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### Title

Excitation Function of the Reaction  $C^{12}(p,pn)C^{11}$  at High Energies

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EXCITATION FUNCTION OF THE REACTION  
 $C^{12}(p,pn)C^{11}$  AT HIGH ENERGIES

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Radiation Laboratory, Department of Physics

University of California, Berkeley

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November 3, 1947

Chupp and McMillan<sup>(1)</sup> have recently measured the excitation curve for

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(1) W. W. Chupp and E. M. McMillan, Phys. Rev., Nov. 1, 1947

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the reaction  $C^{12}(p,pn)C^{11}$  at high energies. Using the model of the nucleus described by Serber<sup>(2)</sup>, the excitation curve of the above reaction has been

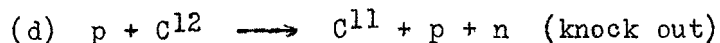
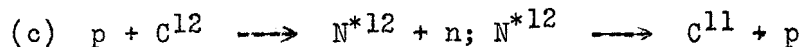
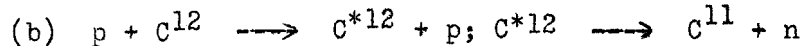
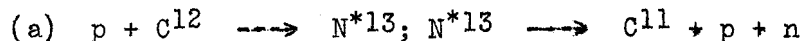
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(2) R. Serber, Phys. Rev., Dec. 1, 1947

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calculated for energies up to 100 Mev. The excitation of the nucleus is determined on the basis that the incident proton makes individual collisions with the nucleons, the transferred energy exciting the nucleus. n-p collisions are taken to be three times more probable than n-n or p-p collisions. Charge exchange is assumed. The calculations were made for both 50% and 100% charge exchange. The decay of the excited nucleus is treated by the usual evaporation mode.

On the above basis, the reaction can go in four ways:



The part played by each of these separate reactions to give the total reaction is shown in Fig. 1 for 50% charge exchange. Reaction (a) contributes

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chiefly in the 40 Mev region. This is the result (1) of the high probability in this region of the incident particle giving up all of its energy in a few collisions and thus of being captured; and (2) of the energy dependence of the  $N^{13} \rightarrow C^{11} + p + n$  reaction. Above the 40 Mev region there is an increased probability of boiling off three or more particles, and below the 40 Mev region, only one particle. Reaction (b) takes place when the incident proton passes through the nucleus and makes few collisions before emerging with most of its original energy. Because of the much greater probability of excited  $C^{12}$  breaking down into three  $\alpha$  particles, this reaction contributes very little to the total reaction. It does contribute somewhat more for 50% charge exchange since a one collision non-exchange process can then contribute. Reaction (c) is made possible by a net charge exchange taking place when the incident proton passes through the nucleus, so that it emerges as a neutron. Excited  $N^{12}$  is formed as the intermediate product. For small excitation energies ( $\sim 10$  Mev)  $N^{12}$  will definitely boil off one proton, but this probability rapidly drops off for higher excitation energies, because of competing processes coming into play. As a result of this only a single p-n exchange collision is effective in giving reaction (c), a two (or more) collision process leaving too much excitation energy. This results in making the reaction practically directly proportional to the amount of charge exchange, which, accordingly, exerts a direct influence on the yield of the total reaction at high energies. Reaction (d) is the knock out reaction. It is assumed that a knock out reaction can occur only if the nucleon struck by the incident particle travels from the point of collision to the outside of the nucleus, without colliding with other nucleons. Otherwise, the struck nucleon excites the nucleus by its collisions with the other nucleons and so stays in. The knock out reaction (d) is probable only if the incident proton makes just the one collision.

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The total reaction for both 50% and 100% charge exchange is plotted on a range scale in Fig. 2, assuming 140 Mev protons incident on a carbon block. The attenuation of the incident beam is taken into account. These curves may be compared to the experimental curve<sup>(1)</sup>, which is a straight line parallel to the abscissa from 140 to 60 Mev. The 50% charge exchange curve offers a slightly better fit.

The calculated cross section for the reaction at 62 Mev is:

.049 barns for 50% charge exchange

.064 barns for 100% charge exchange

The experimental value<sup>(3)</sup> is  $.067 \pm .007$  barns for 62 Mev incident protons.

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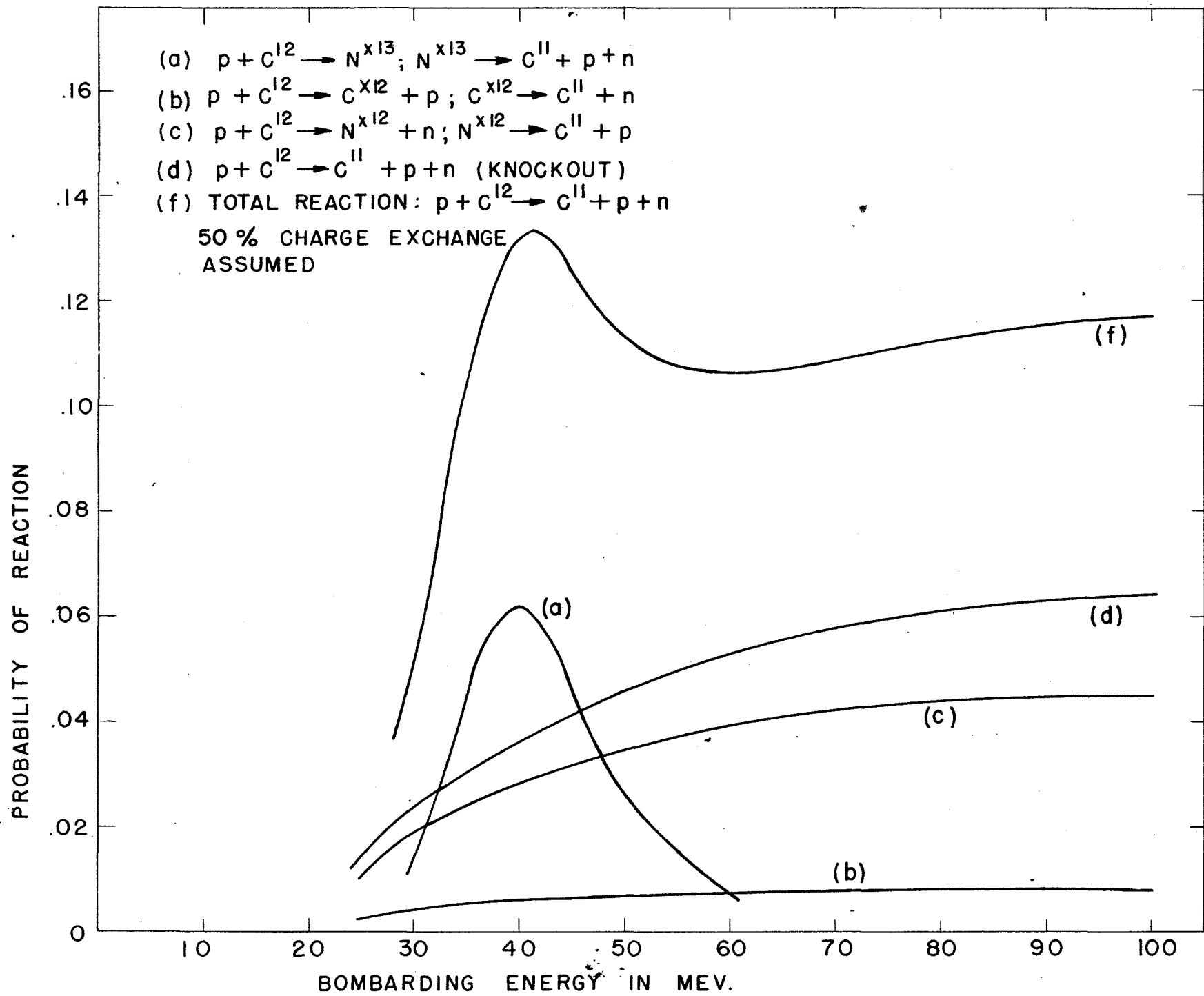
(3) E. M. McMillan and R. D. Miller, Phys Rev., to be published.

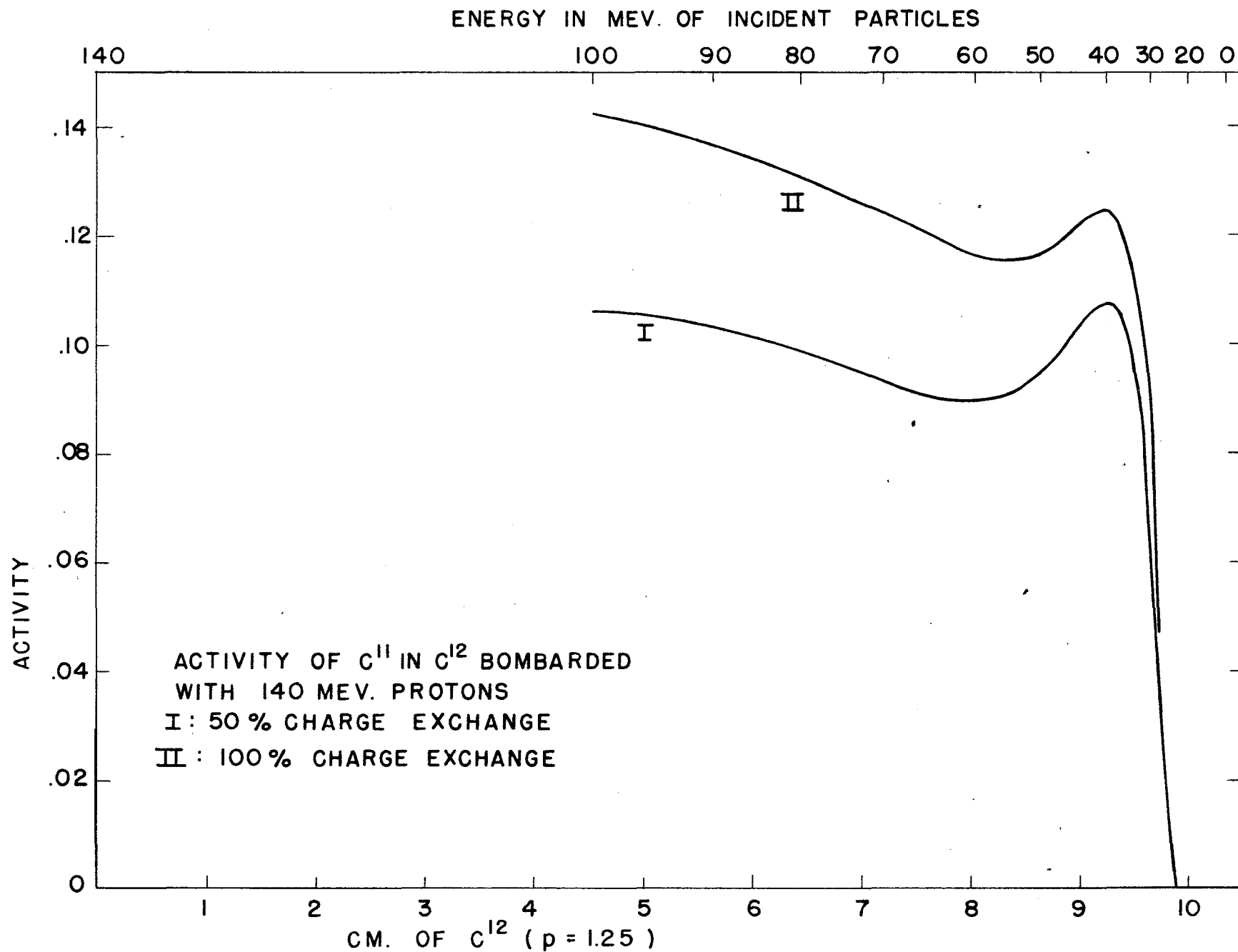
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