ISOTOPICALLY ANOMALOUS Ti IN PRESOLAR SiC FROM THE MURCHISON METEORITE

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ABSTRACT

The Ti isotopic compositions of 14 large (8–23 μm) interstellar SiC grains from the Murchison meteorite have been measured. Three SiC grains with normal isotopic compositions of C, N, and Si also have normal Ti but the other 11 grains with anomalous C, N, and Si-isotopic compositions also have anomalous Ti. The anomalous Ti qualitatively bears the signature of neutron-capture nucleosynthesis with excesses in the minor isotopes 46Ti, 47Ti, 49Ti, and 50Ti, relative to the major isotope 48Ti. The anomalies range in magnitude up to 15% for 46Ti and 50Ti with smaller anomalies at 47Ti and 49Ti relative to 48Ti when normalized to the solar abundances. The Si- and Ti-isotopic compositions are correlated in the sense that the grains with the largest 50Ti excesses have the largest 28Si excesses. While the anomalies are qualitatively consistent with the patterns predicted by n-capture nucleosynthesis, the correlations between anomalies in different isotopes differ substantially from predictions for the He-burning shell of AGB stars and core He-burning in massive stars. However, uncertainties in n-capture cross sections are large and require refinement before a full evaluation of the predictions for nucleosynthesis in proposed stellar sources can be made.

Subject headings: abundances — interstellar: matter — meteors and meteorites — nucleosynthesis

1. INTRODUCTION

Variations in the isotopic compositions of Fe-peak elements are commonly found in refractory inclusions composed of Ca, Al, Mg, and Ti oxides (CAIs, for Ca, Al-rich inclusions). Of these elements, Ti has been the most frequently measured and anomalies have been resolved in almost every inclusion analyzed so far. Most CAIs from the Allende CV3 meteorite have excesses in 50Ti of ~1 part per thousand (permil, ‰) with anomalies in the other minor isotopes generally not clearly resolved. In the rare FUN inclusions (with mass-independent fractionation and unknown nuclear isotopic effects) excesses up to 3.5‰ and deficits of 5.1‰ have been measured in 50Ti and effects in 47Ti and 49Ti are well resolved after normalization to the 46Ti/48Ti ratio (Niederer, Papasterassiou, & Wassenburg 1981). The largest 50Ti anomalies are found in single hibonite crystals from CM2 meteorites such as Murchison and Murray and range in size from ~70‰ to ~273‰ (Hinton, Davis, & Scatena-Wachsel 1987; Ireland 1990). 50Ti anomalies and correlated anomalies in 48Ca, 54Cr and 64Ni have been taken as evidence of n-rich equilibrium nucleosynthesis and the pattern of excesses in these isotopes has been found to match to a remarkable degree the predictions of the multiple-zone-mixing (MZM) model of Hartmann, Woosley, & El Eid (1985) for nucleosynthesis in n-rich supernova ejecta. The recent isolation and isotopic characterization of interstellar SiC from primitive meteorites offers the possibility of finding Ti with a distinctly different nucleosynthetic signature. SiC from Murchison, originally isolated as the carrier of Xe-S and Ne-E(H) (Tang & Anders 1988), has been found to have 13C excesses, 15N deficits, and fossil 26Mg from the decay of 26Al, which are characteristics of H-burning nucleosynthesis in the CNO cycle; however, Ne, Kr, Xe, Ba, and Nd bear the signature of s-process nucleosynthesis (Zinner, Tang, & Anders 1989; Lewis, Amari, & Anders 1990; Ott & Begemann 1990; Zinner, Amari, & Lewis 1991b; Zinner et al. 1991a). Si-isotopic abundances also have a neutron-capture-type signature with enrichments of 28Si and 30Si relative to 26Si (Tang et al. 1989; Zinner, Tang, & Anders 1989; Alexander et al. 1990; Stone et al. 1990), but this general pattern can also be produced by hydrostatic burning of C, Ne, and Si (Arnett & Thielemann 1985; Thielemann & Arnett 1985) and by explosive burning of He, C, and Ne (Woosley 1986). The Kr-isotopic compositions in different size fractions of SiC (Lewis et al. 1990) have been successfully modeled by Gallino et al. (1990) who considered the s-process in the He-burning shell of AGB stars to be responsible for the observed variations. The L separation series of Murchison (Amari, Lewis & Anders 1991a) yielded a significant number of unusually large interstellar SiC crystals and thus offered the unprecedented opportunity to measure the isotopic compositions of many elements in individual grains. A detailed account of this work is given elsewhere (Virag et al. 1991); here we report Ti-isotopic measurements on a selected subset of the grains. Preliminary results of this work were presented at the 22d Lunar and Planetary Science Conference (Ireland, Zinner, & Amari 1991).

2. EXPERIMENTAL TECHNIQUES

Fourteen large (8–23 μm) individual SiC grains from separate LU of the Murchison CM2 meteorite (Wopenka et al. 1989) were analyzed for their Ti-isotopic compositions with the Sensitive High mass-Resolution Ion MicroProbe (SHRIMP) at the ANU according to the technique described by Ireland (1988). These grains had been characterized previously with a modified Cameca IMS-3f ion microprobe at Washington University for their C-, N-, and Si-isotopic compositions (Virag et al. 1991); Ti as well as other trace-element concentrations had also been measured in some of the grains. The Ti concentrations are generally low, less than 100 ppm, but some grains have Ti concentrations up to several thousand ppm (see Table 1, which also lists the C-, N-, and Si-isotopic compositions of