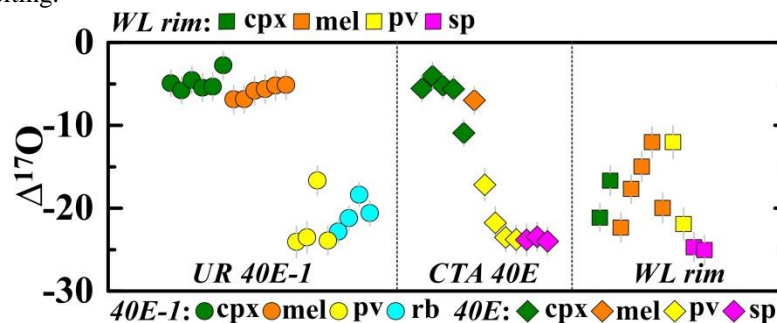


## OXYGEN-ISOTOPE COMPOSITION OF ULTRAREFRACTORY CAI FROM CV3 CHONDRITE EFREMOVKA.

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**Introduction:** Compound Ca,Al-rich inclusions (CAIs), including ultrarefractory (UR) CAI-bearing inclusions, can potentially provide constraints on the chronology, degree of isotope heterogeneity, fractionation in bulk chemical composition and evolution of oxygen-isotope reservoirs in the early Solar System. Oxygen-isotope compositions have been previously reported for a limited number of UR CAIs. In CAI *Romulus* from Murchison (CM2), all primary minerals, including Zr,Y,Ti-oxide and Zr,Sc-rich pyroxene have similar, <sup>16</sup>O-rich compositions ( $\Delta^{17}\text{O} \sim -19\text{‰}$ ) [1]. In CAI *E101.1* from Efremovka (CV3), Zr,Sc-rich pyroxenes are <sup>16</sup>O-depleted relative to spinel, Al,Ti-diopside and melilite; perovskite shows variations in  $\Delta^{17}\text{O}$  [2]. In CAI *3N-24* from NWA 3118 (CV3), Zr,Sc,Y-oxides and Zr,Sc-rich Al,Ti-diopside are <sup>16</sup>O-poor ( $\Delta^{17}\text{O} \sim -2\text{‰}$  to  $-5\text{‰}$ ), whereas spinel is <sup>16</sup>O-rich ( $\Delta^{17}\text{O} \sim -23\pm 2\text{‰}$ ) [3]. In UR CAI *33E-1* from Efremovka, Zr,Sc,Y-oxides and Zr,Sc-rich Al,Ti-diopside are also <sup>16</sup>O-depleted ( $\Delta^{17}\text{O} \sim -2\text{‰}$  to  $-5\text{‰}$ ) compared to Al,Ti-diopside and spinel of the FTA CAI *33E* and WL-rim Al,Ti-diopside ( $\Delta^{17}\text{O} \sim -23\pm 2\text{‰}$ ) [3]. Based on these observations, Ivanova et al. [3] suggested that UR CAIs originated in <sup>16</sup>O-rich gaseous reservoir and subsequently experienced isotope exchange in <sup>16</sup>O-poor gaseous reservoir. Due to the lack of knowledge of O-isotope self-diffusion in Zr,Sc,Y-rich pyroxenes, Zr,Sc,Y-rich oxides, and Y-rich perovskite, the mechanism of O-isotope exchange (gas-melt or gas-solid in the nebular vs. fluid – rock interaction on the chondrite parent bodies) [4–6]. Here we report O-isotope compositions of minerals from a ~ 1 cm-sized compound Efremovka CAI composed of UR (*40E-1*) and CTA (*40E*) inclusions.

**Results and Discussion:** The compound CTA CAI *40E* consists of gehlenitic melilite ( $\text{Åk}_{\sim 20-30}$ ), spinel, perovskite (~1 wt%  $\text{V}_2\text{O}_3$ ), and Zr,Sc-bearing grossmanite (in wt%: 0.31  $\text{ZrO}_2$ , 0.61  $\text{Sc}_2\text{O}_3$ , 23.2  $\text{Al}_2\text{O}_3$ ; 13.0  $\text{TiO}_2$ ). The UR CAI *40E-1* consists of gehlenitic melilite ( $\text{Åk}_{5-20}$ ), abundant perovskite (in wt%: ~1  $\text{V}_2\text{O}_3$ , ~0.86  $\text{ZrO}_2$ ), Zr,Sc-rich grossmanite (in wt%: ~1.2  $\text{Zr}_2\text{O}_3$ , ~1.2  $\text{Sc}_2\text{O}_3$ , up 3.2  $\text{V}_2\text{O}_3$ , 21.6  $\text{Al}_2\text{O}_3$ ; 18.0  $\text{TiO}_2$ ), and rubinite [7]. Rubinite overgrows grossmanite, and contains 1.9 wt%  $\text{ZrO}_2$  and 3.6 wt%  $\text{Sc}_2\text{O}_3$ . The compound CAI is surrounded by the Wark-Lovering (WL) rim layers of spinel, nearly pure gehlenite ( $\text{Åk}_{\sim 5}$ ), grossmanite and Al,Ti-diopside. The bulk composition of *40E-1* plots outside of and below the field of CTA CAIs probably due to the unusually high abundance of perovskite, which results in a high Ca/Al ratio [8]. Oxygen isotopic compositions of the mineral phases in CTA CAI *40E*, UR CAI *40E-1*, and WL rim are variable. In UR CAI *40E-1*, spinel and rubinite are <sup>16</sup>O-rich ( $\Delta^{17}\text{O} \sim -24\pm 1.8\text{‰}$ , and  $-21\pm 1.5\text{‰}$ ); perovskite shows a range of  $\Delta^{17}\text{O}$  (from  $\sim -24$  to  $\sim -12\text{‰}$ ). Grossmanite and melilite are <sup>16</sup>O-poor ( $\Delta^{17}\text{O} \sim -5\pm 1.6\text{‰}$  and  $-6\pm 1.7\text{‰}$ ). In CTA CAI *40E*, grossmanite and melilite are <sup>16</sup>O-depleted ( $\Delta^{17}\text{O} \sim -7$  to  $-4\pm 1.6\text{‰}$ ). In the WL rim, clinopyroxene and melilite show a range of  $\Delta^{17}\text{O}$  (from  $-21$  to  $-17\text{‰}$  and from  $-22$  to  $-12\pm 1.7\text{‰}$ ); spinel is <sup>16</sup>O-rich ( $\Delta^{17}\text{O} \sim -25\pm 1.7\text{‰}$ ). We conclude that the compound UR + CTA CAI originated in <sup>16</sup>O-rich gaseous reservoir and subsequently experienced exchange with an external <sup>16</sup>O-poor reservoir, possibly during partial melting.



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