

TELLURIUM ISOTOPE ANOMALY IN ACID RESISTANT FRACTION OF ALLENDE METEORITE

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Introduction: Primitive chondrites with petrologic types of 3 or less provide key information regarding the timing and processes of the solar system formation. Nucleosynthetic isotope anomalies found in primitive chondrites also give clues for understanding the origin of materials from which our solar system has formed.

Tellurium is an intriguing element for the study of nucleosynthetic isotope anomalies in meteorites. Tellurium has eight stable isotopes produced by stellar nucleosynthesis of the p-process (¹²⁰Te), s-process (^{122,123,124,125,126}Te) and r-process (^{125,126,128,130}Te). However, no resolvable Te isotope anomalies are reported for bulk chondrites, sulfide and metal fractions of iron meteorites, and acid leachates of carbonaceous chondrites [1, 2]. Small potential nucleosynthetic Te isotope anomalies are found in Allende CAIs, although further verification is needed to exclude the possibility of analytical artifact [2]. The largest nucleosynthetic Te isotopic anomalies hitherto obtained are in presolar nanodiamonds from the Allende meteorite [3, 4].

In our previous study, we have reported Te isotope compositions in acid leachates from three carbonaceous chondrites, Murchison (CM2), Allende (CV3) and Tagish Lake (C2-ung) [5]. There were no Te isotopic anomalies in these leaching samples, except for the acid resistant fraction of Allende. However, the cause of the isotope anomaly in the residue was not clear. In this study, to obtain further precise Te isotope data, approximately 10 g of samples were newly used for Te isotope analysis. We discuss the results of these Te isotope measurements, in particular, the Te isotope composition in acid resistant fraction of the Allende.

Experimental: Approximately 10 g of powdered Allende (CV3), Murchison (CM2) and Tagish Lake (C2, ung.) were subjected to the sequential acid leaching procedure based on [6]. In this study, we took an additional step (step 7) to completely decompose the residue that survived in the six leaching steps. The details of the steps are given in [5]. All the sample solutions obtained in the steps 1-7 were subjected to the Te purification via three-step column chemistry. Te isotope measurements were carried out by thermal ionization mass spectrometry in negative ion mode (TRITON *plus* at Tokyo Institute of Technology, ThermoFisher Scientific). The detail of the chemical separation and mass spectrometry is described in [7].

Results and Discussion: With the exception for the step 7 of Allende, all the acid leaching samples from Allende, Murchison, and Tagish Lake had identi-

cal isotope compositions to the terrestrial standard within the analytical uncertainties as with our previous experiment using 1g of samples. Such characteristics of Te isotope compositions in acid leachates for Allende and Murchison are essentially the same as the previous study that used the same meteorite [1]. In addition to Allende and Murchison, even acid leachates and residue for Tagish Lake, a meteorite which has higher presolar grain abundances relative to Allende and Murchison, displayed no Te isotope anomalies. The results imply that these meteorites do not possess internal Te isotope anomalies of nucleosynthetic origin that preserved in presolar grains.

For the Allende step7, a negative anomaly of $\delta^{130}\text{Te}$ was observed when the $^{124}\text{Te}/^{128}\text{Te}$ ratio was used as the normalization parameter to correct for the mass fractionation during TIMS analysis. Interestingly, no isotope anomalies were observed on the Te isotope composition of the Allende step 7 when mass fractionation was corrected by the isotope pairs of $^{122}\text{Te}/^{124}\text{Te}$, $^{122}\text{Te}/^{123}\text{Te}$, $^{123}\text{Te}/^{124}\text{Te}$, and $^{126}\text{Te}/^{125}\text{Te}$. The inconsistency is presumably caused by relatively large analytical uncertainties in cases of when mass fractionation was normalized by the isotope pairs of $^{122}\text{Te}/^{124}\text{Te}$, $^{122}\text{Te}/^{123}\text{Te}$, $^{123}\text{Te}/^{124}\text{Te}$, and $^{126}\text{Te}/^{125}\text{Te}$, implying that it was impossible to distinguish the $\delta^{128}\text{Te}$ and $\delta^{130}\text{Te}$ values of the Allende step 7 from the terrestrial values.

To evaluate whether the isotopic composition in the acid residue of Allende really has an anomalous $^{130}\text{Te}/^{128}\text{Te}$ ratio, we performed mixing calculations to reproduce the observed Te isotopic pattern for the Allende step 7. The Te isotope patterns were calculated by mixing the terrestrial component and the component which has an anomalous Te isotope composition in various mixing ratios. In these calculations, we need to evaluate the effect of mass fractionation during TIMS analysis. The mass fractionation in mass spectrometer can be described by the exponential law as described below;

$$\left(\frac{{}^m\text{Te}}{{}^n\text{Te}} \right)_{\text{meas}} = \left(\frac{{}^m\text{Te}}{{}^n\text{Te}} \right)_{\text{ture}} \left(\frac{M_m}{M_n} \right)^f$$

where m and n represent the mass numbers, M_m and M_n represent the mass of ${}^m\text{Te}$ and ${}^n\text{Te}$, respectively, and f represents the mass fractionation factor (e.g., [8]). Because the magnitude of the fractionation for samples cannot be uniquely fixed, the Te isotope compositions were calculated by assuming various mass fractiona-

tion factors ranging from -0.3 to 0.3, the range that was observed in terrestrial standard measurements.

Fig. 1 shows the synthetic isotope patterns and Te isotope composition in the step 7 of Allende. Incorporation of 0.02 % of the s-process component calculated by [9] (Fig.1 (i)) cannot reproduce the Te isotope pattern of the Allende step 7, especially for ^{125}Te . The Te composition of the Allende step 7 can be explained either by ii) depletion of r-process component calculated in [4], or by iii) mixing of an anomalous Te composition in nanodiamond reported by [3]. With the analytical uncertainties of the measurement in this study, it is impossible to distinguish which component actually caused the observed Te isotope anomaly in the Allende step 7. However, the isotope pattern of (ii) would be plausible for reproduction of the isotope composition in the Allende step 7. To discriminate the difference between ii) and iii), further precise analysis is needed, such as using the double spike method.

The origin of nanodiamonds in carbonaceous chondrites remains controversial. Presolar isotopic signatures in nanodiamonds are reported for Xe and Te, which suggest supernovae for their origin [3, 10]. However, some studies have argued that the majority of nanodiamonds are of solar origin [11, 12]. For the study of nanodiamond fractions separated from Murchison, small amount of SiC were contained in the nanodiamond fractions [13]. Yokoyama et al. (2007) reported small, but resolvable enrichment in s-process Os isotopes in the nanodiamond fractions from Allende. [14] However, those Os isotope anomalies could be explained by the mixing of the presolar SiC and terrestrial components. For the diamond fraction from Allende, Pt isotope anomalies seem to be consistent with the neutron burst model [15] for the origin of heavy trace elements in the diamonds [16].

For the results of the step 7 of Murchison and Tagish Lake, the absence of Te isotope anomalies indicates that anomalous Te was lost from presolar SiC grains, although the SiC grains are strongly acid resistant. Thus, it is clear that the carrier of Te isotope anomalies in the Allende step 7 is not presolar SiC grains. If nanodiamonds truly carry anomalous Te and Xe isotope compositions but not for Os and Sr, the difference would be caused by the difference of volatility of individual elements. A likely scenario for the Xe isotope anomalies in nanodiamonds is the ion implantation from a supernova into the structure of nanodiamonds [11]. If this is the case, the ion implantation occurs only for volatile elements. Further research is needed to analyze precise isotope compositions in nanodiamonds for volatile and moderately volatile elements such as Zn, Sn, and Se.

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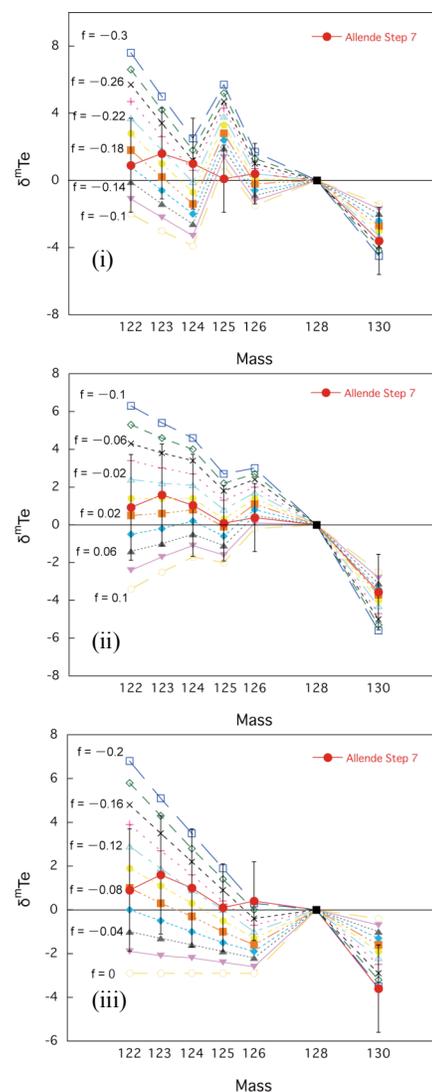


Fig. 1. The Te isotope ratios of the step 7 of Allende and the synthetic isotope pattern.