

ON THE VARIATIONS OF THE ELEMENTAL COMPOSITION OF THE P3 COMPONENT IN PRESOLAR DIAMONDS. A. V. Fisenko¹, A. B. Verchovsky², L. F. Semjonova¹, I. P. Wright² and C. T. Pillinger², ¹Vernadsky Institute of Geochemistry and Analytical Chemistry RAS, Moscow, Russia, anatolii@fis.home.chg.ru, ²The Open University, Walton Hall, Milton Keynes MK7 6AA, UK.

Introduction: In the present study we focus mostly on the effects of parent body thermal metamorphism on variations of the elemental composition of P3 noble gases and the corresponding variations in release characteristics of the noble gases. In particular we analyse element variations in the low (<800°C) and high (>800°C) temperature parts of the P3 gases (labeled below as P3-L and P3-H respectively), released during stepped pyrolysis. This aspect of P3 noble gases behavior in presolar diamonds has not been analysed in detail so far. Below we use the data published in [1].

Results: *Element variations in P3 gases:* The elemental composition of the P3 component in nanodiamonds from unprocessed meteorites is different from that present in samples that are known to have been thermally metamorphosed. The most primitive meteorite in terms of thermal processing is thought to be Orgueil. As can be seen from Figure 1, in all metamorphosed meteorites the P3 component tends to have a depletion of Kr and an enrichment of Ar relative to Xe compared to the abundance of the elements in P3 of Orgueil. The same trend is observed in Figure 2 where the integral amounts of all types of gases released up to 800°C are shown: experimental points for the most metamorphosed meteorites deviate to the left from the HL-P3 mixing line.

For each separate meteorite the elemental compositions of P3-L and P3-H are different (Fig. 1). This difference seems to be dependent on the metamorphic history. For instance, for Orgueil, a thermally unprocessed but significantly aqueous altered meteorite, P3-L and P3-H have similar Kr/Xe but different Ar/Xe ratios. Similar variations are observed for Semarkona and Bishunpur. The most significant differences between P3-L and P3-H (in terms of Kr/Xe ratio) are observed for the thermally processed meteorites such as Kainsaz, Leoville and Vigarano. However, variations in Kr/Xe ratios for Vigarano are opposite to those observed for Kainsaz and Leoville. We speculate that it is a particular combination of mild aqueous alterations with thermal processing

in Vigarano which is responsible for the difference. For the more strongly metamorphosed Allende and Indarch, representing correspondingly oxidised and reduced groups, Kr/Xe ratios for P3-H are extremely different (Allende is similar to Vigarano, while Indarch is similar to Kainsaz and Leoville).

Discussions: An important point that follows from the observations presented above is that if Orgueil is indeed the least thermally processed solar system material (i.e. its P3 gases most really represent the true P3 composition) then the elemental variations between noble gases of the component observed during parent body metamorphism and laboratory step heating cannot be simply explained by diffusion fractionation. We suggest two possibilities to explain this paradox.

The first possibility suggests that, in spite of low temperature processing, Orgueil material has, in fact, lost most of its original P3 component in a process resulting in element fractionation (diffusion-like separation). This would mean that the true P3 composition must have much higher Kr/Xe and Ar/Xe ratios. On the plot (Fig. 1) the point corresponding to this hypothetical composition must lie somewhere in the upper right corner. In this case all the other bulk P3 compositions, corresponding to the thermally and aqueous altered meteorites, would be the result of diffusive element separation in which lighter elements were lost preferentially to the heavier ones. The spread of the points on the plot (Fig. 1) should then be explained by particular conditions of metamorphism in different parent bodies.

As far as the variations in the compositions of P3-L and P3-H are concerned, one could suggest that they reside in diamond populations of different origins and hence P3 compositions. Such an explanation is supported by the observation [2] that release temperature of implanted noble gases strongly depends on the total radiation dose acquired by diamonds (i.e. on the number of defects produced in their structure). Therefore, variations in P3-L and P3-H compositions cannot be compared directly since the diamond populations,

where these components are located, can also have a different response to metamorphism.

The *alternative possibility* suggests that the true P3 composition corresponds to that observed in Orgueil and that the noble gas element variations in other meteorites are in some way related to their release along the damage tracks which were produced during implantation of the ions in the first place. In this case we basically follow the results of [3] who showed that a bimodal noble gas release is produced as a result of a single implantation event, though our interpretation of the observation is quite different from that presented in [3]. We also suggest that only tracks produced by P3 gases have remained in the diamond structure, since during implantation of HL gases the temperature was high enough to anneal defects associated with these gases.

Tracks created by different noble gases are not equal in terms of the damage they produce in diamond structure. For instance, calculations using TRIM code [4] indicate that for a diamond target implantation of noble gas ions with the same energy (1.2 keV) produces a higher number of vacancies in tracks formed by Xe and Kr compared to those for Ar (1.2x in a surface layer of ~ 8 Å thickness). This difference could, in fact, be even higher if implantation energy of Xe and Kr was higher than that for Ar. This seems to be quite a real possibility since stepped combustion results indicate that surface concentration of Ar in nanodiamonds is higher than that for Xe [5]. Thermal metamorphism and/or aqueous alterations could lead to a further disparity in the track defects associated with different noble gases.

We suggest that noble gases of the P3-L component are associated with the most defective tracks. As tracks containing Ar are relatively less defective than those with Kr and Xe, then Ar should be released during thermal metamorphism or laboratory heating less effectively than Xe and Kr. Thus, the element variations shown in Figure 1 can be explained. Preferential loss of Kr over Xe could be connected with diffusion effects, if tracks associated with those gases are equally defective.

Noble gases in the less damaged tracks are thought to represent the P3-H component. From thermally unmetamorphosed meteorites like Orgueil these gases are released during laboratory

stepped heating only when the diamond structure degrades. Therefore their release temperature coincides with that for HL gases. Thermal metamorphism and aqueous alteration lead to a modification of the tracks resulting in a decrease of the release temperature of P3-H gases.

References [1] Huss G. R and Lewis R. S. (1994) *Meteoritics*, 29, 794-829. [2] Verchovsky A. B. et al. (2000) J. Conf. Abstr. (Goldschmidt 2000) 5, CDROM abstr. 1050. [3] Koscheev et al. (2001) *Nature* 412, 615-617. [4] (2003) www.srim.org. [5] Verchovsky A. B. et al. (1998) *Science* 281, 1165-1168.

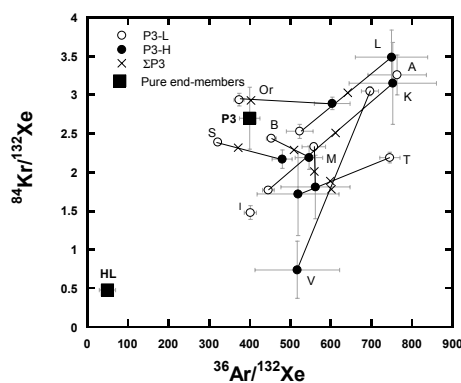


Figure 1. Element variation in P3 component in meteorites analysed in [1]. The letters correspond to the meteorites names.

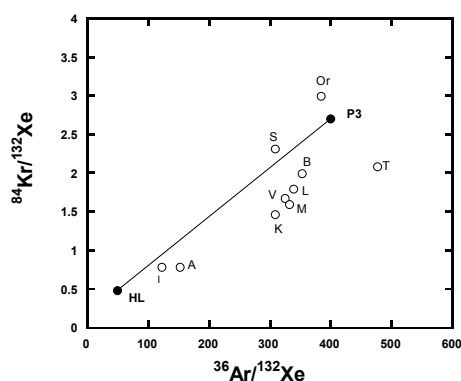


Figure 2. Element variation in the total gas release (HL+P3) up to 800°C in the same meteorites shown in Fig. 1.