Separation of Q from carbon in CR meteorites during stepped combustion

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SEPARATION OF Q FROM CARBON IN CR METEORITES DURING STEPPED COMBUSTION. A. B. Verchovsky1, V. K. Pearson1, A. V. Fisenko2, L.F. Semenova2, M. A. Sephton3 and I.P. Wright1, 1Department of Physical Sciences, Open University, Walton Hall, Milton Keynes, MK7 6AA UK (a.verchovsky@open.ac.uk); 2Vernadsky Institute RAS, Kosygin st. 19, Moscow, Russia; 3Department of Earth Sciences, Imperial College, London, UK.

Introduction: The nature of the planetary noble gas carrier (Q) in meteorites remains uncertain. It is known that it is likely to be carbonaceous, but represents only a small fraction of the total macromolecular material. Q is oxidizable with nitric and other oxidizing acids. It seems to be partly destroyed with pyridine and may have an organic structure. Previously, we have shown that during parent body thermal metamorphism Q is less affected than the majority of other carbonaceous materials [1]. If organic matter is graphitized, as has happened in the enstatite chondrite parent bodies, Q remains unaffected. In the present study we have found that Q is also separable from the majority of carbon in type 2 and 3 CR chondrites during stepped combustion. It is possible that this is because Q has become encased within the matrix, in contrast to other carbon phases, during parent body metamorphism.

Samples and analysis: We have analysed 12 whole rock CR meteorites of all petrological groups: CR1 (GRO 95577 and Al Rais); CR2 (EET 92042, EET 87770, EET 26259, PCA 91082, GRA 95229, MAC 87320, Acfer 059, and El Djouf) and CR3 (NWA 1152 and SAH 00182). Their C, N, Ar and (for 4 of them) Xe isotopes have been measured simultaneously using our mass spectrometric complex Finesse [1, 2]. The gases have been released by stepped combustion in the temperature range from 200 to 1400°C with 100°C increments.

Results: The concentration of 36Ar in the samples varies by more than an order of magnitude from 2.4 x 10^{-7} to 5 x 10^{-6} cc/g. There is no other carrier, apart from Q, that can provide such high concentrations of 36Ar in the bulk meteorites including nanodiamonds. This follows from the known concentration of 38Ar in nanodiamonds [3] and the concentration of nanodiamonds in CR meteorites [4].

Independent of petrologic type, most C and N in the samples is released in the temperature range from 300 to 800°C with a peak release at about 500°C (Figs. 1, 2). Variations of δ13C and δ15N are within the range found in the same or similar samples earlier [5, 6]. In contrast to C and N, the release pattern of 36Ar strongly depends on the petrologic type: in CR1s it is broad and almost similar to C and N (Fig. 1), in CR2s it is narrow (between 900 and 1100°C) with a peak at 1000°C, and in CR3s it tends to have a 100°C higher release temperature than in CR2s (Fig.2). In one case (NWA 1152), Ar has a bimodal release with peaks at 800 and 1100°C. Xe, apart from a peak coinciding with Ar release at 1000°C, also has a higher T peak at 1200°C (Fig. 2). 36Ar/32Xe ratios for the total release of the gases are close to that expected for the Q component.

Discussion: The most important observation is the separation of carbon and 36Ar during stepped combustion of CR2 and CR3 samples. Most low-temperature carbonaceous material in the bulk samples of all petrological types can be easily accessed and oxidized by the molecular oxygen used in the experiments. In the CR1 samples, Q and other carbonaceous materials are equally accessible for oxygen. For CR2 and CR3 samples, the situation is significantly different. Up to 800-900°C, oxygen does not react with Q, possibly because the phase is somehow isolated from its direct access. One of the explanations for this could be that the Q grains are encased within the matrix which remains stable at T<900°C. At T>900°C, the matrix opens up and oxygen reacts with Q grains releasing...
noble gases. Ar can be released from Q without oxygen at such a high temperatures. However in this case its release pattern is broader [7]. Therefore we believe that oxygen plays a role during Ar and Xe release. The results for oxidation of HF/HCl residue of Renazzo (CR2) [1] can be regarded as an argument in favor of the above explanation: in this case, Q noble gases are released at low temperatures simultaneously with the majority of carbon. The results here suggest that very little carbon is associated with Q-Ar. The highest 36Ar/C ratio of 0.1 cc/g is obtained for PCA 91082 at 1000°C. This is probably the highest concentration of Ar observed so far in Solar System objects.

Separation of C and Q phases during stepped combustion suggests a physical relation between release of Q-Ar and Xe release. The extremely high 36Ar/C ratio (up to 0.1 cc/g) in some of CR2 and CR3 meteorites suggests that Q may not be carbonaceous at all. Apart from noble gases, Q contains isotopically light N (δ15N<-140‰), that may be related to solar nitrogen.

Conclusions. Q is a separate phase with different properties from most carbonaceous materials in CR3 chondrites. During metamorphism in CR parent bodies, Q becomes encased in the matrix preventing it from being oxidized in the laboratory and allowing it to be efficiently separated from other carbonaceous phases during stepped combustion. The extremely high 36Ar/C ratio (up to 0.1 cc/g) in some of CR2 and CR3 meteorites suggests that Q carrier in such a way that it becomes soluble in the acids.

References: