

HINTS FOR NEUTRINO-PROCESS BORON IN PRESOLAR SILICON CARBIDE GRAINS FROM SUPERNOVAE

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ABSTRACT

We have studied more than 1000 presolar silicon carbide (SiC) grains from the Murchison CM2 chondrite for C- and Si-isotopic compositions. Twelve SiC X grains, characterized by strong enrichments in ^{28}Si and believed to originate from Type II Supernovae (SNeII), were also measured for Li- and B-isotopic compositions. None of these grains show resolvable isotope anomalies in Li or B. For the seven X grains without Li and B contributions from nearby or attached SiC grains of distinct origins we find on average $^7\text{Li}/^6\text{Li} = 11.83 \pm 0.29$ (solar system: 12.06) and $^{11}\text{B}/^{10}\text{B} = 4.68 \pm 0.31$ (solar system: 4.03). The average $^7\text{Li}/^6\text{Li}$ is compatible with the solar system ratio and the lithium in the X grains is likely largely dominated by contaminating Li of laboratory or meteoritic origin. Also, most of the boron in X grains appears to be contamination but the small ^{11}B excess of $\sim 16\%$, significant at the 2σ level, can be considered a hint for the presence of boron produced by the neutrino process in the parent SNeII. Despite this finding, a quantitative comparison of the B isotope and abundance data of X grains with model predictions reveals deficiencies in our current understanding of the details of B production in SNeII as well as on B chemistry and condensation in SNII ejecta.

Key words: circumstellar matter – nuclear reactions, nucleosynthesis, abundances – supernovae: general

1. INTRODUCTION

Among the light and intermediate-mass elements Li, Be, and B are those with the lowest abundances (Lodders et al. 2009). This is because they are largely by-passed by standard stellar nucleosynthesis. Their production relies to a large extent on spallation reactions between high-energy (> 100 MeV) Galactic cosmic rays (GCRs), consisting mostly of protons and alpha-particles, and abundant target nuclei such as ^{12}C , ^{14}N , and ^{16}O in the interstellar medium (ISM). Predicted Li and B isotope ratios are $^7\text{Li}/^6\text{Li} \sim 1.4$ and $^{11}\text{B}/^{10}\text{B} = 2.5$ (Reeves 1994), significantly lower than the solar system ratios which are $^7\text{Li}/^6\text{Li} = 12.06$ (Seitz et al. 2007) and $^{11}\text{B}/^{10}\text{B} = 4.03$ (CI average; Zhai et al. 1996). It was proposed that Li, Be, and B can also be produced by spallation reactions between low-energy (MeV range) C and O nuclei and interstellar H in star-forming regions (Cassé et al. 1995). These reactions are predicted to result in a $\sim 2\times$ lower than solar $^7\text{Li}/^6\text{Li}$ ratio, i.e., in a shift in the same direction as with the standard GCR spallation scenario, but in a $\sim 1.5\times$ higher than solar $^{11}\text{B}/^{10}\text{B}$ ratio.

In massive stars, Li, Be, and B are largely destroyed during pre-main-sequence and main-sequence evolution but models predict production of significant amounts of ^7Li and ^{11}B by the ν -process and of ^{11}B also by α -capture on ^7Be and ^7Li in a later evolutionary phase when such stars explode as Type II supernovae (SNeII; Woosley & Weaver 1995; Rauscher et al. 2002; Yoshida et al. 2008). The predicted Li and B isotope ratios depend on a variety of stellar parameters, e.g., mass and neutrino temperature. Compared to their initial abundances at stellar birth, ^7Li will not change significantly but ^{11}B is expected to be heavily enriched in the ejecta. In the overall ejecta of the $15 M_{\odot}$ SNII model by Rauscher et al. (2002), the predicted $^7\text{Li}/^6\text{Li}$ and $^{11}\text{B}/^{10}\text{B}$ ratios are ~ 3000 and ~ 300 , respectively, i.e., much higher than the solar system ratios.

It is apparent that in order to account for the observed solar system Li and B isotope ratios, contributions from at least two sources are required. Here we will use so-called presolar grains

to get new insights into the production of the Li and B isotopes. Presolar grains are samples of stardust, nm to μm in size, that are found in small quantities in primitive meteorites (Lodders & Amari 2005; Zinner 2007; Hoppe 2008). These grains formed in the winds of evolved stars and in the ejecta of stellar explosions and their isotopic compositions can be used to get information on, e.g., stellar nucleosynthesis and evolution, Galactic chemical evolution, and grain processing in the ISM. Presolar grains exhibit large isotope anomalies (with respect to solar system abundances) not only in the major elements but also in a large number of minor and trace elements contained in the grains. Among the identified presolar minerals are silicon carbide (SiC), graphite, silicon nitride, refractory oxides, and silicates. Most of the presolar grains apparently are from 1 to $3 M_{\odot}$ asymptotic giant branch (AGB) stars but a noticeable fraction appears to come from SNeII. Among these grains are the so-called SiC X grains (Amari et al. 1992; Nittler et al. 1996; Hoppe et al. 2000) which comprise about 1% of all presolar SiC grains. The X grains show higher than solar $^{12}\text{C}/^{13}\text{C}$ (most grains), lower than solar $^{14}\text{N}/^{15}\text{N}$, and large excesses in ^{28}Si . They also carry the decay products of now extinct ^{26}Al (half-life $\sim 700,000$ yr), ^{44}Ti (half-life 60 yr), and possibly ^{49}V (half-life 330 days).

Li- and B-isotopic compositions have been measured in presolar SiC grains from AGB stars (Huss et al. 1997; Hoppe et al. 2001; Gyngard et al. 2007, 2009; Lyon et al. 2007). No B isotope anomalies could be identified in these studies; however, Gyngard et al. (2009) found large ^6Li enrichments of up to 30%, probably resulting from cosmic ray irradiation while the grains were traveling through interstellar space. From these enrichments cosmic ray exposure ages of between 40 and 1000 Myr were inferred. Lyon et al. (2007) developed a new separation method for isolating presolar SiC from meteorites that keeps surface alterations minimal. The authors found very high Li and B abundances in the outer layers of the SiC grains with Li/Si and B/Si ratios of up to $\sim 10^{-2}$; in the interior these ratios drop to $\sim 10^{-5}$. These results are interpreted as evidence of implantation of high-velocity Li and B ions into the grains by

shock waves as the grains traveled through star-forming regions some time after their condensation in the outflow of an AGB star that was their progenitor.

In addition to the studies on AGB star grains several SiC X grains were measured for B abundances and isotopic compositions by Hoppe et al. (2001). These authors found no B isotope anomalies within rather large uncertainties and B concentrations lower than expected in view of predicted B production in SNeII and condensation calculations. The close-to-normal B-isotopic compositions were likely the result of B laboratory contamination and the lower than expected B/Si ratios have been interpreted to reflect lower B production in SNeII than currently predicted and/or specific mixing conditions in the SN ejecta in which the X grains were formed. In this work we extend the study by Hoppe et al. (2001) in that we used the new generation NanoSIMS ion probe, which permits to make isotope studies with much better spatial resolution, thereby minimizing contributions from B contamination, and with higher precision than was possible with the conventional ion probe used in the study by Hoppe et al. (2001). Furthermore, we included Li isotope measurements in our study of X grains.

2. EXPERIMENTAL

The SiC grains of this study were separated from a 30 g sample of the Murchison CM2 meteorite (Besmehn & Hoppe 2003), following the technique of Amari et al. (1994). Thousands of SiC grains were transferred to several clean Au foils, one of which (sample “Muri7”) was used for the study presented here. Areas suitable for ion imaging (see below) were selected in the Leo 1530 field emission scanning electron microscope (SEM) at the Max Planck Institute for Chemistry in Mainz.

The SiC X grains were identified by ion imaging with the Cameca NanoSIMS 50 ion probe at Max Planck Institute for Chemistry (Gröner & Hoppe 2006). Prior to ion imaging the samples were cleaned by pre-sputtering $170 \times 170 \mu\text{m}^2$ sized areas for about 20 minutes with a Cs^+ ion beam of ~ 100 pA. The ion imaging consists essentially of three steps: (1) acquisition of ion images of $^{12}\text{C}^-$, $^{13}\text{C}^-$, $^{28}\text{Si}^-$, $^{29}\text{Si}^-$, and $^{30}\text{Si}^-$ in a multi-collection mode, produced by rastering (256×256 pixels, $15,000 \mu\text{s pixel}^{-1}$) a focused primary Cs^+ ion beam (~ 100 nm, ~ 1 pA) over $30 \times 30 \mu\text{m}^2$ sized areas on the Au foil; (2) recognition of SiC grains based on the ^{28}Si ion image and acquisition of ion images with size of two times the grain size around each identified grain with an integration time of 60 s; and (3) movement of the sample stage to the adjacent area and repetition with step (1). A total of 99 areas were analyzed in this way. All X grains were then documented in the SEM.

Except one grain, which could not be relocated in the NanoSIMS, all X grains were analyzed for Li- and B-isotopic compositions. For this purpose, $^6\text{Li}^+$, $^7\text{Li}^+$, $^{10}\text{B}^+$, $^{11}\text{B}^+$, and $^{28}\text{Si}^+$ ions, produced by rastering (64×64 pixels) an O^- primary ion beam (< 1 – 5 pA, 300 – 500 nm) over (2×2) to $(7 \times 7) \mu\text{m}^2$ sized areas around the grains, were measured in a multi-collection mode. Between 25 and 52 image planes were recorded for each grain. Prior to the isotope measurements the grains were cleaned by pre-sputtering with an ~ 100 pA O^- beam for 3–5 minutes.

Three different standards were used to infer the relative sensitivity factors (RSF) for Li/Si ($\varepsilon(\text{Li})/\varepsilon(\text{Si})$) and B/Si ($\varepsilon(\text{B})/\varepsilon(\text{Si})$), and the instrumental mass fractionation for Li and B isotope measurements: A NIST SRM611 glass wafer (485 ppm Li, 356 ppm B; Pearce et al. 1997), small ($\sim 1 \mu\text{m}$) SRM611 glass grains dispersed on a clean Au foil, and a synthetic SiC wafer doped with ^7Li and ^{11}B (with $^{7}\text{Li}/^{28}\text{Si} = 1.14 \times 10^{-4}$ and

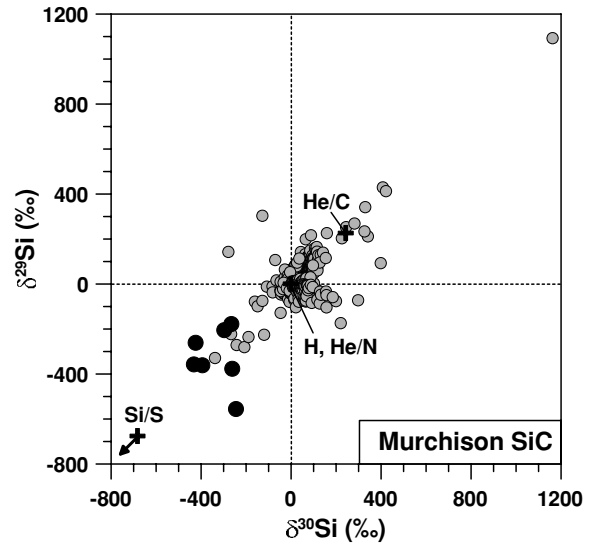


Figure 1. Silicon-isotopic compositions of presolar SiC grains in this study given as per mil deviation from the solar system $^{29}\text{Si}/^{28}\text{Si}$ and $^{30}\text{Si}/^{28}\text{Si}$ ratios. X grains without contributions from nearby SiC grains of distinct origins and analyzed for Li- and B-isotopic compositions are shown in black. The Si-isotopic compositions in the Si/S, He/C, He/N, and H zones of a $15 M_{\odot}$ SNeII (Rauscher et al. 2002) are shown for comparison.

$^{11}\text{B}/^{28}\text{Si} = 1.42 \times 10^{-4}$ at peak position; sample from Toray Research Center, Japan). The inferred B/Si RSF values for B/Si measured in the SRM611 glass wafer and the doped SiC gave essentially the same result with $\varepsilon(\text{B})/\varepsilon(\text{Si}) \sim 0.5$, i.e., there is no large matrix effect. Lithium in the SRM611 glass wafer turned out to be very heterogeneous and in most locations very low and no useful $\varepsilon(\text{Li})/\varepsilon(\text{Si})$ could be obtained; from measurements on the doped SiC standard we inferred $\varepsilon(\text{Li})/\varepsilon(\text{Si}) \sim 6$. Large differences are evident when the RSF values measured on the SRM611 glass wafer and grain mount are compared. The measurements on the grains gave $\varepsilon(\text{Li})/\varepsilon(\text{Si}) \sim 15$ and $\varepsilon(\text{B})/\varepsilon(\text{Si}) \sim 2$, about factors of 2.5 and 4 larger than those measured in the doped SiC and/or SRM611 glass wafer. Apparently, the Li/Si and B/Si ratios are very sensitive to topographic effects, probably due to the short distance between the sample and extraction lens in the NanoSIMS. The RSF values inferred from the SRM611 grain measurements were used to determine Li/Si and B/Si ratios in the X grains of this study. We note that the uncertainties on the Li/Si and B/Si ratios in X grains are at least a factor of two. Measured B isotope ratios in X grains were normalized to measurements on SRM611 ($^{11}\text{B}/^{10}\text{B} = 4.04$; Kasemann et al. 2001); measured $^{11}\text{B}^+/^{10}\text{B}^+$ ratios were the same in the SRM611 glass wafer and the grains within the measurement error of about 2%, i.e., topographic effects are largely negligible for B isotope measurements. Measured Li isotope ratios in X grains were normalized to measurements on Li contamination on the Muri7 sample mount and Li in the SRM611 grains (assumed to have the solar system $^7\text{Li}/^6\text{Li}$ of 12.06; Seitz et al. 2007) which showed identical $^7\text{Li}^+/^6\text{Li}^+$ ratios within the measurement error of 2%.

3. RESULTS AND DISCUSSION

By ion imaging, 1125 presolar SiC grains were identified. Based on their C- and Si-isotopic compositions (Figure 1), about 2% are AB grains, 85% mainstream grains, 4% Y grains, and 4% Z grains. Thirteen X grains were found (Table 1),

Table 1
C-, Si-, Li-, and B-isotopic Compositions of SiC X Grains from the Murchison Meteorite

Grain	Size (μm)	$^{12}\text{C}/^{13}\text{C}$	$\delta^{29}\text{Si}^a$ (‰)	$\delta^{30}\text{Si}^a$ (‰)	$^7\text{Li}/^6\text{Li}$	$^{11}\text{B}/^{10}\text{B}$	Li/Si (10^{-5})	B/Si (10^{-5})
Single X grains								
X1	0.6	114 ± 2	-178 ± 11	-265 ± 9	11.87 ± 0.63	4.51 ± 0.77	9.69	3.33
X2	1.2	128 ± 2	-377 ± 11	-261 ± 10	12.06 ± 0.62	5.06 ± 0.58	23.8	18.8
X3	1.5	244 ± 5	-205 ± 10	-297 ± 7	11.48 ± 0.86	4.54 ± 0.63	1.76	1.92
X4	1.0	241 ± 6	-556 ± 10	-245 ± 9	12.00 ± 0.56	4.85 ± 1.19	24.8	3.31
X9	0.6	38 ± 1	-361 ± 10	-394 ± 8	11.20 ± 1.01	4.19 ± 0.70	10.8	11.4
X11	0.8	326 ± 14	-358 ± 12	-432 ± 11	11.78 ± 2.03	4.99 ± 1.88	3.66	3.00
X13	0.7	345 ± 6	-261 ± 10	-424 ± 7	11.59 ± 0.93	4.37 ± 2.04	10.7	1.14
Average					11.83 ± 0.29	4.68 ± 0.31		
X grains + other nearby/attached SiC grains								
X5		34 ± 1	-226 ± 11	-120 ± 10	12.21 ± 0.41	4.36 ± 0.40	40.2	18.8
X6		88 ± 1	-236 ± 11	-189 ± 9	13.06 ± 1.36	3.83 ± 0.27	2.15	14.2
X7		78 ± 1	-281 ± 11	-208 ± 10	11.20 ± 2.40	11.47 ± 6.36	8.28	9.48
X8		76 ± 1	-223 ± 10	-266 ± 8	11.29 ± 0.64	4.27 ± 0.29	4.80	12.4
X12		83 ± 1	-271 ± 11	-242 ± 10	11.54 ± 0.52	4.13 ± 0.46	24.3	14.2
Average					11.90 ± 0.28	4.16 ± 0.17		
Solar		89	0	0	12.06	4.03	5.6	1.9

Note. $\delta^i\text{Si} = [(^i\text{Si}/^{28}\text{Si})/(^i\text{Si}/^{28}\text{Si})_{\odot} - 1] \times 1000$.

representing about 1% of all SiC grains. Some grains could not be unequivocally referred to one of these groups. These abundances are in line with previous studies (e.g., Nittler & Alexander 2003; Zinner et al. 2007; Hoppe et al. 2010). Following ion imaging all X grains were relocated in the SEM. Seven X grains turned out to be single grains with sizes between 0.6 and 1.5 μm (Table 1), the remaining grains comprise in fact at least two grains. The single grains have $^{12}\text{C}/^{13}\text{C}$ ratios between 38 and 345, with six of them having isotopically light C, $\delta^{29}\text{Si}$ from $-178‰$ to $-556‰$, and $\delta^{30}\text{Si}$ from $-245‰$ to $-432‰$. All Li and B isotope ratios of single X grains as well as of grain agglomerates (one agglomerate could not be relocated in the NanoSIMS for B and Li measurements) are solar within 1.2σ ($^7\text{Li}/^6\text{Li}$) and 1.8σ ($^{11}\text{B}/^{10}\text{B}$) (Figures 2 and 3). When averages (calculated by integrating the respective ion signals over all grains, errors are calculated from counting statistics) of the seven X grains are considered then $^7\text{Li}/^6\text{Li}$ is solar as well; for $^{11}\text{B}/^{10}\text{B}$, however, there is a small ^{11}B excess of $161‰ \pm 77‰$, i.e., the anomaly is about 2σ . For the single X grains, Li/Si ratios are $0.3\text{--}4.5 \times$ solar (median: $1.9 \times$), B/Si ratios are $0.6\text{--}10 \times$ solar (median: $1.7 \times$). These abundances bear systematic uncertainties of at least a factor of two (see above).

Elements like Mg and Ca are not expected to condense in large amounts into SiC (Hoppe et al. 2001). This is in agreement with measurements on SiC X grains that show strong depletions of these elements by 2–4 orders of magnitude relative to solar abundances (Hoppe et al. 2001). Because of its chemical similarity we would expect the same for Li. However, Li/Si ratios are around solar in the X grains of this study (Table 1), i.e., SN Li, expected to be strongly enriched in ^7Li (Figures 2 and 4), is likely to represent only a tiny fraction of measured Li. Since the other potential Li production scenarios, namely, spallation reactions, will result in strong enrichments in ^6Li (Figure 2), which is not observed, the conclusion is inevitable that the observed Li is dominated by laboratory or meteoritic contamination. This conclusion is in line with the measurements by Gyngard et al. (2009) on presolar SiC grains of likely AGB star origins. These authors observed large ^6Li enrichments which were interpreted

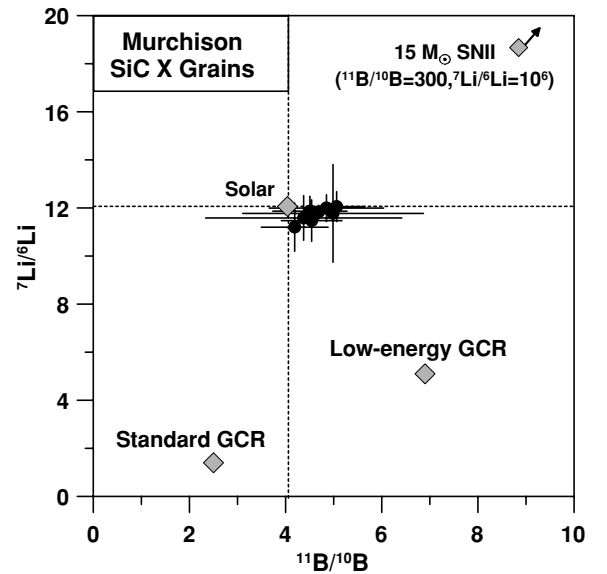


Figure 2. Li- and B-isotopic ratios in seven SiC X grains. Predictions for spallation-produced Li and B by GCR (Reeves 1994; Cassé et al. 1995) and for a $15 M_{\odot}$ SNII (Rauscher et al. 2002) with consideration of special mixing conditions (model s15a28c, relative mass fractions of selected SN zones: Si/S/He/C:He/N:H = 0.14%:36.6%:21.6%:41.6%) are shown for comparison.

to be the result of cosmic ray spallation reactions with exposure times between 40 and 1000 Myr. However, Li/Si ratios are about two to three orders of magnitude lower in the grains studied by Gyngard et al. (2009) than those in the X grains of this study. If we assume comparable exposure times then we must conclude that standard GCR-produced Li could have accounted only marginally to the Li in the X grains studied here. If we assume an extremely violent irradiation scenario around the SN parent stars, the contribution of spallation-produced Li might be higher. However, in a simple two-component mixing calculation, considering spallation-produced Li with $^7\text{Li}/^6\text{Li} =$

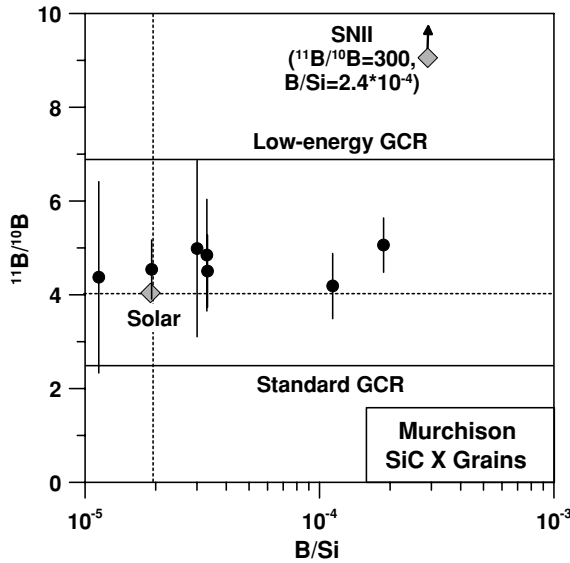


Figure 3. Boron-isotopic compositions as a function of B/Si ratios in SiC X grains. Predictions for GCR-produced B (Reeves 1994; Cassé et al. 1995) and B from a $15 M_{\odot}$ SNII (Rauscher et al. 2002) with consideration of specific mixing conditions (see the legend to Figure 2) are shown for comparison.

5 (by taking the higher value of the two spallation scenarios, ${}^7\text{Li}/{}^6\text{Li} \sim 1.5$ for standard GCR and 5 for low-energy GCR; Reeves 1994; Reedy 1989; Cassé et al. 1995) and Li contamination with ${}^7\text{Li}/{}^6\text{Li} = 12.06$, the contribution of spallogenic Li is limited to $\sim 4\%$ given the observed 2σ lower limit for the average ${}^7\text{Li}/{}^6\text{Li}$ ratio of 11.46 in our X grains. Here we included also the five X grains that are not single grains because AGB star grains, which would not have experienced the extreme irradiation, would contribute only negligibly to the overall Li. In this scenario, $\text{Li}_{\text{spal}}/\text{Si}$ is $\sim 10^{-6}$, about three orders of magnitude higher than what would be expected from standard GCR irradiation if spallogenic Li retention for grain sizes in the range of the X grains considered here is taken into account (Gyngard et al. 2009). We consider this as extremely unlikely and the contribution of spallogenic Li is likely much lower.

For B we are facing a different situation. Since irradiation production of Li and B will lead to $\text{B}/\text{Li} \sim 1$ (Reedy 1989; Cassé et al. 1995), like for Li, a contribution of spallogenic B to the overall B in X grains is likely to be negligible. However, based on the similarity of B and Al chemistry under equilibrium condensation conditions with $\text{C}/\text{O} > 1$ and observed Al abundances in X grains, Hoppe et al. (2001) argued that B abundances in X grains should roughly reflect B abundances at the condensation site in SNII ejecta. When matter from the different SNII zones (Meyer et al. 1995) is mixed in different proportions, then it is possible to reproduce many of the isotopic signatures of X grains (e.g., Hoppe et al. 2000; Lin et al. 2010). Typical mixing scenarios consider matter from the He/C, He/N, and H zones to account for observed C- and N-isotopic ratios and $\text{C}/\text{O} > 1$ and matter from the inner Si/S zone to account for the observed enrichments in ${}^{28}\text{Si}$ (cf. Figure 1). In Figure 4, we have plotted profiles of ${}^7\text{Li}$, ${}^{10}\text{B}$, ${}^{11}\text{B}$, ${}^{12}\text{C}$, ${}^{13}\text{C}$, and ${}^{28}\text{Si}$ in the interior of a $15 M_{\odot}$ SNII (Rauscher et al. 2002). As can be seen, B/Si ratios are high in the He/C (and O/C) zone and mixing scenarios that can reproduce the C, N, and Si isotope ratios of typical X grains have B/Si ratios on the order of 10^{-4} , about one order of magnitude higher than observed in the X grains of this study. This implies that the B condensation is not as efficient as predicted (Hoppe et al. 2001)

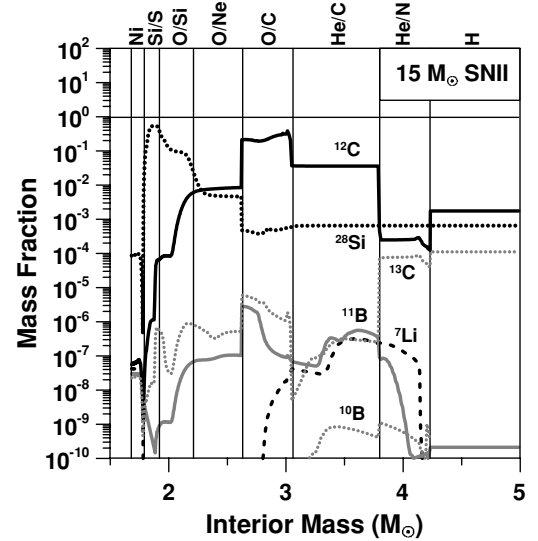


Figure 4. Profiles for mass fractions of selected isotopes in the interior of a $15 M_{\odot}$ SNII (model s15a28c; Rauscher et al. 2002). The different SN zones are indicated at the top.

or that the B production in SNII, to a large extent the result of ν -reactions (Woosley & Weaver 1995; Rauscher et al. 2002; Yoshida et al. 2008), is much lower than thought. Boron from SNII is expected to be heavily enriched in ${}^{11}\text{B}$. In order to account for the observed range of C- and Si-isotopic compositions of the X grains of this study material from the He/C, He/N, H, and Si/S zones must be mixed in variable proportions. Since B is dominated by B from the He/C zone (Figure 4), ${}^{11}\text{B}/{}^{10}\text{B}$ does not vary much in the different SN mixtures; for mixtures that can reproduce the C- and Si-isotopic signatures of our X grains, ${}^{11}\text{B}/{}^{10}\text{B}$ is always much larger than the solar ${}^{11}\text{B}/{}^{10}\text{B}$ ratio and varies by only a factor of 2.5. Because of this it is justified to treat the X grains together as a single B reservoir and to draw conclusions from the average ${}^{11}\text{B}/{}^{10}\text{B}$ ratio. For a typical X grain with ${}^{12}\text{C}/{}^{13}\text{C} = 200$ and $\delta^{29,30}\text{Si} = -330\text{‰}$, an SN mixing calculation, based on the $15 M_{\odot}$ SN model of Rauscher et al. (2002), gives ${}^{11}\text{B}/{}^{10}\text{B} \sim 300$ and $\text{B}/\text{Si} \sim 10^{-4}$ (scenario 1). Even if we assume that the ${}^{11}\text{B}$ production is 10 times less efficient than predicted then ${}^{11}\text{B}/{}^{10}\text{B}$ is still around 30 and $\text{B}/\text{Si} \sim 10^{-5}$ (scenario 2). These ${}^{11}\text{B}/{}^{10}\text{B}$ ratios are significantly higher than observed in the X grains of this study and we conclude that much of the observed B is contamination. With 12% (scenario 1) and, respectively, 14% (scenario 2) SN B (the percentages comprise the sum of ${}^{10}\text{B}$ and ${}^{11}\text{B}$) and the remainder B contamination, the observed ${}^{11}\text{B}/{}^{10}\text{B}$ in the X grains can be reproduced. In both scenarios, the fraction of B with SN origin has $\text{B}/\text{Si} \sim 10^{-6}$ which is one (scenario 2) or two (scenario 1) orders of magnitude lower than predicted for the SN mixtures. In any case, the small ${}^{11}\text{B}$ enrichments in X grains, significant at the 2σ level, i.e., with 95% confidence, give a first observational hint that SNeII are in fact a source of ${}^{11}\text{B}$. We also note, however, that the B isotope and abundance data reveal deficiencies in our current understanding of the details of B production in SNeII as well as on B chemistry and condensation in SNII ejecta. It is hoped that these issues will be addressed in improved models of the ν -process in SNeII and of dust condensation in SN ejecta.

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