines carrying the external energy and momentum, to separate the graph into two portions such that each portion has exactly four external spinor lines.

As an indication of the possible convergence of the power series describing the kernel, a lower limit to the number of irreducible graphs is given.

Let $N(n)$ denote the number of graphs of order n, whether reducible or irreducible, and $N_I(n)$ the number of irreducible graphs. Then a difference equation for $N_I(n)$ can be set up, in a manner exactly parallel to the Bethe-Salpeter equation.

$$\frac{N(n)}{n!}=\frac{N_I(n)}{n!}+\frac{N_I(n-2)}{(n-2)!}\frac{N(2)}{2!}+\cdots+\frac{N_I(2)}{2!}\frac{N(n-2)}{(n-2)!}. \quad (1)$$

This equation is obtained by requiring that the last $(n-2r)$ points, as described by the arrows on the spinor lines carrying the external energy and momentum, should form an irreducible graph, while the first $2r$ form a graph which may be reducible.

If

$$\Phi(v)=\sum_{n=0}^{\infty} v^n\frac{N(n)}{n!}, \quad \Psi(v)=\sum_{n=2}^{\infty} v^n\frac{N_I(n)}{n!},$$

Eq. (1), in terms of generating functions, can be written

$$\Phi(v)=1+\Phi(v)\Psi(v), \quad (2)$$

which models the Bethe-Salpeter equation.

Now if "ladder" graphs are considered, for which only virtual boson exchange between the two spinor lines takes place, then we have

$$N(n)/n!=\tfrac{1}{2}(n/2)!,$$

and it is evident that $N(n)\geqslant N_I(n)$.

Also

$$\frac{N_I(n)}{n!}\geqslant\frac{N(n)}{n!}-\sum_{r=1}^{\frac{1}{2}(n-2)}\frac{N(2r)}{2r!}\frac{N(n-2r)}{(n-2r)!}. \quad (3)$$

Then the ratio of succeeding terms in the summation,

$$R_r=\frac{N(2r)N(n-2r)}{N(2r+2)N(n-2r-2)}\frac{(2r+2)(2r+1)}{(n-2r)(n-2r-2)}=\frac{n-2r}{2r+2}>R_{r+1}$$

and $R_1R_2\cdots R_{\frac{1}{2}(n-2)}=1$. Also $R_r=1$ for $(n-2r)/(2r+2)=1$, that is for $r=(n-2)/4$, so that

$$R_r\gtrless 1 \quad \text{for} \quad r\lessgtr(n-2)/4.$$

Then the inequality can be written

$$\frac{N_I(n)}{n!}\geqslant\frac{N(n)}{n!}-\frac{2N(n-2)}{(n-2)!}\frac{N(2)}{2!}-\frac{2N(n-4)}{(n-4)!}\frac{N(4)}{4!}\left(1+\frac{1}{R_4}+\frac{1}{R_4R_6}+\cdots+\frac{1}{R_4\cdots R_{\frac{1}{2}(n-4)}}\right)$$
$$\geqslant\frac{N(n)}{n!}-\frac{2N(n-2)}{(n-2)!}\frac{N(2)}{2!}-nC\frac{N(n-4)}{(n-4)!}\frac{N(4)}{4!},$$

where C is independent of n.

So

$$[N(n)/n!][1-O(1/n)]\leq N_I(n)/n!\leq N(n)/n!.$$

Hence $N_I(n)/n!$ increases as rapidly as $N(n)/n!$, namely $\log[N_I(n)/n!]\sim\frac{1}{2}n\log n+O(n)$. Thus there are, in this sense, as many terms in the kernel of the Bethe-Salpeter equation as in the original perturbation expansion, and so this kernel may very well not form a convergent series in the coupling constant, in the same way as the Born approximation for the S-matrix may not lead to a convergent series.

This result then raises the question of the meaning of the approximate solution of an integral equation, obtained by neglecting further terms in the kernel, when this kernel could not be approximated indefinitely with increasing order. This would be particularly difficult to justify in the case of pseudoscalar meson-nucleon interactions, for which the experimentally determined coupling constant is large.

This result can be modified trivially to fit any of the field theories so far introduced.

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