show that the apparatus is, in fact, capable of detecting delayed coincidences due to a finite lifetime. The shape of the resulting curve (not shown) was compatible with the 0.304-μsec. half-life[3] of ThC'.

In order to set an upper limit on the mean life τ of the 411-kev excited state of Hg^{198}, the β-pulse delay portion of the Au^{198} resolution curve has been plotted on a semilogarithmic scale in Fig. 2. The roughly exponential fall-off of the experimental curve is common to the results for Co^{60}, Cs^{134}, and Au^{198} and thus is instrumental. A dashed line in Fig. 2 indicates the shape the curve would have if the mean life of the Hg^{198} excited state were as long as 3×10^{-9} sec. Figure 2 demonstrates that the mean life τ of the 411-kev excited state of Hg^{198} is less than 3×10^{-9} sec.

An incidental result is that the excited states of Ni^{60} and Ba^{134} which are concerned in γ-γ-coincidences from Co^{60} and Cs^{134}, respectively, all have mean lives shorter than 3×10^{-9} sec.

MacIntyre's result for the mean life ($2.3\pm0.2\times10^{-8}$ sec.) can probably be explained by the fact that he compared β-γ-coincidences from Au^{198} with those from Na^{24}. The pulses from Na^{24} γ-rays (1.38 and 2.76 Mev) would be many times larger than those from Au^{198} γ-rays (0.411 Mev): in a coincidence system using amplifiers of finite rise time the result would be a greater lag in the detection of the Au^{198} γ-ray pulses and consequently an apparent finite lifetime of the Hg^{198} excited state.

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On the Spatial Alignment of Nuclei

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CONSIDERABLE interest centers on the problem of producing a system containing nuclei in a reasonably well-ordered state of alignment in space. Such a system makes possible studies of angular dependence of the scattering and absorption of polarized nucleons and of angular distributions in radioactive decay, relative to the spin axis of the nuclei.[1,2]

The most direct method of achieving a net alignment is to place the substance in a magnetic field H_0. If thermal equilibrium exists between the spin system and its surroundings, a Boltzmann distribution of the spins over the $2I+1$ equally spaced energy levels results, with the lowest level, corresponding to the spin nearly parallel or antiparallel to the field, becoming most heavily populated. Practical difficulties are presented by the fact that the nuclei must be put into an extremely strong field and at the same time must be in thermal contact with a paramagnetic substance in a weak field, because a reasonable degree of orientation is achieved only at the lowest temperatures so far attainable by adiabatic demagnetization, with the nuclei in the strongest field obtainable. A somewhat simpler method may be available for nuclei of paramagnetic ions, which may be oriented by the intense fields of the oriented ions themselves, at low enough temperatures.[3,4] In both cases the sample containing the nuclei must be kept in a field while the other experiments are performed lest random orientations be resumed.

The purpose of this note is to outline an experimentally less difficult method by which a partial alignment of nuclei might be achieved. It is known that the $2I+1$-fold degeneracy of a nucleus can be partially lifted through an interaction between the nuclear electric quadrupole moment and a crystalline electric field having axial symmetry.[5,6] The component m_I of angular momentum along the axis becomes a good quantum number, in the absence of a strong magnetic interaction, although levels differing only in sign of m_I are not separated. So far, because of difficulties attendant on finding suitable samples, only moderate quadrupole splittings have been found, such as the 720 kc/sec. in Al_2O_3.[6] On the other hand, it must be expected that very much larger splittings exist in, for instance, crystals composed of molecules having p-type covalent bonds.[7] One would expect, in fact, splittings of the order of hundreds or thousands of megacycles as in gaseous molecules[8] because the gradient of the electric field at the nucleus is determined by the other nuclei and the electrons of the molecule itself (in contrast to the situation in ionic crystals where the ion containing a nucleus is primarily in a singlet S state and probably contributes little to the gradient of the electric field at the nucleus).

A crystal having quadrupole splittings of this order of magnitude need only be brought into thermal equilibrium with a substance that has been adiabatically demagnetized to a temperature of a few hundredths of a degree and the nuclei will fall into the lowest energy levels. This would mean either the highest or lowest absolute values of the component of the nuclear spin along the major axis of the tensor grad $\mathbf{E}$ at the nucleus would predominate. Either case could be found depending upon the sign of the quadrupole coupling constant $eQ(\partial^2V/\partial z^2)$. Therefore, the nuclei would be aligned, respectively, either simultaneously almost parallel and antiparallel to this axis in the molecule, or precessing nearly in a plane perpendicular to this axis. If the molecules could be crystallized in such a way that this axis was alike for all, one achieves a certain kind of nuclear orientation. A fairly sizable single crystal or some technique of orienting small crystals would give the desired result if the crystal does not contain non-equivalent orientations of the molecules, with respect to the crystal axes.

Although the kind of alignment resulting is not as unambiguous as in the magnetic alignment, several advantages are apparent. In radioactive emission, anticipated angular distributions involve even powers of $\cos\theta$,[1] for which, if true, the ambiguity is not a disadvantage. The thermal contact with the paramagnetic substance may be easier to achieve because the nuclear sample can be put into the magnetic field while the paramagnetic magnetization and adiabatic demagnetization are performed. This is so because the magnetic splittings are only small perturbations on the electric ones. If the crystal containing the nuclear sample itself could be made also to contain the paramagnetic ions, the thermal contact could be very strong, and the paramagnetic ions, by their relaxation processes, could help to bring about thermal relaxation of the nuclear system. Once thermal equilibrium is established the sample may be completely removed from the magnetic field, simplifying some of the experiments on the aligned nuclei.

To find such a high frequency splitting and to demonstrate the temperature of the spin system, ordinary nuclear paramagnetic resonance experiments at moderate frequencies can be of assistance. With an odd half-integral spin, one could observe the resonance absorption in the transition between the still degenerate levels $m_I=\pm\frac{1}{2}$, when the degeneracy is removed by a magnetic field. If the axis of symmetry of the electric field lies along the magnetic field, one expects to find a resonance line at the frequency corresponding to the normal gyromagnetic ratio, but, if the quadrupole splitting is strong, the frequency would be very sensitive to a small angular displacement from this position. By a perturbation calculation, regarding the Zeeman energy as a small perturbation on the large quadrupole energy, one can find the amount of the quadrupole splitting.

If the intensity of the line is observed as the temperature is reduced to such a degree that $kT<h\nu$ where ν is the quadrupole splitting frequency, either of two things will occur, determined by the sign of the quadrupole coupling constant. If the $m_I=\pm\frac{1}{2}$ levels are the lowest, then the line would get more intense as $1/T$ until a critical temperature is reached where a fairly pronounced increase in intensity would accompany the preferential population of these states. If $m_I=\pm I$ are the lowest, the observed line would go through a maximum and then decrease as the $m_I=\pm\frac{1}{2}$ levels become depopulated.

Preliminary experimental work directed toward this end is underway. Details of the calculations of quadrupole interactions in fields of axial symmetry will be published elsewhere.

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Double-Probe Method for Determination of Electron Temperatures in Steady and Time-Varying Gas Discharges

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THE single-probe method of Langmuir and Mott-Smith[1] is not well suited for measurements in time-varying discharges and in particular not in decaying plasmas following the interruption of a discharge. In the latter case this follows from the fact that efforts to operate the probe above plasma potential are defeated by the fact that the plasma potential constantly recedes so as to maintain itself positive with respect to the probe. The use of two probes connected in a floating circuit overcomes the difficulties of the single-probe method and permits the determination of such quantities as electron temperature and density in both steady and time-varying discharges. Dow[2] has described a double-probe method for determining the electron temperature in the ionosphere. He appears to do this from values of i_e very close to the regions of V_{D1} or V_{D2} only (see Fig. 1). In these regions, the method appears to be less accurate and uses data which are generally discarded in the method here described.

Two probes are connected together through a resistor and a variable potential source V_B. The entire measuring system is permitted to float. By means of a scope across the resistor, the instantaneous current I_D can be determined. In practice one varies V_B and determines I_D and V_D, the potential difference between the probes.

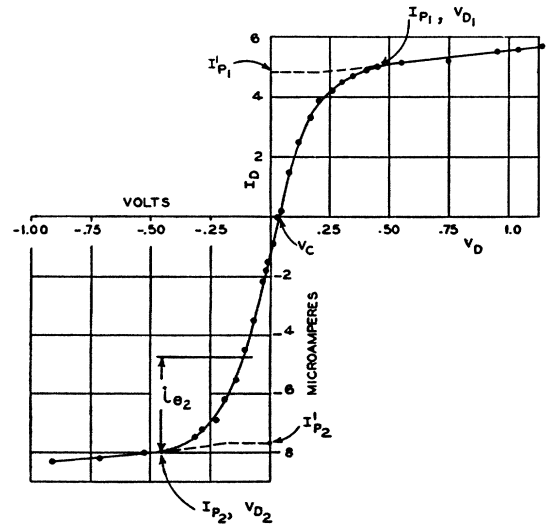

FIG. 1. Current *vs.* voltage characteristic of floating double-probe system immersed in plasma.

A typical plot is shown in Fig. 1. These data were obtained in an argon-filled hot-cathode diode, 100 μsec. following the interruption of a discharge.

From the equality of the total electron and ion currents to the probes, it follows that:

$$\left(\frac{I_{p1}+I_{p2}}{ie_2}-1\right)=k\exp[-11{,}600(V_d/T_e)]=\Gamma, \tag{1}$$

where

$$k=(A_1/A_2)(j_{01}/j_{02})\exp[+11{,}600(V_c/T_e)]. \tag{2}$$

A_1 and A_2 are the areas of probes 1 and 2. j_{01} and j_{02} are the random electron current densities at probes 1 and 2. ie_2, the electron current to probe No. 2, is equal to the difference between I_d and I_{p2}. The other symbols are defined in Fig. 1. The slope of log Γ *vs.* V_d yields T_e. Figure 2 is a plot of (1) for the data of Fig. 1. For this case, $T_e=1065°$K. The linear regions beyond I_{p1} and I_{p2} in Fig. 1 correspond to saturated ion current only, to one probe or the other. Since the current to one of the probes in these regions is purely ionic, the current flow is generally determined by space charge and not by orbital-limited-current relations.[1]

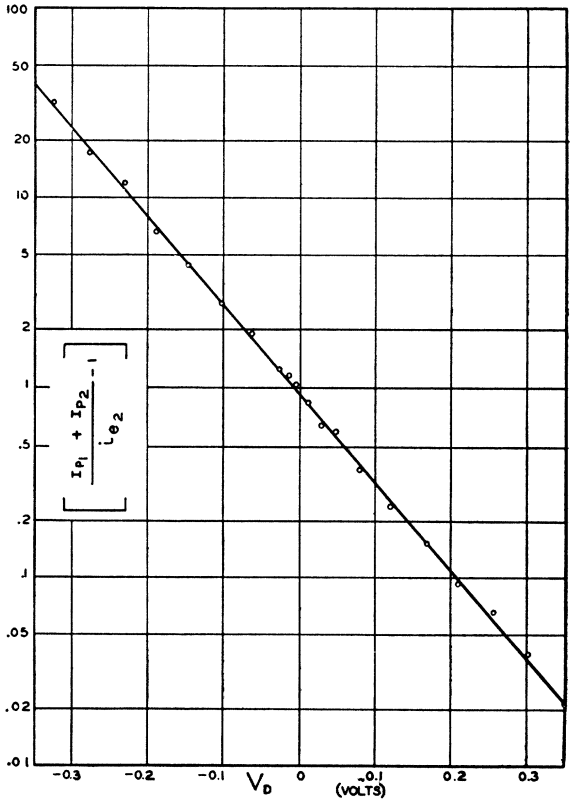

FIG. 2. Logarithmic plot for determination of electron temperature.

A more rapid determination of T_e can be obtained from Fig. 1, and the relation

$$T_e=11{,}600G(1-G)(dV_d/dI_d)V_{d=0}(I_{p1}+I_{p2}), \tag{3}$$

where

$$G=\frac{[ie_2]V_{D=0}}{I_{p1}+I_{p2}}. \tag{4}$$

If the slope of the regions of positive ion saturation is considerable, then in place of I_{p1} and I_{p2} one uses quantities obtained as follows: Extend the positive ion saturation curves linearly as shown in Fig. 2 and use for I_{p1} and I_{p2}, the ordinates at points $\frac{2}{3}$ of