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SUMMARY OF THE RESEARCH PROGRESS MEETING OF MARCH 6, 1952

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April 8, 1952

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Berkeley, California
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I. Products of Carbon Disintegration by 330 Mev Protons. W. Barkas

Dr. Perlman of UCRL was interested in spallation products and so an experiment was undertaken by W. Barkas and J. K. Bowker to identify the fragments from targets bombarded by protons, using a nuclear emulsion detector. Since many of the fragments are stable nuclei they can not be detected by counting beta radiation and a mass spectrometer experiment is needed to determine what comes off. The schematics of the experiment is shown in Figure 1 as follows:

![Figure 1](image-url)

The diameter of the orbit was roughly two feet. A one mil polystyrene foil was exposed to 330 Mev protons and the spallation products were recorded on a photo emulsion plate. Then the radius of curvature and the track length were measured accurately. The estimated charge from the appearance of the track was
also recorded. The parameters were connected by the relationship

\[
\frac{Z^i (H \rho)}{A} = G \left( \frac{Z^2 R^*}{A} \right) \quad V > V_0
\]

where \( V_0 \) is the velocity at which an ion picks up electrons. \( Z^i \) is the charge carried by the ion in the magnetic field, \( H \) is the magnetic field, \( \rho \) is the radius of curvature, \( A \) is the atomic weight, \( Z \) is the atomic number, and \( G \) is a universal function. \( R^* \) is the reduced range calculated by comparison with the proton range. The difference between the true and reduced range as a function of the charge and mass is not yet known to any degree of certainty.

Figure 2 is a plot of \( \log \rho \) vs \( \log R \). The single charged particles are represented by dots, those with at least two units of charge by crosses and those estimated to have more than two units of charge by \( \Theta \). The points or particles, generally fall into easily distinguishable groups, which were then identified from the range-radius of curvature relationship as corresponding to certain nuclei as shown by the lines on the plot. However, several points which fell in certain areas could not be identified and were thought to be due to background or possibly to unidentified groups. These were: two points between the \( H^1 \) and \( H^2 \) lines, three points between the \( \text{He}^3 \) and \( \text{He}^4 \) lines and three points beyond the \( \text{He}^7 \) line in the short range portion. No single charged particles are found to the left of the \( \text{He}^3 \) line. Hence there is no evidence for the \( \text{He}^4 \) particle, though a representative line is shown for it. Also, \( \text{Be}^7 \) and a number of other nuclei should fit in the scheme somewhere but they have not yet been resolved. Too, no characteristic fragments with "hammers" were found for \( \text{Li}^8 \) or \( \text{B}^8 \).
A table of the percent abundance of each of the spallation products follows:

<table>
<thead>
<tr>
<th>Spall</th>
<th>% Abundance</th>
<th>Spall</th>
<th>% Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>H¹</td>
<td>25.0</td>
<td>He⁴</td>
<td>41.5</td>
</tr>
<tr>
<td>H²</td>
<td>7.4</td>
<td>Group (Li⁶, Be⁷)</td>
<td>3.3</td>
</tr>
<tr>
<td>H³</td>
<td>4.6</td>
<td>&quot; (Li⁷, He⁶, He⁷)</td>
<td>4.9</td>
</tr>
<tr>
<td>H³&gt;3</td>
<td>0</td>
<td>Li⁸, B⁸</td>
<td>0</td>
</tr>
<tr>
<td>He³</td>
<td>0</td>
<td>Other groups and background</td>
<td>6.2</td>
</tr>
<tr>
<td>He³</td>
<td>7.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It is significant to note that the abundance of He⁴ is as much as 41.5 percent of the total and that H¹ is 25 percent. The alpha and proton energy range is 9 or 10 Mev, giving about 50 microns range for the alpha particles. Range straggling increases at low range and hence resolution is not good in the short range groups. The additional straggling is calculated by

\[
\left\langle (\Delta R)^2 \right\rangle = 0.047 \ (R) \ (\text{microns})^2
\]

It is planned to run other experiments with Be and U targets and to compare the findings of the spallation products from different nuclei.

A brief report, UCRL-1702, has also been submitted on this experiment by W. H. Barkas and J. K. Bowker.

II. Stopping Power of Compounds for the 340 Mev Proton Beam, T. J. Thompson

The talk was based on an experiment for which an abstract report, UCRL-1555, has been submitted by T. J. Thompson; entitled "Effect of Chemical Structure on Stopping Powers for High Energy Protons". The abstract is quoted as follows:
"The stopping power of various organic compounds relative to copper is being measured for protons of mean energy 270 Mev. The compounds selected consist of C, H, N, O and Cl in various combinations so that possible structural effects on the stopping power may be observed. The sample thickness is selected so as to reduce the energy of the beam from 340 Mev to approximately 200 Mev. The remainder of the proton range is dissipated in copper absorbers of variable thickness. Ionization chambers before and behind the absorber column are used to obtain Bragg curves of absorber thickness vs. relative ionization in the usual manner. It is known that the stopping power of a compound is very nearly an additive function of the stopping power of the elements making up the compound. The relative stopping power at 270 Mev, while not strictly additive, is, in the cases tested additive within the accuracy of most nuclear experiments. There appears to be, however, a measurable deviation from additivity. Preliminary results, which must be further verified, indicate that unsaturated compounds (e.g. benzene) have slightly higher stopping power than would a mixture of graphite and saturated compound (e.g. cyclohexane) of the same atomic constitution. Details will be discussed. Experiments with other compounds and solutions and the liquid gasses are being carried out."

Information Division
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ANALYSIS OF CARBON SPALLATION PRODUCTS
(330 MEV PROTONS)

Fig. 2