

## CHROMIUM ISOTOPE COMPOSITIONS OF REFRACTORY INCLUSIONS: IMPLICATIONS FOR ISOTOPIC VARIABILITY IN THE EARLY SOLAR SYSTEM.

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**Introduction:** Calcium-aluminum-rich inclusions (CAIs) in chondrites are the first solids formed in the early Solar System and preserve a record of the earliest processes and conditions in the solar nebula [1]. CAIs exhibit mass-independent anomalies in a variety of isotope systems, and these anomalies are thought to represent formation in an isotopically distinct reservoir when compared to chondrite parent bodies and terrestrial planets ([2] and references therein). Previous studies of Cr isotopic anomalies in CAIs have focused exclusively on inclusions from CV3 chondrites Allende ( $n \approx 25$ ) and Vigarano ( $n = 4$ ) [3-9]. This present study is part of a larger, ongoing project to determine the mass-independent Cr and Ti isotope compositions of a diverse group of CAIs from other chondrites and chondrite groups, with the goal of providing a more rigorous assessment of the isotopic composition and variability of the broader CAI-forming region in the early Solar System [10-15]. We have previously reported the Cr isotope composition of 11 CAIs from several CV3 and CK3 chondrites and here we report the Cr isotopic compositions of an additional 5 relatively pristine CAIs from 4 CV3 chondrites: “Saguaro” from NWA 5508, “ZT6” from NWA 2900, “ZT10” from NWA 6991, and “ZT13” and “ZT14” from Axtell. The Ti isotope compositions of these CAIs have been reported in our earlier work [11-12, 14-15].

**Analytical Methods:** All sample handling and chemical processing was conducted under clean laboratory conditions in the Isotope Cosmochemistry and Geochronology Laboratory (ICGL) at Arizona State University (ASU). Each CAI was carefully extracted from the meteorite slab and subsequently digested in an HF:HNO<sub>3</sub> mix in a Parr bomb. A 5% aliquot was reserved for measurement of elemental abundances (including the REEs) on the iCAP-Q quadrupole inductively coupled plasma mass spectrometer (ICPMS) in the Keck Laboratory at ASU. A portion of the remainder of each sample solution was processed for the separation of elements of interest, and Cr was purified using procedures adapted from [16]. Purified Cr samples and standards were analyzed on the Thermo Neptune multicollector ICPMS in the ICGL using methods similar to those described previously [10]. Samples and standards (800 ppb concentration) were introduced using an Elemental Scientific Apex-Q desolvating nebulizer with a 100  $\mu$ L/min flow rate. Measurements were done in high resolution mode to avoid polyatomic interferences [17]. The intensities of <sup>50</sup>Cr, <sup>52</sup>Cr, <sup>53</sup>Cr, and <sup>54</sup>Cr were measured, along with <sup>49</sup>Ti, <sup>51</sup>V, and <sup>56</sup>Fe to monitor and correct for isobaric interferences. The Cr isotopic data are reported relative to the NBS 979 Cr standard after internal normalization to <sup>50</sup>Cr/<sup>52</sup>Cr (=0.051859; [18]).

**Results and Discussion:** The 16 CAIs in this sample suite (5 of which are reported here for the first time) represent diverse petrologic and geochemical types. This sample set includes CAIs with Group I REE patterns (Lisa, ZT1, ZT6, ZT7, ZT13, Saguaro), Group II patterns (Homer, ZT2, ZT3, ZT5, ZT9, ZT10, ZT14), and Group III patterns (Marge, Bart, ZT8). These 16 CAIs make up a single population of  $\epsilon^{54}\text{Cr}$  values that range from  $3.16 \pm 0.30$  to  $7.28 \pm 0.22$  ( $3.50 \pm 0.22$  to  $6.15 \pm 0.31$  in the 5 new CAIs reported here). The  $\epsilon^{54}\text{Cr}$  values for CAIs from the various CV3 chondrites included in this study fall within the range of  $\epsilon^{54}\text{Cr}$  values of previously measured CAIs from the CV3 chondrites Allende and Vigarano [3-9]; the previously reported  $\epsilon^{54}\text{Cr}$  values of the two CAIs from CK3 chondrites fall within this same range [10]. This supports the previous assertion (based on Ti isotope compositions) that CAIs from CV and CK chondrites originated in a common nebular reservoir [15, 19]. As was also reported previously for  $\epsilon^{50}\text{Ti}$  values in CAIs [15, 20], there appears to be no correlation between REE patterns and  $\epsilon^{54}\text{Cr}$  in the 16 CAI samples that we have studied thus far. The resolvable variation in  $\epsilon^{54}\text{Cr}$  is consistent with the variation in  $\epsilon^{50}\text{Ti}$  in these same CAIs [11-12, 14-15] and indicates that the CAI-forming reservoir preserved isotopic variability in multiple elements.

**References:** [1] MacPherson G. J. (2014), *Treatise on Geochemistry* (2nd Ed.), 139–179. [2] Dauphas N. and Schauble E. A. (2016), *Annual Review of Earth and Planetary Science* 44, 709–783. [3] Birck J. -L. and Allègre C. J. (1984) *Geophysical Research Letters* 11, 943–946. [4] Birck J. -L. and Allègre C. J. (1985) *Geophysical Research Letters* 12, 745–748. [5] Papanastassiou D. A. (1986) *The Astrophysical Journal* 308, 27–30. [6] Birck J. L. and Lugmair G. W. (1988) *Earth and Planetary Science Letters* 90, 131–143. [7] Loss R. D. et al. (1994) *The Astrophysical Journal* 436, L193–L196. [8] Bogdanovski O. et al. (2002) *LPSC XXXIII*, Abstract #1802. [9] Mercer C. M. et al. (2015) *LPSC XLVI*, Abstract #2920. [10] Mane P. et al. (2016) *LPSC XLVII*, Abstract #2778. [11] Torrano Z. A. et al. (2017) *LPSC XLVIII*, Abstract #3045. [12] Torrano Z. A. et al. (2017) *MetSoc 80*, Abstract #6318. [13] Torrano Z. A. et al. (2018) *LPSC XLIX*, Abstract #2405. [14] Torrano Z. A. et al. (2019) *LPSC L*, Abstract #1501. [15] Torrano Z. A. et al. (in review) *Geochimica et Cosmochimica Acta*. [16] Yamakawa A. et al. (2009) *Analytical Chemistry* 81, No. 23, p. 9787–9794. [17] Schoenberg R. et al. (2008) *Chemical Geology*, 249, 294–306. [18] Shields W. R. et al. (1966) *Journal of Research of the National Bureau of Standards*, 70A, No. 2, 193–197. [19] Ebert S. et al. (2018) *Earth and Planetary Science Letters* 498, 257–265. [20] Davis A. M. et al. (2018) *Geochimica et Cosmochimica Acta*, 221, 275–295.