EXCITED STATES OF C\textsuperscript{12} IN THE REGION 11 TO 14 MEV. FROM B\textsuperscript{11} (d, n) C\textsuperscript{12} REACTION

BY EVANI KONDAIAH

(Tata Institute of Fundamental Research, Bombay)

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JOHNSON\textsuperscript{1,2} reported a number of excited levels in C\textsuperscript{12} in the region 11 to 14 Mev. However, he did not use a separated B\textsuperscript{11} target. In the present study, a separated B\textsuperscript{11} target has been bombarded with 1 Mev. deuterons produced by the Cockcroft-Walton accelerator at the Australian National University in Canberra.\textsuperscript{3} 200 micron thick C\textsubscript{2} nuclear emulsion plates have been exposed to the outgoing neutrons at 0\degree and 90\degree to the deuteron beam direction. Similar exposure with a blank target has also been made. While scanning the plates, only such recoil proton tracks that made an angle not greater than 10\degree with the incident neutron direction have been chosen; hence, the errors caused by uncertainties in dip measurements are less than 2\%.

The data obtained has been statistically analysed as follows:

A polynomial regression of fifth degree, namely,

\[ Y = a + bX + cX^2 + dX^3 + eX^4 + fX^5 \]

has been fitted to the observed data.* In this equation, Y is the number of tracks to be expected at the energy X, if fifth degree polynomial were to fit the entire data. In most of the cases considered, the fifth degree polynomial is found to take into account mainly the basic downward trend of the observations. If a peak is present in the expected values, it is taken as indicative of genuine maximum provided the observed value at that energy is above this peak. Where there is no peak in the expected values, \( \chi^2 \) test is used to locate the peaks in the observed data. Applying the \( \chi^2 \) test, we find that some of the values in the observed data are decidedly higher than the corresponding expected values and have highly significant \( \chi^2 \) values. If these few significantly high \( \chi^2 \) values are struck off from the total \( \chi^2 \) values, the rest of the regression fits well by \( \chi^2 \) test. The conclusion, therefore, is that these few high values in the observed data represent the only energy ranges where maxima are seen to lie as far as the present data is concerned.

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* Refer to "Statistical Tables for Biological, Agricultural and Medical Research," by Fisher and Yates.
Excited States of $^{13}C$ in the Region 11 to 14 Mev.

**FIG. 1.** $^6$ (d, n) $^{13}C^*$ - $^0$* SPECTRUM
578 TRACKS

**FIG. 2.** $^6$ (d, n) $^{13}C$ - $^0$* SPECTRUM
878 TRACKS

Figs. 1-2
Figs. 1 and 2 show the neutron spectra at 0° and 90° respectively. The positions of the neutron peaks located by the above-mentioned statistical analysis are shown with arrows. In both the figures we see the neutron continuum due to three and four particle break up of the compound nucleus C\textsuperscript{13}. The neutron peaks corresponding to the different excited levels in C\textsuperscript{12} are seen superposed over this neutron continuum. The shaded portion at the bottom of the two figures shows the background.

### Table I

<table>
<thead>
<tr>
<th>(E\textsubscript{n})\textsuperscript{0°}</th>
<th>Q\textsubscript{0°}</th>
<th>(E\textsubscript{n})\textsuperscript{90°}</th>
<th>Q\textsubscript{90°}</th>
<th>Q\textsubscript{Average}</th>
<th>C\textsubscript{12}</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.85 ± 0.05</td>
<td>-0.13</td>
<td>0.6 ± 0.05</td>
<td>-0.18</td>
<td>-0.15</td>
<td>13.9 ± 0.1</td>
</tr>
<tr>
<td>1.05 ± 0.05</td>
<td>0.06</td>
<td>0.85 ± 0.05</td>
<td>0.09</td>
<td>0.08</td>
<td>13.6 ± 0.1</td>
</tr>
<tr>
<td>1.95 ± 0.05</td>
<td>0.95</td>
<td></td>
<td>...</td>
<td>...</td>
<td>12.9 ± 0.1</td>
</tr>
<tr>
<td>2.75 ± 0.05</td>
<td>1.77</td>
<td>2.25 ± 0.05</td>
<td>1.6</td>
<td>1.69</td>
<td>12.0 ± 0.1</td>
</tr>
</tbody>
</table>

Table I summarises the results obtained from this investigation. The Q values are calculated from

\[
Q_\theta = \frac{13}{12} \frac{E_n}{E_D} - \frac{1}{6} \sqrt{2} \frac{E_n E_D}{E_D} \cos \theta - \frac{5}{6} E_D,
\]

where \(\theta = 0^\circ\) or 90° as the case may be; \(E_n\) is the energy of the neutron peak and \(E_D\) is that of the bombarding deuteron beam. \(Q_{\text{ground}}\) is taken as 13.724 Mev.\(^2\)

The neutron peak corresponding to the 1.95 Mev. peak in the 0° spectrum should be situated at about 1.65 Mev. in the 90° spectrum. Though there is some rise in this region of the 90° spectrum, this does not appear to be significant in the statistical analysis.

I wish to express my thanks to Professors D. D. Kosambi and B. Peters for discussion. Mr. U. V. Ramamohan Rao's help in carrying out the statistical analysis is gratefully acknowledged. Part of this work was done during my stay at Canberra and I am thankful to Prof. E. W. Titterton for his kind co-operation.

### References

3. Titterton \(\ldots\) *Nuclonics*, 1952, 10, 28.