POTASSIUM ELEMENTAL AND ISOTOPIC COMPOSITIONS OF CHONDRITIC COMPONENTS IN ALLENDE CARBONACEOUS CHONDRITE. Y. Jiang[1, 2], P. Koefoed[3], C.-H. Li[2, 4], W. B. Hsu[1, 2] and K. Wang (王昆)[3*]. [1]CAS Key Laboratory of Planetary Sciences, Purple Mountain Observatory, Chinese Academy of Sciences. [2]CAS Center for Excellence in Comparative Planetology, China. [3]Dept. Earth & Planetary Sciences and McDonnell Center for the Space Sciences, Washington University in St. Louis. [4]Key Laboratory of Crust-Mantle Materials and Environments, School of Earth and Space Sciences, University of Science and Technology of China. *Corresponding author: wangkun@wustl.edu.

Introduction: Moderately volatile elements can provide constraints on chondrule formation, such as condensation and evaporation process they experienced. Under conditions of cooling rates ~ 10 to 1000 K/hour for chondrules and low pressures of ~ 10^{-6} to 10^{-3} bars of the solar protoplanetary disk, kinetic effects should lead to heavy isotope enrichments in the chondrules via free evaporation. Both experimental and theoretical calculations indicate that there should be extensive evaporation of alkali elements like K and Na, resulting in isotopic enrichments in chondrules with low K abundances [1]. However, no systematic K isotopic fractionations have been found in chondrules. Previous K isotope analysis on individual chondrules in type 3 ordinary chondrites (Bishunpur and Semarkona) have been carried out by *in situ* SIMS analyses, however, their large variability, to a great extent, was considered to be analytical artifacts due to isobar interferences and the matrix effect associated with the SIMS technique [2, 3]. Precision constraints (1 to 4‰) may have also greatly limited their ability to reveal small δ^{41}K isotopic differences that occur in the chondrules.

Here, we make use of a new MC-ICP-MS method with improved precision (with internal precision of better than 0.05‰; 2 standard error; and long-term external precision better than 0.11‰; 2 standard deviation; [4]) to search for possible K isotopic variations in chondrules. This is the first K isotope report for chondritic components in carbonaceous chondrites.

Samples and analytical methods: Allende (CV3) is a “witnessed fall”, which has minimal terrestrial contamination. Furthermore, it is petrologic type 3, and is amongst the most intensively investigated meteorites. Allende has the largest average chondrule diameter (~ 1 mm) and relatively high chondrule abundance (~ 45 vol%), making it suitable for hand-picking of chondrules.

Under a petrographic microscope, we handpicked chondrules and matrix from ~ 20 g Allende sample. Most chondrules are perfect spheres, while some have irregular shapes. Every chondrule here is intact, which means they have neither lost mass nor adhered by significant matrix. Analysis was conducted on a total of twenty eight fractions, consisting of eighteen chondrule fractions, two matrix fractions, three refractory inclusions and five bulk fractions. The eighteen chondrule fractions were made up of twelve individual chondrules (from CH1 to CH12), one big chondrule (being split into two fractions CH13A and CH13B), the largest chondrule (CH14, just part of it was analysed) and several small chondrules (CH15 containing 3 small chondrules, 5 for CH16, 5 for CH17) (**Fig. 1**).

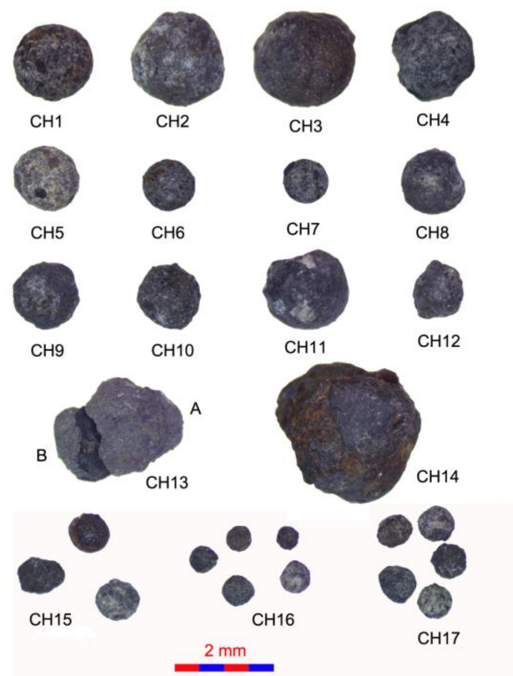

Fig. 1 Chondrules handpicked out in Allende (CV3) carbonaceous chondrite.

All K isotope analyses were conducted using a Thermo Scientific Neptune *Plus* MC-ICP-MS at Washington University in St. Louis. Details of the analytical method including purification are given in [4].

Results: The K isotopic compositions of Allende components are presented in Fig. 2. The δ^{41}K for all 18 individual and representative chondrules analyzed in this study lie between −0.87‰ and −0.24‰, with an average of −0.42 ± 0.20 ‰. The matrix show K isotope values of −0.60 ± 0.05‰ and −0.52 ± 0.08‰, almost consistent with that of the bulk. Five different chips of bulk give a relatively tight range (δ^{41}K: −0.62 ~ −0.46‰), with an average of −0.53 ± 0.07‰. CAIs (Ca, Al-rich refraction inclusions) are earliest formed condensates (about 4.57 Ga) in the Solar System, and are not a carrier of K, thus not supposed to contain any intrinsic K. Surprisingly, they have unusually high K contents (0.48 ~ 0.57wt%), compared to chondrules (0.003 ~ 0.17wt%). The δ^{41}K for CAIs falls within the scope of chondrules (−0.25 ~ −0.30‰) (Fig. 2).

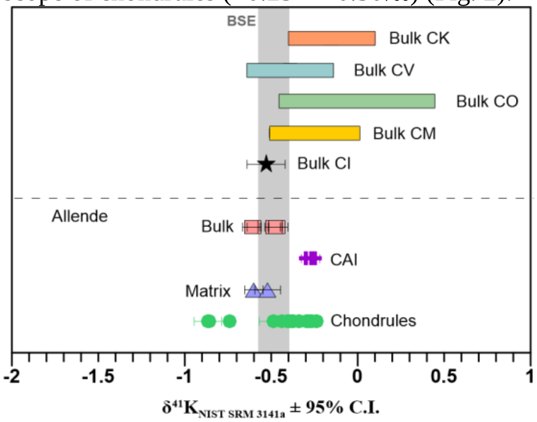

Fig. 2 The K isotopic compositions of Allende chondrules, matrix, CAIs and bulk, compared to bulk analysis of carbonaceous chondrites CI, CM, CO, CV and CK [5]. The bulk silicate Earth (BSE, gray) is also shown [6].

The plot between K isotopic compositions (δ^{41}K) and K concentrations of chondrules does not show significant trends (Fig. 3). Also there is no correlation between the δ^{41}K of chondrules and their corresponding weight/mass. Most chondrules, from the biggest to the smallest ones, are relatively clustered in the range of −0.49 ~ −0.24‰. All chondrules in Allende display a negative correlation between **(**Na, K)/Al ratios and chondrule weight (Fig. 4), which was also observed among type I chondrules in Semarkona [2].

Discussion: This is the first report on the K isotopic compositions of chondritic components in a carbonaceous chondrite. With the improved precision, we confirm the K isotopic compositions of chondrules are resolvable. Small variations (0.63‰) in δ^{41}K of 18 individual and representative chondrules were observed. We do not observe any significant correlations between the K isotopic compositions and K elemental concentrations or ratios or chondrule mass, which is consistent with what has been reported for type 3 ordinary chondrites [2, 3]. Since K is fluid-mobile, it is susceptible to modification in the parent body. Parent body processes, e.g. aqueous alteration, could modify to large degrees the K elemental and isotopic compositions of chondritic components. For example, CAIs should have no intrinsic K, however, here we observed high K contents (~ 4400 ppm). In addition, there is an inverse correlation between K/Al ratios and chondrule mass (Fig. 4): the smaller the chondrules, the higher K/Al ratios. Both observations suggest K (and other alkali elements) migrated into CAIs and preferentially smaller chondrules (larger surface/mass ratios) from the matrix. Thus, the absence of extreme K isotope kinetic fractionation in chondrules [2, 3; and this study] can be explained as the consequences of K isotopic re-equilibration during parent-body processes. Their K isotopic compositions can not be used to infer the condition during the loss of volatile elements in the solar nebula environment.

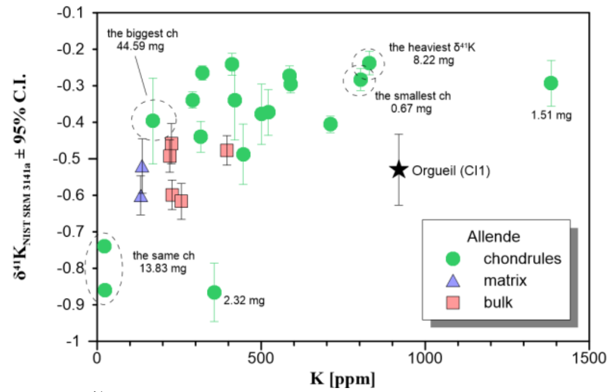

Fig. 3 δ^{41}K versus K [ppm] for all Allende chondrules, matrix and bulk fractions. The weight/mass information for some chondrules have been labelled. Also shown is CI chondrites Orgueil [7] for comparison. CAIs were not plotted because of unusually high K contents (~ 4400 ppm).

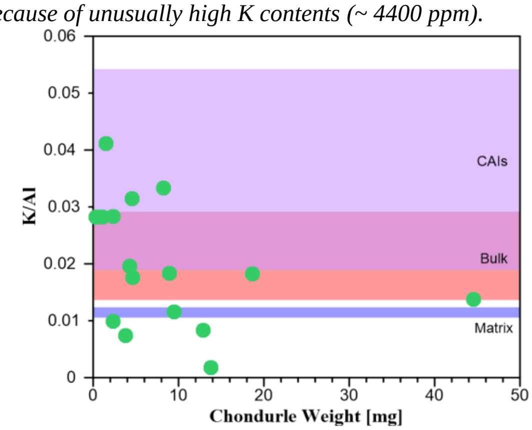

Fig. 4 The K/Al ratio versus chondrule weight for all Allende chondrules (green solid circles). The K/Al for matrix, CAIs and bulk of Allende are also shown for comparison.

Acknowledgments: This work was supported by NSFC (Grants Nos. 41873076, 41703019) and Minor Planet Foundation of PMO.

References: [1] Yu Y. et al. (2003) *GCA*, 67: 773–786. [2] Alexander C M. O'D. et al. (2000) *Meteoritics & Planet. Sci.*, 35: 859–868. [3] Alexander C M. O'D and Grossman J. N. (2005) *Meteoritics & Planet. Sci.*,40: 541–556.[4] Chen H. et al. (2019) *J. Anal. At. Spectrom.*, 160–171. [5] Bloom H. et al. (2018) 49th LPSC#1193. [6] Wang K. and Jacobsen S. B. (2016) *GCA*, 178, 223–232. [7] Wang K and Jacobsen S.B. (2016) *Nature* 538, 487–490.