Solar Wind Implantation Model for the Incorporation of ^{10}Be in Calcium Aluminum Inclusions

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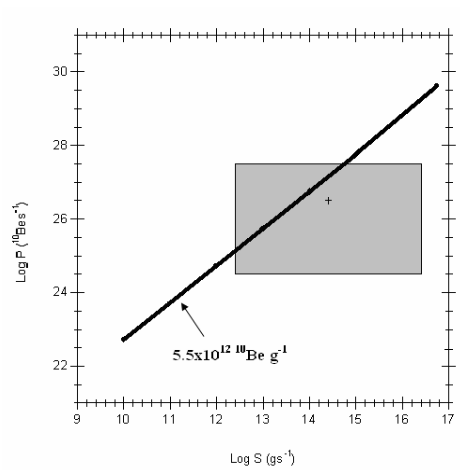
Introduction: Measurements of the decay products of now extinct radionuclides indicate that CAIs likely contained ^{10}Be at the time of their formation [1]. Since ^{10}Be is not formed nucleosynthetically [2], the presence of live ^{10}Be in CAIs at the time of formation seemingly requires the exposure of these materials to energetic particles.

There is yet another mechanism for incorporating ^{10}Be in solar system materials. It is known that ^{10}Be is currently produced in the atmosphere of the sun through the spallation of oxygen with energetic protons. This spallogenic ^{10}Be in entrained with the solar wind and implanted in solar system materials exposed to the solar wind. Nishiizumi & Caffee [3] detected solar-wind-implanted ^{10}Be in Apollo 17 trench samples. They calculated the current escape rate of ^{10}Be at the surface of the Sun to be 0.13±0.05 10Be $cm^{-2}s^{-1}$.

Model: We propose that the ^{10}Be incorporated into CAIs was created in the proto-solar atmosphere rather than in-situ in the CAIs (cf. Lee et al. [4], Gounelle et al. [5]) The production mechanism is the same that we observe now, bombardment of O by solar energetic protons and He nuclei. The production of ^{10}Be scales with energetic particle flux. This ^{10}Be escapes the proto-solar atmosphere entrained in the solar wind. Some fraction of this outward flowing ^{10}Be is incorporated into the inward flowing material which has dropped from the accretion funnel flow.In the region in which the inflowing material and outflowing solar wind intersect ^{10}Be is incorporated into the precursor CAI material.The fluctuating x-wind model of Shu et al. [6,7,& 8] provides the basic framework for incorporation of ^{10}Be into CAI-precursor materials and the subsequent transportation of these implanted refractory materials to asteroidal distances.

We find the rate at which this refractory material is carried into the x-region,called here the refractory mass inflow rate, S, is $2.5x10^{14}$ g s^{-1}. The modern production rate at the surface of the the sun of ^{10}Be is $8.0±3.0×10^{21}$ s^{-1}. We scale modern spallation ^{10}Be production to ancient energetic particle fluxes .The ancient production rate $3.2±1.2x10^{27}s^{-1}$, corresponding to an increase of $\sim 4x10^5$ over contemporary levels (cf. [9]) Some fraction of this ancient ^{10}Be, called here the effective outflow rate, P, is incorporated into CAI material.

Results: The concentration of ^{10}Be found in refractory rock predicted by our model is given by $\frac{P}{S}$ .For stated values of S and P above, we predict the concentration of ^{10}Be to be $1.3×10^{12}±0.5×10^{12}$ g^{-1}. McKeegan et al. [1] report a ratio of $^{10}Be/^{9}Be=9.5×10^{-4}$ in CAIs from Allende. Assuming a concentration of 100 ppb as an order of magnitude estimate for Be, the corresponding ^{10}Be concentration in CAIs is $5.5×10^{12}$ g^{-1}. Plotted below in the figure is the logarithm of the effective ^{10}Be outflow rate in the x-region vs. logarithm of the refractory material inflow rate. The model point + represents predicted ^{10}Be concentrations in CAIs of $1.3x10^{12}$ g^{-1} and gray region indicate a range of plausible values for these parameters. We also plot the set of log P and log S which would lead to the canonical ^{10}Be content in CAIs of $5.5x10^{12}$ ^{10}Be g^{-1}, represented by the line.



Conclusions: Predictions made here with the implantation model are consistent with measurements of ^{10}Be in CAIs.

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