HIGH-PRECISION SIMS CHONDRULE OXYGEN ISOTOPE RATIOS FROM THE YAMATO 82094 UNGROUPED CARBONACEOUS CHONDRITE. T. J. Tenner¹, M. Kimura²,³, and N.T. Kita¹. ¹WiscSIMS, Dept. of Geoscience, Univ. of Wisconsin-Madison, USA (tenner@wisc.edu), ²Faculty of Science, Ibaraki University, Mito, Japan, ³National Institute of Polar Research, Tokyo, Japan.

Introduction: Yamato (Y) 82094 is a petrologic type 3.2 ungrouped carbonaceous chondrite [1]. The ratio of chondrules (78 vol. %) to matrix (11 vol. %) is high relative to CO, CV, and CR chondrites (45-60 vol. % chondrules vs. 30-50 vol. % matrix), but similar to CH and ordinary chondrites [2-4]. The average diameter of Y-82094 chondrules (330 µm; [1]) is distinct from those of CH (20 µm), CO (150 µm), CB (200 µm), CR (700 µm), and CV/CK (900 µm) chondrites, as well as chondrules from ordinary chondrites (450-550 µm) [5]. Y-82094 is dominated by type I (Mg#silicate > 90) chondrules (99.1 %); type II (Mg#silicate < 90) chondrules are rare (0.9 %), akin to other carbonaceous chondrites but different from LL3 chondrites, in which ~50 % are type II chondrules [6]. The Y-82094 bulk O-isotope ratio (δ¹⁷O: −7.62 ‰; δ¹⁸O: −4.52 ‰; [7]) is similar to that of other carbonaceous chondrites [8], but the O-isotope distribution among its chondrules is unknown. Here, we present O-isotope measurements of chondrules from Y-82094.

Samples & Methods: 34 chondrules were analyzed by SIMS, from NIPR sections 91-1, 91-4, 96-1, and 96-2. 27 are type I chondrules (15 porphyritic olivine-pyroxene, or POP; 8 Al-rich; 2 barred olivine; 1 porphyritic olivine, or PO; 1 porphyritic pyroxene) and 7 are type II (3 POP, 4 PO). In 22 of 34 chondrules, constituent low-Ca pyroxene Mg#'s define the chondrule Mg#, as Fe-Mg diffusion is slower in low-Ca pyroxene relative to olivine [9]; for the remaining type I chondrules, Mg#'s of olivine phenocrysts without FeO enrichment from thermal metamorphism define chondrule Mg#; for the remaining type II chondrules, Mg#'s of olivine phenocrysts without FeO-poor relict cores define chondrule Mg#. Electron microprobe techniques are described in [1]. Oxygen 3-isotope ratios were measured with the WiscSIMS Cameca IMS 1280, using multi-collector Faraday cups, as detailed in [6]. A primary Cs+ ion beam (intensity: 2.6 nA) produced a 15 x 10 µm spot size. San Carlos olivine bracketing analyses correspond to δ¹⁸O, δ¹⁷O, and Δ¹⁷O of exogenic external reproducibilities (2SD) of 0.4, 0.5 and 0.5 ‰, respectively. 295 SIMS analyses of chondrule phenocrysts (olivine, pyroxene, plagioclase, spinel) were acquired (5 to 10 spots per chondrule). Homogeneous phenocryst O-isotope data per chondrule determine the averaged “host” value; phenocrysts with Δ¹⁷O (= δ¹⁷O − 0.52 × δ¹⁸O) values differing by more than 0.7 ‰ (the 3SD external reproducibility) of the host chondrule Δ¹⁷O were defined as relict grains.

Results and Discussion: Regardless of the types of phases measured, all chondrules have multiple homogeneous O-isotope data (2 to 9 per chondrule) that define their host value. Host chondrule O-isotope ratios plot on/near the PCM [10] line, between the CCAM [11] and Young & Russell [12] lines (Fig. 1). The distribution of host chondrule O-isotope ratios is similar to those from other carbonaceous chondrites [10,13-18], but different than that of LL3 chondrites [6] (Fig. 1). Type I chondrules in Y-82094 are ¹⁸O-rich relative to type II chondrules (Fig. 1), consistent with Acfer 094 (ungr. C), CO, CR, and CV chondrite chondrules [10,13-18]. Type II PO and POP chondrules have distinct Δ¹⁷O values (~2.6 ‰ to ~3.0 ‰ vs. ~+0.1 ‰, respectively); the type II POP chondrules are ~1 ‰ lower in δ¹⁸O and ~1 ‰ higher in δ¹⁷O, relative to the PCM line. 16 of 35 chondrules have relict olivine and/or spinel grains plotting on/near the PCM line. The percentage of relict-grain-bearing chondrules in Y-82094 is similar to that from Acfer 094, CO, and CV chondrites [10,13,18]. Relict spinels (n = 2) are ¹⁸O-rich, with Δ¹⁷O values of ~9.4 ‰ and ~19.0 ‰. Relict olivine grains are ¹⁸O-rich (n = 31) and ¹⁸O-poor (n = 5) relative to their host chondrule values. 31 of 36 relict olivine grains have Δ¹⁷O between −3.8 ‰ and −8.0 ‰, or within the range of host Y-82094 chondrule values, while the remaining five grains are ¹⁸O enriched (Δ¹⁷O: −10.5 ‰ to −20.6 ‰).
Chondrule $\Delta^{17}O$ vs. Mg#: 25 of 34 chondrules have Mg#'s between 98.7 and 99.6, with host $\Delta^{17}O$ values between –3.9‰ and –8.1‰ (average: –5.5‰; Fig. 2a). Two Mg# ~97.3 type I chondrules and the type II PO chondrules (Mg# 63.6 to 75.9) have $\Delta^{17}O$ values between –2.6‰ and –3.0‰. Type II POP chondrules ($\Delta^{17}O$: ~+0.1‰) are FeO-poor (Mg#: 80.6 to 87.7) relative to the type II PO chondrules (Fig. 2a).

Mg# ~99 chondrules with $\Delta^{17}O$ near –5.5‰ are pervasive in Y-82094, Acfer 094, CO, CR, and CV chondrites [10,13-18] (Fig. 2). These are the signatures of a dominant chondrule-forming environment within the carbonaceous chondrite accretion region, especially considering the high percentage of type I chondrules in carbonaceous chondrites (75–99+; e.g. [1-3,19]). According to metal-silicate phase equilibria, this environment existed under highly reducing conditions (log $f_{O_2}$ = log IW: ~–3.5; Fig. 2a), equivalent to a CI dust enrichment of ~50× [20].

The $\Delta^{17}O$ ~–2.6‰ to ~–3.0‰ type II PO chondrules are consistent with chondrules from other carbonaceous chondrites (Fig. 2), supporting the hypothesis [14,17] that addition of relatively $^{16}O$-poor H$_2$O to the highest Mg# chondrule precursors, perhaps through increased dust enrichment [17], contributed to a more oxidized chondrule-forming environment (Fig. 2a). Although rare in Y-82094, type II chondrules sample two distinct O-isotope reservoirs, which could reflect different H$_2$O amounts and/or different O-isotopes of H$_2$O in respective environments. The $\Delta^{17}O$ ~–2.6‰ to ~–3.0‰ type II PO chondrules are consistent with most CO, Acfer 094, and CV type II chondrules, and some CR type II chondrules (Fig. 2). The $\Delta^{17}O$ values of Y-82094 type II POP chondrules (~+0.1‰) are similar to some Acfer 094 and CR type II chondrules (Fig. 2), as well as type II chondrules from LL3 chondrites (~0.1‰ to +1.2‰; [6]), but they differ in $\delta^{18}O$ and $\delta^{17}O$ (Fig. 3). Finally, Y-82094 type II POP chondrules likely formed at more oxidized conditions than LL3 type I chondrules (e.g. x-axes of Fig. 2a), even though they overlap in $\delta^{18}O$ and $\delta^{17}O$ (Fig. 3). Therefore, Y-82094 type II POP chondrules likely formed in a different environment than LL3 type I chondrules.

References:

Fig. 2. Comparison of chondrule Mg# versus host $\Delta^{17}O$ in Y-82094 (a) and Acfer 094 [10], CO [13], CR [14-17], and CV [18] chondrules (b). Log $f_{O_2}$ estimates are based on data from [20].

Fig. 3. O 3-isotope plot near LL3 chondrite chondrule data [6]. Dashed oval is the distribution of type I LL3 chondrules.