interaction, or by an interaction of a recoiling nucleon with another nucleon, occurred. Because of the low energy of the recoiling nucleons and therefore the small cross section (about 3×10^{-27} cm^2),[3] the latter process is improbable. Only 80 events where a backward scattered meson is observed, in the 460 analyzed, can lead to recoil nucleons more energetic than 250 Mev. These recoil nucleons would be expected to produce at most 0.2 meson, not six.

Table I describes the characteristics of the events, listing kinetic energy and angle of emission (laboratory system) of the two mesons and the number of additional particles emitted in the disintegration. The relatively great number of prongs in events 1, 3, and 4 suggest that these are processes occurring in light nuclei. Specifically, event 1 can be explained on energy grounds as having taken place in a carbon nucleus, disintegrating into two protons of 4.7 and 6.5 Mev (range determination) and a $_4\text{Be}^9$ nucleus of 2–3 Mev.

Figure 1 is a photomicrograph of event 1; *i* is the incoming meson and *a* and *b* the emitted mesons.

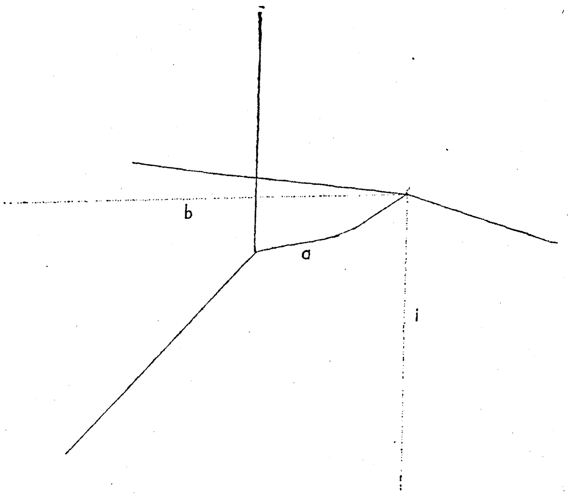

FIG. 1. Meson production, event 1.

Event 7 (Fig. 2) has been found after scanning more than the 460 events referred to. Here only the incoming meson *i* and the emitted mesons *a* and *b* can be seen. This event can, on the basis of energy and momentum considerations (within the limit of experimental errors), be explained as meson production in a hydrogen nucleus of the emulsion.

Thus far no positive mesons coming out of stars could be identified. However, in adjacent emulsions several π-μ-e decays have been observed, supporting the conclusions on meson production.

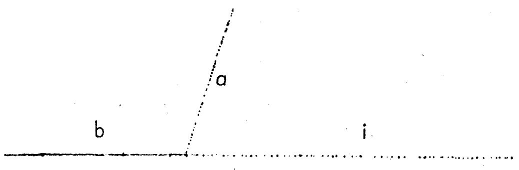

FIG. 2. Meson production, event 7.

In addition to the 6 events mentioned above, 8 more have been found which are consistent with interactions with meson production. However, the tracks are too short for unmistakable identification.

Therefore the percentage of events with two charged mesons is 1.3 percent to 3 percent, considering the 460 interactions among which the events have been found. This percentage has to be increased in order to take into account events where one or both mesons have been absorbed. We have found that with 500-Mev incident mesons, charged mesons leave the nucleus in only 38 percent of the interactions (55 percent if neutral mesons are considered). Since the energy of the emitted mesons is generally smaller in two-meson events, still fewer of these mesons escape. It is estimated (based on experiments with incident mesons of lower energy) that the number of 2-meson events reported here constitute at the most 25 percent of all events in which a charged meson—observed or absorbed—is produced. The above figure would then represent 5.2 percent to 12 percent of all interactions.

From these experiments nothing can be learned about the production of π^0 mesons, and therefore the actual cross section of meson-meson production at 500-Mev meson energy cannot be compared with theoretical data.

Recently Yang and Fermi[4] independently calculated the probabilities for meson-meson production for various meson energies available from the cosmotron. The calculations are based on the Fermi theory of meson production and on considerations concerning isotopic spin conservation; the calculations apply for meson-nucleon collisions and assume an interaction radius $r=\hbar/\mu c$.

Assuming (1) the validity of these calculations for meson-nucleon collisions inside the nucleus, (2) the equality of number of protons and neutrons for emulsion nuclei, and (3) the equality of π^--p and π^--n cross sections,[5] the fraction of events leading to two charged mesons is 16 percent or 18 percent (the second number includes events with 2 charged and 1 neutral meson). This figure is about twice the value calculated from experimental data, but considering the meager statistics and the simplified assumptions, the disagreement is probably not too serious

The authors wish to thank the entire staff of the Brookhaven cosmotron for their cooperation, Mrs. E. Medd and Mrs. B. Cozine for their efficient work in scanning and measuring the plates, Mrs. E. Schwarzer and Mrs. M. Carter for their help in developing the plates, and Mr. Robert F. Smith for making the photomicrographs. We are indebted to Drs. S. J. Lindenbaum and L. C. L. Yuan for their aid and advice in exposures and to Drs. C. N. Yang and G. Snow for interesting discussions.

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Operation of a Glaser Bubble Chamber with Liquid Hydrogen

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GLASER has recently demonstrated that ionizing radiation can trigger violent boiling in highly superheated ether and pentane.[1] He has further shown that it is possible to photograph tracks of bubbles which mark the paths of ionizing particles passing through the liquid.

A bubble chamber using liquid hydrogen should prove useful for studying nuclear events involving protons. For example, it would provide a hydrogen target of greater density and purity than can be achieved in a cloud chamber.

In this letter we report preliminary experiments which strongly suggest that a useful liquid hydrogen bubble chamber can be realized. We have been able to produce superheated liquid hydrogen and to trigger its boiling with minimum ionization particles.

The apparatus is shown in Fig. 1. The chamber itself was a pyrex bulb which could be observed by eye through the unsilvered nitrogen and hydrogen Dewars. The bulb communicated through a pyrex capillary with input and exhaust hydrogen lines. The pressure was controlled by means of valves on these lines. The temperature of the bulb was controlled by a resistance wire heater which opposed the conduction cooling of the pyrex capillary whose lower end was at the temperature of the liquid hydrogen bath.

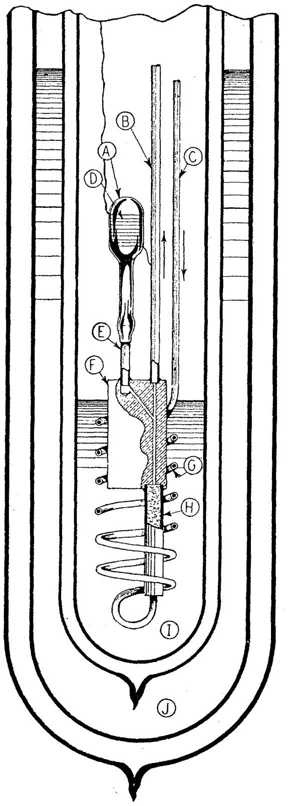

Fig. 1. Liquid hydrogen bubble chamber. *A*: Pyrex bulb. Volume 3 cm³. Inside diameter 12 mm. *B*: Exhaust tube. *C*: Input tube for purified hydrogen gas. *D*: 23-ohm heater wire wound on pyrex bulb. Operating current 80 milliamperes. *E*: Kovar tube. *F*: Copper block. *G*: Coil to condense incoming hydrogen. *H*: Glass wool trap to keep particles out of bulb. *I*: Liquid hydrogen bath. *J*: Liquid nitrogen jacket.

By controlling the temperature and pressure inside the bulb the chamber could be filled with liquid hydrogen in equilibrium with its vapor. Raising the pressure slightly would cause the vapor phase to disappear in the bulb. Thereafter, when the pressure was lowered well below the equilibrium vapor pressure the liquid could be kept in the bulb without boiling for considerable lengths of time.

The temperature was such that the liquid hydrogen was in equilibrium with its vapor at 3 atmospheres. In order to fill the bulb in a short time a filling pressure of $3\frac{2}{3}$ atmospheres was used. When the bulb was completely full the pressure was suddenly reduced from $3\frac{2}{3}$ to 1 atmosphere.

In the absence of radiation other than cosmic radiation the liquid hydrogen would remain superheated for periods up to 70 seconds before boiling. The average delay for 40 such expansions was 22 seconds. The boiling triggered immediately, however, when the bulb was exposed to a 15-millicurie Co^{60} source at a distance of 5 meters. Occasionally delays up to 2 seconds were observed but in nearly every one of 37 such expansions the delay was too short to be observed by eye.

Similar results were obtained with liquid nitrogen using higher temperatures and pressures.

The authors wish to thank Dr. Donald Glaser for his cooperation in planning this experiment. We are also much indebted to Dr. Lother Meyer for much advice and for assistance in operating the cryostat. Dr. Earl Long has been most generous in making the facilities of the Low Temperature Laboratory of the Institute for the Study of Metals available to us.

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Bromine Isotopes Produced by Carbon-Ion Bombardment of Copper*

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In addition to providing a novel means for the synthesis of transplutonium elements,[1] the accelerated carbon-ion beam of the Berkeley 60-inch cyclotron may also be used conveniently for the study of neutron-deficient nuclides, for it is a property of carbon-ion-induced transmutations in any but the lightest elements that the ratio of protons to neutrons added to the target nucleus is virtually always larger than unity.

The 60-inch cyclotron, which accelerates He^4 (+2) ions to ~40 Mev, should in theory produce C^{12} (+6) ions of ~120 Mev. However, unpublished experiments with G. B. Rossi and A. Ghiorso[2] have shown that the energy spread of the internal carbon ion beam is wide, a most probable energy being perhaps nearer to 90 than to 120 Mev. Beam currents measured through 1.5 mils of tantalum absorber, corresponding to the passage of ions with kinetic energies exceeding ~80 Mev, have averaged between 0.01 and 0.1 μa.

Copper foils have been bombarded in the carbon beam, and bromine chemical fractions subsequently isolated. Their decay curves showed two activities, with half-lives of 95±3 minutes and 36±2 minutes, as shown in Fig. 1. The first of these is to be identified with the 1.7-hour bromine isotope discovered by Woodward, McCown, and Pool,[3] and assigned by them to Br^{75}, on the basis

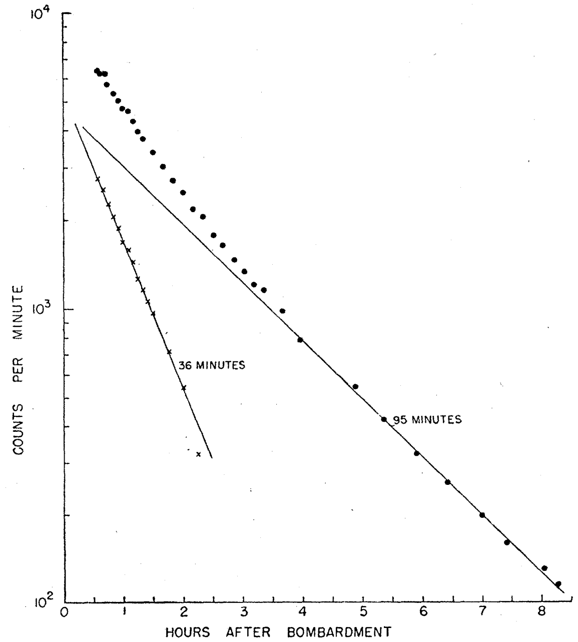

Fig. 1. Typical decay curve of bromine fraction from Cu+C^{12} bombardments.