for the deeper potential with the reproduction of the
data being slightly improved upon that of previous
results using the 33 MeV optical model parameters.

It is expected that with the knowledge gained from
this work, a more detailed reaction mechanism and
nuclear structure study will ensue.

LIGHT ELEMENT NUCLEOSYNTHESIS

T.P. Walker and V.E. Viola
Indiana University Cyclotron Facility, Bloomington, Indiana 47405

G.J. Mathews
Lawrence Livermore National Laboratory, Livermore, California 94550

In order to examine the influence of new $^6$Li and
$^7$Li data reported elsewhere in this report on light
element nucleosynthesis via the galactic cosmic ray
(GCR) + instellar medium (ISM) mechanism,\(^1\) new
calculations have recently been performed using a
leaky-box model. This calculation includes cross
sections from a recent review of all data relevant to
Li, Be and B nucleosynthesis,\(^2\) as well as new abundance
tables for the interstellar medium and galactic cosmic
rays.\(^3\) In these calculations it is assumed that the
galactic lifetime is $10^{10}$ years and the cosmic ray mean
path for escape is $5 g/cm^2$. To examine the limits on
$^6$Li production established by the data, two assumptions
are included concerning the $(\alpha,pn)$ cross section above
200 MeV: (1) This cross section decreases
exponentially above 200 MeV and (2) a constant value of
3.4 mb is valid for all energies above 200 MeV. The
results of the calculation are given in Table I, where
they are compared with experimental abundances for Li,
Be and B isotopes taken from Ref. 4.

With respect to the absolute abundance of $^6$Li, the
calculations for both $\alpha + \alpha$ cross section assumptions
agree with the data within the limits of error. The
model calculations also give quite satisfactory
agreement with the observed elemental abundance ratios,
$^6$Li/$^9$Be and B/Li, well within the error factors for
these ratios. Hence, the present study reinforces
previous conclusions that $^6$Li, $^9$Be, $^{10}$B and $^{11}$B can be
well-accounted for by the GCR + ISM mechanism and

Table I
Lithium abundance ratios predicted by galactic cosmic ray + interstellar medium model. All abundances are
relative to $H = 10^{12}$ atoms. Parentheses indicate error
factors for experimental values.

<table>
<thead>
<tr>
<th></th>
<th>$^6$Li</th>
<th>$^7$Li</th>
<th>$^7$Li/$^6$Li</th>
<th>$^6$Li/$^9$Be</th>
<th>B/$^6$Li</th>
</tr>
</thead>
<tbody>
<tr>
<td>expt(^a)</td>
<td>90(2)</td>
<td>900(2)</td>
<td>12.6 ± 0.2</td>
<td>5.0(3)</td>
<td>2.2(3)</td>
</tr>
<tr>
<td>calc(^b)</td>
<td>110</td>
<td>160</td>
<td>1.4</td>
<td>7.3</td>
<td>2.3</td>
</tr>
<tr>
<td>calc(^c)</td>
<td>130</td>
<td>160</td>
<td>1.2</td>
<td>8.6</td>
<td>1.9</td>
</tr>
</tbody>
</table>

\(^a\) - Ref. 4; however, it has been proposed that the
primordial Li abundance may be significantly lower.
See Ref. 7.

\(^b\) - Assumes $\sigma(\alpha Li)$ decreases exponentially beyond 200
MeV.

\(^c\) - Assumes $\sigma(\alpha Li) = 3.4$ mb for all $E_\alpha > 200$ MeV.

\(^1\) J.D. Brown, W.P. Jones, D.W. Millet, H. Nann, P.M.
Lister, F. Khazaie, J.R. Comfort; IUCF Annual

\(^2\) F. Entexami, A.K. Bank, O. Karban, P.M. Lewis, S.
demonstrates that overproduction of $^6$Li by the $\alpha + \alpha$ reaction is not a serious problem for the model.

The inability of the GCR + ISM model to account for the well-established $^7$Li/$^6$Li ratio (Table I) has long been recognized. The results of the present measurement simply amplify this discrepancy. Since $^7$Li is also produced in big bang nucleosynthesis, the $^7$Li/$^6$Li isotopic ratio can be most easily understood in terms of a model in which the major source of $^7$Li is the big bang and that for $^6$Li is the GCR + ISM mechanism. In fact, using the standard model and a universal baryon density which reproduces the observed $^2$H, $^3$He and $^4$He abundances, cosmological nucleosynthesis calculations produce just that amount of $^7$Li required to yield the correct $^7$Li/$^6$Li ratio. Hence, the two models - cosmological nucleosynthesis in the big bang and GCR interactions with the ISM - can successfully account for all light element nucleosynthesis in a quantitative fashion.

An alternative interpretation of the failure of the GCR + ISM model to reproduce $^7$Li/$^6$Li is to demand - a priori - that the additional $^7$Li must come from the big bang. The salient variable in the calculation then becomes the baryon density of the universe. Using this approach, big bang calculations with the standard model require a baryon density $\rho_B \sim 5 \times 10^{-31}$ g/cm$^3$ to produce the required $^7$Li. This value is an order of magnitude lower than the critical density of the universe, implying the universe is open and will expand forever (assuming neutrinos have negligible mass).

Even more sensitive estimates of $\rho_B$, which partially account for effects due to galactic infall and astration, can be obtained by examining the ratio of $^7$Li to $^2$H, both of which exhibit a very sensitive dependence on $\rho_B$.