and Fernbach[8] which used parameters obtained by fitting proton elastic scattering and polarization data. These parameters are: radius constant, $r_0 = 1.25$ fermis; real potential, $V = 51$ Mev; imaginary potential, $W = 11$ Mev; and diffuseness parameter, $a = 0.65$ fermis. The spin-orbit potential used was 20 times the Thomas term. This yielded a reaction cross section, $\sigma_R = 805$ millibarns.[9] Considering the experimental errors, we feel that the experimental results we obtain for these nuclei do agree with surface-absorption optical-model calculations.

Reaction cross sections of a number of other nuclei are being determined by this method. Preliminary results for 10-Mev protons are in reasonable agreement with surface-absorption optical-model calculations, using parameters that fit polarization and elastic scattering, over a wide region of the periodic table.

†Work was performed under the auspices of the U. S. Atomic Energy Commission.

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DECOUPLING OF A TIME-DEPENDENT PERTURBATION CAUSED BY AFTEREFFECTS OF HOLE FORMATION

B. -G. Pettersson, T. R. Gerholm, J. Thun, and K. Siegbahn
Institute of Physics, University of Uppsala, Uppsala, Sweden
(Received November 7, 1960)

It has been suggested[1] that the aftereffects caused by the formation of a hole in one of the electron shells by electron capture or internal conversion might give rise to a time-dependent magnetic coupling between the electron shell and the nucleus. Such a coupling, if it exists, should affect the angular correlation between successive nuclear radiations, resulting in a more or less complete wipeout of the angular correlation pattern. Experimental studies of this effect have led to confusing results. Some experimenters[2] claim to have found evidence for the aftereffects of hole formation. Even a completely isotropic correlation has been reported.[3] Others,[4-6] however, have been led to the conclusion that there is no observable attenuation caused by the aftereffects.

The main reason for this disagreement is probably due to the interference between the eventual hole effect and the simultaneously present quadrupole interaction. The latter also gives an attenuation due to the coupling between the nuclear quadrupole moment, eQ, and the crystalline electric field gradients $\partial E/\partial z$. It is possible, however, to separate the two effects by means of delayed angular correlation experiments. Abragam and Pound[7] have shown that the quadrupole attenuation can be described by means of attenuation factors $G_{2\nu}$. The angular correlation is then given by

$$W(\theta, t) = 1 + G_2(t)A_2P_2(\theta) + G_4(t)A_4P_4(\theta). \quad (1)$$

For $G_2(t)$ one has for spin 5/2 of the intermediate level

$$G_2(t) = \tfrac{1}{5}(1 + \tfrac{13}{7}\cos\omega_0 t + \tfrac{10}{7}\cos 2\omega_0 t + \tfrac{5}{7}\cos 3\omega_0 t),$$

where ω_0 is the ground precession frequency and t is the time delay. In the case of delayed angular correlations the actually observed $G_2(t)$ becomes a weighted mean of $G_2(t)$ for the time range in question determined by the resolving time of the coincidence circuit. $\bar{G}_2(t)$ can be evaluated by integrating over (1). The delayed angular correlations can then be used to determine the strength of the quadrupole interaction. An additional attenuation, which cannot be accounted for by the quadrupole interaction mechanism is then, presumably, due to the aftereffects.

For our experiment we have chosen the 165-kev conversion electron 134-kev gamma cascade in Hg^{197m}. The intermediate level has a mean life of 9×10^{-9} sec,[8] which allows for delayed angular correlations and still is sufficiently short to permit a reasonable competition between the quad-

rupole and magnetic couplings.

In an extensive series of measurements[9] we have studied this correlation for varying source conditions. Sources were produced by bombarding gold with 18-Mev protons and the Hg^{197m} activity was vacuum-evaporated onto the backing material which was cooled with liquid air. Thus it was possible to vary the source environment by choosing different backing materials. Four metallic environment backings of Ag, Au, Al, and Ga were used. Four different insulators were used, namely: rubber hydrochloride, Mylar, Mg oxide, and Al oxide. In Fig. 1 are given the calculated quadrupole attenuation factors $\overline{G}_2(t)$ for the three different delay positions used. The attenuations observed are in complete agreement with the theory for all metallic sources. For insulating source environment, however, we were forced

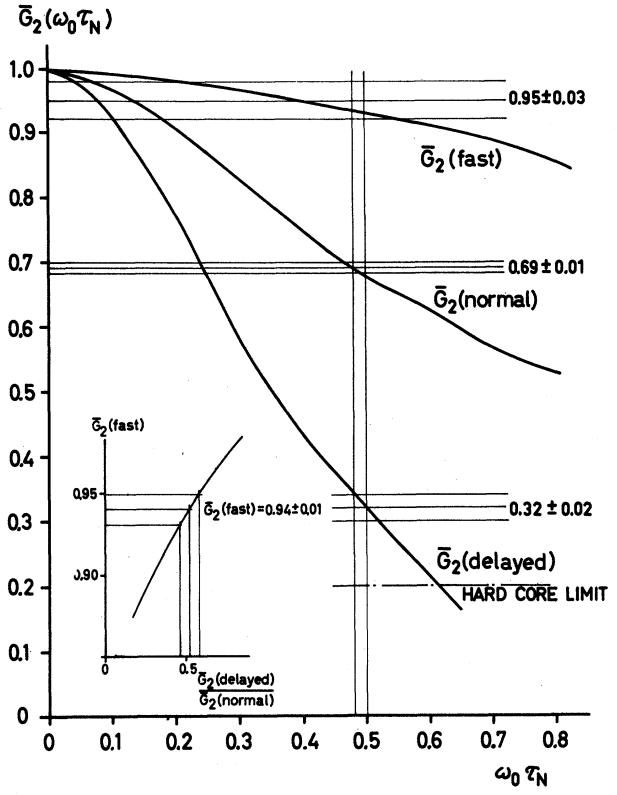

FIG. 1. $\overline{G}_2(\omega_0\tau_N)$ as a function of the strength of the quadrupole coupling, $\omega_0\tau_N$, for the three different delay positions used. The experimental results given in the figure correspond to correlations measured with an Au backing. Insert: Results for a rubber hydrochloride backing; $\overline{G}_2(\text{delayed})/\overline{G}_2(\text{normal})$ corresponds to a theoretical $\overline{G}_2(\text{fast}) = 0.94 \pm 0.01$ to be compared with the experimentally obtained value 0.66 ± 0.04, thus indicating an additional attenuation $G_2(\text{hole}) = 0.70 \pm 0.05$.

to assume an additional attenuation mechanism. The ratio of the A_2 coefficients measured in the fast, normal, and delayed positions are compatible with a pure quadrupole interaction mechanism. However, the absolute values show an additional attenuation of a fast "on-off" character present immediately after the K conversion. Thus we may write $\overline{G}_2(\text{fast}) = \overline{G}_2(\text{hole}) \times \overline{G}_2(Q, \text{fast})$. As shown in the insert of Fig. 1, we can use the ratio of $\overline{G}_2(\text{normal})/\overline{G}_2(\text{delayed})$ to predict $\overline{G}_2(Q, \text{fast})$ which is then to be compared with the experimentally measured $\overline{G}_2(\text{fast})$. In this way $\overline{G}_2(\text{hole})$ is determined. The four different insulating source environments, mentioned above, all gave the same results, namely, $\overline{G}_2(\text{hole}) = 0.70$.

These results are consistent with an aftereffect mechanism. For metallic sources the total recovery time is supposed to be very short ($\lesssim 10^{-14}$ sec) because of the availability of conducting electrons to neutralize the ion. For insulators, however, it is conceivable that the atom can remain in a highly ionized state for an appreciable time. The unpaired electron spins in the outermost orbits then give rise to a magnetic coupling which may be quite large. To exclude the possibility that the attenuation observed for insulator source-backings is due to the charging up of the source, we measured the 130 kev - 279 kev electron-gamma correlation in Au^{197} where the mean life of the intermediate level, 2.3×10^{-11} sec, is too short to give any attenuation due to extra nuclear fields. No difference between metallic and insulator backings was observed in this case.

To prove our aftereffects hypothesis for insulator source-backings, we have performed a magnetic decoupling experiment. (See Fig. 2.) The source was exposed to a fairly strong (≈ 3000 gauss) magnetic field parallel to the direction of emission of the conversion electrons. The nuclear spin I and the electron spin J then precess around the field axis. The attenuation is thus removed and the resulting angular correlation should be affected by the quadrupole interaction only. There is a slight complication due to the fact that the correction factor, f, for the finite aperture of the electron channel (a magnetic beta-ray spectrometer) depends on the focussing action of the field produced by the decoupling magnet. The appropriate expressions become, for the 180° position used in our experiment,

$$W_0(\text{metal}) = 1 + f_0\,\overline{G}_2(Q, \text{metal})A_2,$$

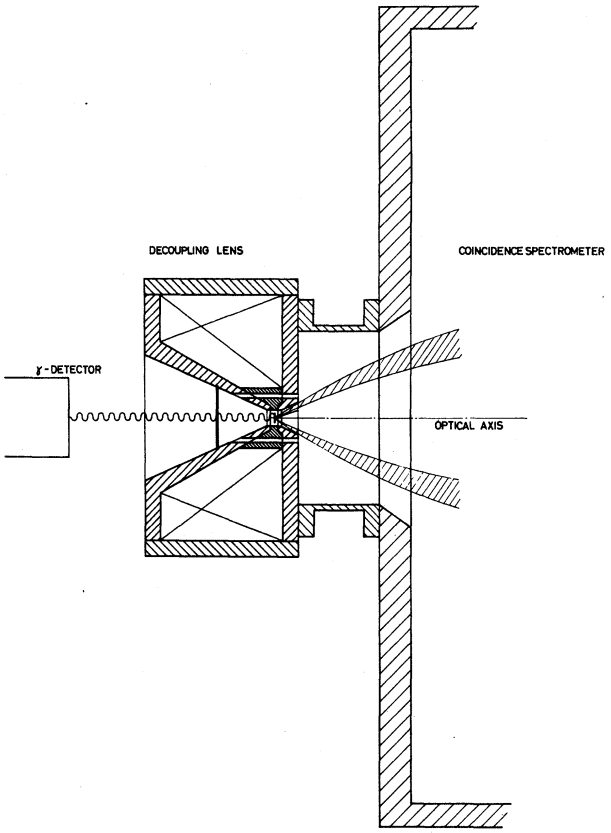

FIG. 2. Magnet used for the decoupling experiment.

$$W_B(\text{metal}) = 1 + f_B \bar{G}_2(Q, \text{metal}) A_2,$$

$$W_0(\text{insul}) = 1 + f_0 \bar{G}_2(\text{hole}) \bar{G}_2(Q, \text{insul}) A_2,$$

$$W_B(\text{insul}) = 1 + f_B \bar{G}_2(Q, \text{insul}) A_2,$$

and

$$A_2(\text{measured}) = f_0 \bar{G}_2(Q) \bar{G}_2(\text{hole}) A_2,$$

determined from an angular correlation measurement on the source used.

The geometrical correction factor f_B was determined for several different metallic sources with different quadrupole interaction couplings. For a given magnetic field, B, the factors f_B thus determined were found to be equal and in agreement with a theoretically calculated value based on the observed increase of the single counting rate in the electron channel. The experiments were performed in the "normal" delay position, where the angular correlation gave $\bar{G}_2(\text{hole}) = 0.70 \pm 0.03$ and $\bar{G}_2(Q) = 0.70 \pm 0.05$. From the coincidence counting rates divided by the electron single counting rates, we obtained from the relations above, for $f_0 = 0.80$ and $A_2 = 0.20$: $\bar{G}_2(\text{hole}) = 0.71 \pm 0.03$ and $\bar{G}_2(Q) = 0.70 \pm 0.05$, in perfect agreement with the angular correlation results. The magnetic decoupling experiment proves the existence of a time-dependent perturbation caused by the aftereffects of hole formation and confirms the conclusions drawn from our delayed coincidence experiments.

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