HIGH-PRECISION RUBIDIUM ISOTOPE ANALYSES IN CHONDRITIC METEORITES - O. Nebel[1,3] F. Wombacher[2], and K. Mezger[3] - [1]Department of Petrology, Vrije Universiteit, De Boelelaan 1085, 1082 HV Amsterdam, The Netherlands (onebel@falw.vu.nl), [2]Institut für Geologische Wissenschaften, Fachrichtung Geochemie, Freie Universität Berlin, Malteserstr. 74-100, 12249 Berlin, Germany, [3]Institut für Mineralogie, Westfälische Wilhelms-Universität, Corrensstr. 24, 48149 Münster, Germany.

Introduction: Volatile elements in early solar system bodies are depleted to variable degrees [1]. This depletion is commonly ascribed to incomplete condensation from a hot solar nebula. The nature and relative extend of volatile element depletion including alkali elements like Li, Na, K and Rb, in chondritic meteorites is, however, not well constrained, i.e. if it is inherited from precursor materials, or whether high energy collisions caused additional and selective volatile loss, potentially accompanied by isotope fractionation effects. The most common moderately volatile alkali metals, Li, K and Rb (half condensation temperatures T_C = 1142 K (Li); 1006 K (K); and 800 K (Rb)[2]) have at least two isotopes and are suitable to detect variations in their natural isotope ratios that may be related to condensation/evaporation during planetary accretion. Potassium isotope compositions are remarkably uniform in bulk chondrites, differentiated meteorites, and in lunar, martian and terrestrial samples e.g., [3]. Lithium isotopes show a lighter isotope composition in carbonaceous chondrites compared to basaltic differentiates from the Earth, Moon, Mars and achondrites [4]. Moreover ordinary chondrites display a tendency towards even lighter Li isotope compositions, which may be evidence for the existence of distinct Li isotope reservoirs in the early solar nebula [4]. Rubidium is the most volatile of the above mentioned alkali elements and provides an alternative alkali-metal isotope tracer for high-temperature processes in cosmochemistry. In addition Rb isotopes can be used to compare isotope fractionation effects observed in chondrites using the highly volatile element Cd (T_C = 652 K) [5].

Due to the relatively high atomic weight of Rb, the natural isotope variations are expected to be only a few per mill which requires precise and accurate isotope ratio measurements. However, high precision measurements of Rb isotopes by TIMS techniques are not possible, due to the large isotope fractionation during the course of an analysis. The TIMS techniques yields high signal intensities but the isotope fractionation during a single analysis is often much bigger than the expected natural variation. Therefore precise Rb isotopes are ideally determined using MC-ICPMS techniques [6, 7]. Here, we report the first high precision analyses of stable Rb isotopes in extraterrestrial rocks, in order to further constrain initial solar system processes related to depletion in moderately volatile elements, and to evaluate possible systematic differences among meteorite classes and Earth.

Analytical Methods: All meteorites used in this study were previously subject to Cd isotope investigation, and sample preparation is reported in Wombacher et al. (cf. [8]). Rubidium was separated from the rock matrix by standard cation exchange chromatography. In order to avoid isobaric interferences during the analyses the Rb fraction was further purified using Eichrom Sr-Spec [7]. Rubidium isotopes were analysed by MC-ICPMS using admixed natural Zr standard solution [7]. Multiple runs of the terrestrial NBS-984 standard solution bracketing sample runs were used to correct for instrumental drift during analytical sessions as reported in Nebel et al. [7]. Variations in the Rb isotope compositions are reported as parts per thousand deviations from the terrestrial standard in a delta notation (δ^{87}Rb [7]). Repeated analyses of an artificially enriched standard solution yielded an external reproducibility of ±0.2 δ^{87}Rb, which is applied to all samples, a lower in-run precision provided.

Results & Discussion: Results of the Rb isotope analyses of Carbonaceous (CC), Ordinary (OC), Rumuruti (RC) and Enstatite chondrites (EC) are presented in Figure 1. Rubidium isotope compositions in EC and one RC appear to be identical to the bulk silicate Earth, except for Ilafegh 009. The result for Ilafegh 009 is in line with the large Cd and Zn isotope fractionations reported for enstatite chondrites other than EH4 [5]. CC show some variations in their Rb isotope composition, also between different meteorite splits, e.g., in the Allende meteorite. The observed variations points to a complex history in different meteorite components and calls for a more detailed study to resolve processes that could have affected the Rb isotope composition during the formation of different chondrite components. OC show an apparent trend towards a lighter isotope composition, with an average δ^{87}Rb value of ~ -1. If this lighter Rb isotope composition in OC (i.e., compared to other primitive meteorites and the Earth) is representative for this chondrite class, the offset argues for a unique formation scenario that differs from that of other solar system materials.

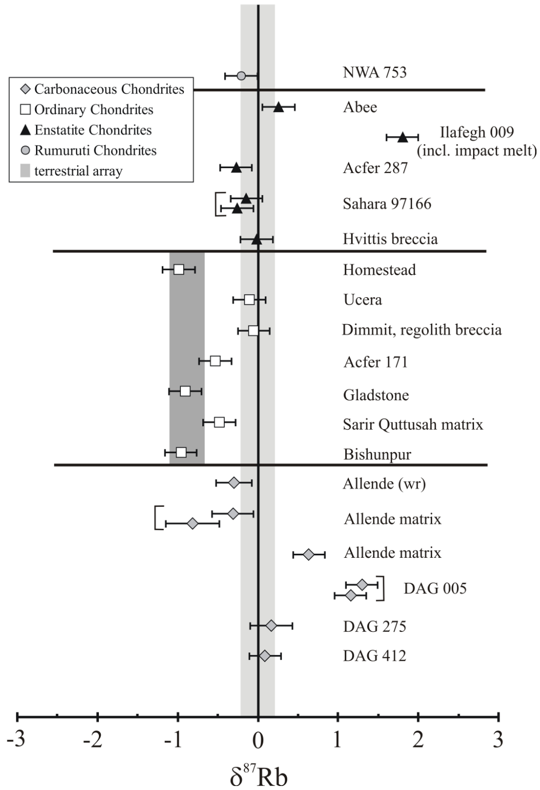

Fig.1: Stable Rb isotope composition in different meteorites expressed in the delta (per mill) notation, which is the deviation from the terrestrial value times 1000

The tendency toward light Rb isotope compositions in OC (relative to CC) is consistent with Li isotope data [4] and, is in agreement with similar trends in Zn and Ag isotopes [9, 10]. Thus, it appears that the alkali elements Li and Rb, and other moderately volatile elements like Zn and Ag tend to display light isotope enrichments in ordinary chondrites. In contrast, Rb isotope compositions show no co-variation with Cd isotope compositions, despite the volatile nature of both elements. Noteworthy, Rb and Li isotopes have very different nuclear properties and nucleosynthetic origins. Thus, a solar nebula reservoir for OC that is distinct from other chondrites with similar light isotope trends in Rb and Li appears unlikely. In contrast, high-energy isotope fractionation processes are more feasible because kinetic condensation in the solar nebular is expected to result in light isotope compositions. A possible explanation is an isotopically lighter gas phase from which OC formed and from which an early refractory component has been removed. This is in agreement with Cd isotope data, that require a scenario in which a parent body process, e.g., in response to thermal metamorphism [5, 8], generates a complementary heavy isotope reservoir..

The Rb isotope composition of the bulk silicate Earth is consistent with the average Rb isotope composition of chondrites. Hence, the formation of the Earth apparently did either not involve significant Rb loss, or this loss was not accompanied by Rb isotope fractionation.

References:

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