

EFFECT OF THERMAL METAMORPHISM ON NOBLE GAS OF CARBONACEOUS CHONDRITES: COMPARISON OF VIGARANO (CV3) AND MARALINGA (CK4). J. Choi^{1,2*}, K. Nagao¹, J. M. Baek¹, and J. I. Lee^{1,2}, ¹Korea Polar Research Institute, 26 Songdomirae-ro, Yeonsu-gu, Incheon 21990, South Korea, ²University of Science and Technology, 217 Gajeong-ro, Yuseong-gu, Daejeon 34113, South Korea. (*jisu@kopri.re.kr)

Introduction: Noble gas isotopic and elemental compositions of meteorites are result of formation and evolution processes of solar system. Primitive chondrites have various components of noble gases such as HL, G, and N from presolar grains, Q gas, solar gas, and in-situ components like radiogenic, fissionogenic, and cosmogenic noble gases. Otherwise, metamorphosed chondrites lost their gases during thermal event, and most of noble gases including gases of presolar grains were disappeared at that time. Subsolar component is primordial noble gas that can be seen in some chondrites including metamorphosed ones [1-7]. It constrains formation process of parent body of meteorites affected by solar gases from Sun [4,5]. Example is enstatite chondrite whose noble gas component is represented as subsolar [6,7]. In carbonaceous chondrites, it is not well studied because it is not a major component unlike that in enstatite chondrites.

We present noble gas compositions of Vigarano CV3 and Maralinga CK4 chondrites. Maralinga has 50:50 chondrules to matrix ratio similar with reduced CV3 chondrites [8]. In this study, changes of noble gas composition resulted from thermal metamorphism are discussed by comparing noble gases of the two carbonaceous chondrites.

Experimental method: Noble gas abundances and isotopic ratios of Vigarano and Maralinga were measured with modified VG-5400 at Korea Polar Research Institute (KOPRI). Bulk samples weighing 22.34 mg of Vigarano and 313.5 mg of Maralinga were prepared for stepwise heating analyses from 400°C to 1800°C per increasing 100°C step. 500 and 1700°C steps of Maralinga were skipped. Released gases were purified by two Ti-Zr getters and two SAES getters before introducing them into the mass spectrometer. All-noble gases were measured, and blank levels were lower than 1% of released noble gases of each heating step except 500 and 1800°C of Vigarano. 1800°C step of Vigarano is not presented as abundance of it is comparable with blank level in all noble gases.

Results and discussion: Cosmogenic component of Xe in Vigarano and Maralinga is neglected in this study. Proportion of cosmogenic ¹³⁰Xe and ¹³²Xe is 0.3 and 0.04 percent of total ¹³⁰Xe and ¹³²Xe of Maralinga. In case of Vigarano, it is much smaller than that of Maralinga due to its high abundance of trapped components.

Xe isotopic ratios and elemental ratios of trapped heavy noble gases. Fig. 1 is a plot of ¹³⁰Xe/¹³²Xe vs. ¹³⁶Xe/¹³²Xe of Vigarano and Maralinga. Xe of low heating steps of both samples is affected by Earth atmosphere, as clearly indicated in step 4 of Vigarano and steps 4-8 of Maralinga. Weathering of Maralinga was classified as Bx, indicating moderate degree of weathering with presence of carbonates derived from the local country rock [8]. Several steps of Maralinga showing atmospheric isotopic ratio coincides with observation of terrestrial weathering. It is also can be seen in Fig. 2. Steps 4-10 of Maralinga show elementally fractionated air. Higher heating steps of Maralinga tend toward Q. Xe isotopic ratios of those steps are plotted between Q-HL-fission derived Xe with ¹³⁶Xe/¹³²Xe as 0.33-0.34 (Fig. 1). Xe isotope distribution of Maralinga (Fig. 1) represents that Xe-Q and Xe-HL are released together, and it is suggested that re trapping of HL gas on phase Q during thermal metamorphism [9]. Whereas ¹³⁶Xe/¹³²Xe of Vigarano ranges 0.32-0.39, and presolar diamond of Vigarano containing HL was separated by [15]. Heavy elements are less elementally fractionated from solar gases in steps 10-13 of Vigarano on Fig. 2, though Xe isotopic ratios of those steps are not different from Q for 11-13 steps, same with previous studies [5,7].

Release pattern of primordial ¹³²Xe. Fig. 3 is released pattern of primordial ¹³²Xe of Vigarano and Maralinga. Primordial Xe is calculated by subtracting atmospheric contamination and fission derived Xe, and includes Q, subsolar, and HL. Release pattern of Vigarano has peaks at 1100 and 1300°C, and it is due to different release temperature of Xe-Q and Xe-subsolar. Subsolar is abundant in first peak, but Q is released mostly in second peak based on elemental ratio of heavy noble gases (Fig. 2). On the other hand, only one peak is observed for Maralinga. It is accordant to Xe isotopic ratios of Maralinga discussed above. Release of primordial ¹³²Xe of Maralinga starts from 800°C step. Maralinga was experienced less than 700-800°C during thermal metamorphism. This is comparable with mineralogical study of CK chondrite [11]. Low abundance of released gas of Maralinga is due to diffusive loss from carriers and destruction of carrier phases such as presolar grains during the thermal metamorphism [9]. Formation environment of chondrites could affect carrier phase of noble gases, e.g., absence of presolar graphite in CV chondrites [12]. However, it

is unclear that how highly oxidized condition of CK chondrites [11] affect noble gas composition and carrier phase of Maralinga.

Subsolar gas. It was reported that subsolar gas is also in LL, CO, and CV chondrites not only in enstatite chondrite [1-3,6], and isotopic ratio of subsolar gas is similar with Q gas [5, 7]. In this study, Vigarano has subsolar gas and its Xe isotope ratios are indistinguishable with Q gas. For Maralinga, however, there is no saying whether it has subsolar gas or not, and also it had subsolar gas or not before thermal metamorphism. Only a window to see it is elemental ratio of heavy noble gases because isotopic ratio cannot separate Q gas and subsolar gas. Elemental ratios of steps 13-18 of Maralinga is in the range of Q gas observed for CO and CV, which have 80-110 of $^{36}\text{Ar}/^{132}\text{Xe}$ and 0.9-1.2 of $^{84}\text{Kr}/^{132}\text{Xe}$ [13 and references there in], and released gases of those steps are mostly from Q modified after thermal metamorphism. Thermal metamorphism can affect two different ways to heavy noble gases of Maralinga; 1) depleting Ar and Kr relative to Xe as increasing metamorphic grade and 2) addition of other component, e.g. subsolar gas in Q of enstatite chondrite [9,10]. If only the depleting of light noble gases is considered, Q of Maralinga before modification by the metamorphism should have higher elemental ratios of heavy noble gases than the measured values of 13-18 steps. Trapping of nebula gases was suggested for higher heavy elemental ratios of Q of CV and CO chondrites than those of CI and CM chondrites [9].

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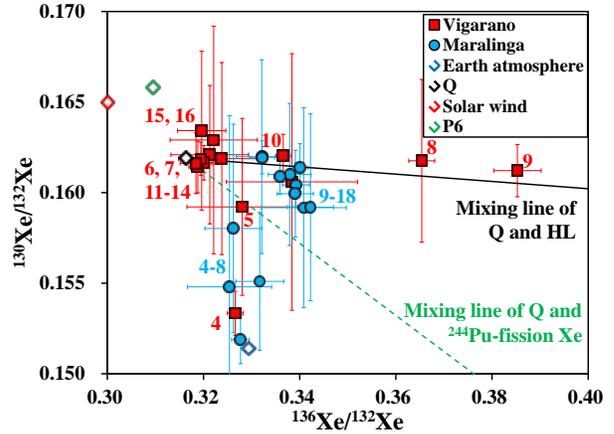


Fig. 1. $^{130}\text{Xe}/^{132}\text{Xe}$ vs. $^{136}\text{Xe}/^{132}\text{Xe}$ ratios of Vigarano and Maralinga. Temperature steps in 100°C are provided besides the plots. References: Q [13], solar wind [14], and P6 [15]. Mixing line of Q-HL [15] and Q-Pu fission [16] are also shown for comparison.

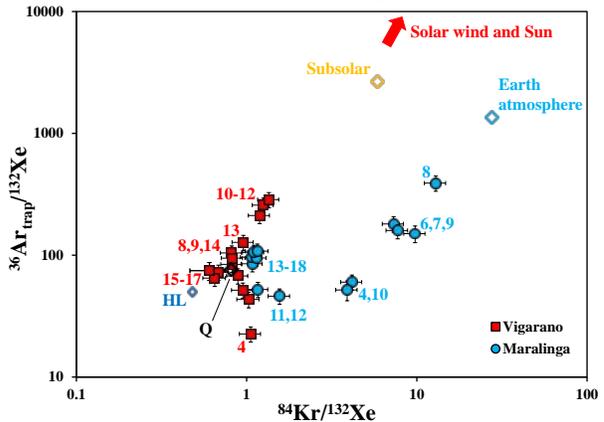


Fig. 2. $^{36}\text{Ar}_{\text{trap}}/^{132}\text{Xe}$ vs. $^{84}\text{Kr}/^{132}\text{Xe}$ ratios of Vigarano and Maralinga. Temperature steps in 100°C are provided besides the plots. References: see caption of Fig. 1. Subsolar is from South Oman enstatite chondrite [6].

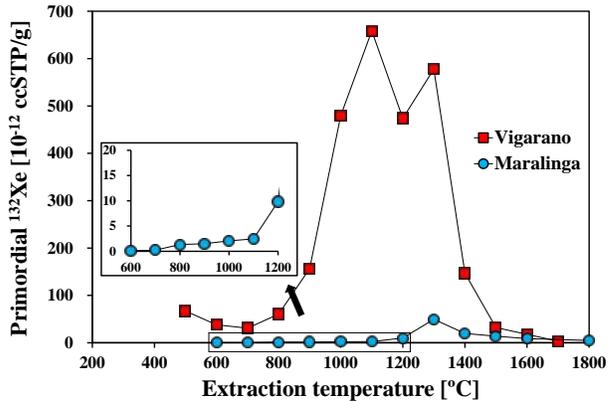


Fig. 3. Release pattern of primordial ^{132}Xe of Vigarano and Maralinga. 400°C step of Vigarano is merged with 500°C step. 400°C step of Maralinga is omitted, because most of it is atmospheric.