FIG. 1. Theoretical curve of energy loss in AgBr in Mev per gram per cm² as a function of E/Mc^2. Blob densities are plotted and normalized to the curve at the points for the decay electrons in the present investigation and that of Morrish. The data of Michaelis and Violet are normalized to the curve for their point at $E/Mc^2 = 580$.

Similar type experiments over restricted portions of the curve have been made at Berkeley[6] and by Morrish,[7] and these data have been included in Fig. 1. The points, Fig. 1, appear to be in reasonable agreement with the theoretical curve; however, the agreement between both the theory and the different observers would be quite good if all statistical errors were doubled. It is probable that this is due to some systematic errors, the nature of which are not known at present.

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Negative μ-Meson Capture in Carbon*

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WE are studying experimentally the behavior of cosmic-ray μ mesons stopped in carbon. Bell and Hincks[1] have shown that the mean life of negative μ mesons in carbon differs from the mean life of positive μ mesons. They compute the nuclear capture rate for negative μ mesons in carbon to be $A = (5.5 \pm 1.5) \times 10^4$ sec⁻¹. The fraction of stopped negative μ mesons which are captured, $F = A/(A + 1/\tau)$, is 0.11 ± 0.03, where τ is the mean life of positive μ mesons. The possible end products of the capture reaction are bound states of B¹² or groups of fragments such as B¹¹ plus a neutron. The object of our investigation is a determination of the probability for the end product to be B¹² in its ground state. We present here a brief description of the method and some preliminary results.

The μ mesons to be studied are stopped in an organic liquid scintillation counter. The counter has a sensitive volume of 4 in.×4½ in.×5 in. viewed by two RCA type C7157 photomulti-

pliers. The pulses from the counter are presented on an oscilloscope and photographed. An arrangement of coincidence and anticoincidence Geiger counters selects events and triggers the oscilloscope sweep. Details of the presentation scheme and of the means used to eliminate spurious events will be presented in a subsequent paper.

Two types of events are investigated. In the first, the pulse from the arriving μ meson is followed by a pulse with a 2 μsec mean delay, indicating that the meson decayed. In the second type of event, the arriving μ-meson pulse is followed by a pulse with a 39 millisecond mean delay, indicating that a C¹² nucleus captured the meson, forming a B¹² nucleus which subsequently decayed by β emission back to C¹².[2] The end product of the capture reaction in the second type of event is B¹² in either the ground state or a bound excited state. (An unbound excited state would decay by neutron emission and a B¹² β particle would never be observed.) A bound excited state would promptly decay by γ emission to the ground state and later a β particle would be emitted. With the present apparatus, the γ ray would in general not be detected, and the event would have the same appearance as if the ground state had been formed in the original capture reaction.

Let D be the number of events observed in which a negative meson decays, as determined from the total number of decays, corrected by the data of Bell and Hincks and by the known positive excess. Let C be the number of capture events observed. Then $P = C/D\tau$ is the rate of the μ-meson capture reaction that results in a B¹² nucleus in the ground state or in a bound excited state. P is thus also an upper limit on the rate of the reaction whose end product is B¹² in the ground state. Our preliminary result is that $P = (5 \pm 2) \times 10^3$ sec⁻¹.

The ratio P/A is 0.09 ± 0.05. This indicates that only about a tenth of the capture reactions result in B¹² in a bound state. If the unbound states of B¹² usually break up into B¹¹ plus a neutron, then from the low value of P/A one would expect the multiplicity of the neutrons emitted in the capture of μ mesons in carbon to be near unity. Although the neutron multiplicity has been measured[3] for the capture of μ mesons in several elements, it has not yet been done for carbon.

A full report will be published upon completion of this investigation.

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Liquid Scintillation Counting of Natural C¹⁴†

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DURING an investigation of the natural C¹⁴ content of liquid scintillation solvents, samples of p-cymene were obtained which gave very different counting rates. A consistently high rate resulted from material whose primary origin, via certain trees, was contemporary atmospheric carbon dioxide[1] and an equally consistent low value was derived from samples synthesized entirely from petroluem chemicals.[2]

Accurate knowledge of these two counting rates and the accompanying backgrounds, along with careful standardization of the C¹⁴ detection efficiencies during the experiments, has allowed easy realization of a number which is the specific activity of natural C¹⁴ in p-cymene and in the constituents of turpentine from which it is derived.

A Los Alamos Model 530 Coincidence-Anticoincidence System[3] was used in this study. 2,5-diphenyloxazole[4] in a concentration of 4 g/l was the liquid scintillation solute and p-cymene volumes of 30 ml and 40 ml were employed. Five complete experiments were run, each at a different instrumental sensitivity. Absolute counting efficiencies were determined with C^{14}-benzoic acid as an internal standard. Mass spectrographic analyses gave a value of 6.00±0.02 percent C^{14} in the carboxyl carbon of the benzoic acid. This was synthesized[5] from carbon dioxide containing 5.96±0.01 percent $C^{14}O_2$. The benzoic acid specific activity was calculated from the C^{14} abundance and a half-life value of 5568 years.[6]

Experimental gross rates were corrected for background and converted to disintegration rates. The average value, from five experiments, of the specific activity of carbon in contemporary p-cymene was 12.9±0.2 disintegrations per minute per gram. This number represents a rather startling departure from the usually quoted value of 15.3±0.1 disintegrations per minute per gram of carbon in wood.[7] Such a difference is not altogether unexpected with both a new counting form and an instrument of twelve times higher efficiency than the Screen Wall Counter used by Libby and co-workers. The accuracy of either number depends on the efficiency calibration of the instrument used and not on the number of samples subsequently counted.

The liquid scintillation counter may soon be routinely used for radiocarbon dating. Further work is being carried out with methanol and methyl ether, both of which can easily be derived from carbon dioxide and which may be incorporated into the solvent system of liquid scintillators. The relatively high background of instruments such as the Los Alamos Model 530 Coincidence-Anticoincidence System is the only serious problem remaining before they can be converted to natural radiocarbon counters. Ways are being explored for lowering counting rates due to thermionic emission, light dark current, natural contamination in the apparatus, and external radiation. These will be reported at a later date.

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Crystal Structure and Nuclear Directional Correlation. I. Pb^{204}†

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THE Zürich group has recently shown in a beautiful experiment[1] that the $\gamma-\gamma$ directional correlation of Cd^{111} in a metallic indium single crystal depends markedly upon the orientation of the crystal axes with respect to the counter axes. Their experiment demonstrates that the main contribution to the effect of extranuclear fields on the directional correlation arises from the interaction between the nuclear quadrupole moment and electric field gradients.

Growing and orienting single crystals is, however, so time-consuming that the method is applicable only to nuclides with relatively long half-lives. In the case of Pb^{204} ($T_{\frac{1}{2}}=65$ min), we therefore chose a different approach to investigate the effect of crystal structure and studied the directional correlation of this isomer in Pb—Tl substitutional alloys. Pb and Tl form mixed crystals over a wide range of composition[2] and display at suitable compositions and temperatures face-centered cubic (f.c.c.), body-centered cubic (b.c.c.), and hexagonal close-packed (h.c.p.) lattices.

We determined the directional correlation function $W(\theta)$ of Pb^{204} for two types of sources at various temperatures. The first type ($\sim$100 percent Tl) was directly produced by irradiating Tl in the cyclotron with deuterons[3] and constitutes therefore a Pb—Tl crystal with vanishingly small Pb content. Such a crystal possesses an h.c.p. lattice below 235°C and a b.c.c. lattice between 235°C and the melting point 303°C. The second type ($\sim$40 percent Tl), prepared by adding Pb to the irradiated Tl, shows the f.c.c. structure of Pb and has a melting point of 365°C.

The measured anisotropies, $A=[W(180°)/W(90°)]-1$, are shown in Figs. 1(a) and 1(b) as a function of the source tempera-

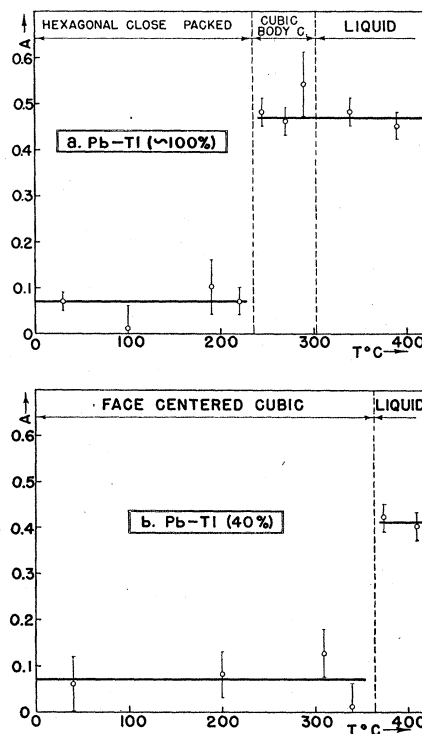Fig. 1. Anisotropy A of the Pb^{204} $\gamma-\gamma$ cascade in Pb—Tl alloys as a function of the source temperature T. (a) 100 percent Tl. (b) 40 percent Tl.

ture T. (The indicated errors are statistical errors only. The measured anisotropies are corrected for scattering in the source[3] and the absolute values may therefore be in error by as much as a factor 1.1. However, this does not affect the relative values.)

The data in Fig. 1 show the importance of the crystal structure for the directional correlation of Pb^{204}. The highest anisotropy, 0.47 (±0.02) is obtained *both* in the solid b.c.c. lattice and in the liquid of corresponding composition.[3] The discussion of the Pb^{204} decay shows that no greater anisotropy is possible.[3] We therefore conclude that the interaction between the nucleus and its surroundings is vanishingly small in the b.c.c. lattice.

However, problems arise in the explanation of the anisotropies for the h.c.p. and the f.c.c. structures (0.07±0.02, and 0.07±0.03, respectively). These values are considerably lower than the lowest ("hard core") value 0.15 predicted by theory for a static quadrupole interaction in randomly oriented crystals.[4] (Attempts to show that a partial orientation of our crystals caused the low values were unsuccessful.) No value for the magnitude of the quadrupole interaction can therefore be given. The fact that the f.c.c. lattice yields the same low anisotropy as does the h.c.p. lattice is also unexplained.