METEORITIC NANODIAMONDS: ALTERNATIVE COMPOSITION OF THE NOBLE-GAS COMPONENTS.

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Introduction. It is accepted that the noble gases in meteoritic nanodiamonds are basically a mixture of three components, designated as P3, P6 and HL [1]. The xenon of the P3 and P6 components (Xe-P3 and Xe-P6, respectively) has almost "normal" isotopic composition, whereas xenon of the HL component (Xe-HL) is essentially anomalous due to enrichment by light and heavy isotopes relative to the composition of the solar xenon. The excesses of light and heavy isotopes of Xe are result of *p*- and *r*-processes. Therefore it is accepted that Xe-HL is a result of the mixing of these isotopes with Xe of normal composition. The Xe-HL isotopic composition is accepted invariable at determination of abundances of the noble-gas components in nanodiamond-rich fractions (NRF) of meteorites of various chemical classes and petrologic types [2].

Here we present the results of calculations of the alternative composition of noble-gas components according to the Xe abundances in NRF of some meteorites. The Xe isotopes of *r*- and *p*-processes (farther are denoted as Xe-(H+L)) are used instead of the Xe-HL in these calculations.

Parameters of the equations. We supposed that the Xe abundances in the NRF are caused by the Xe-P3, Xe-P6, Xe-(H+L), and by the Xe of S-process (Xe-S). These Xe abundances were determined by solution of the equations set. Here, the variables are x, z, and s, that is the ^{130}Xe content of the Xe-P3, Xe-P6, and Xe-S, respectively, and y – the ^{136}Xe content of Xe-(H+L). The parameters b and a, t, d are the measured both the ^{132}Xe content and the ratios ^{130}Xe/^{132}Xe, ^{134}Xe/^{132}Xe and ^{136}Xe/^{132}Xe, respectively. The A, N, and F, as well as B, L, R, and D, T, I coefficients are the ^{132}Xe/^{130}Xe, ^{134}Xe/^{130}Xe and ^{136}Xe/^{130}Xe ratios of the Xe-P3, Xe-P6, and Xe-S, respectively. The E and M coefficients are the ^{132}Xe/^{136}Xe and ^{134}Xe/^{136}Xe ratios of Xe-(H+L). As it's seen, the ^{130}Xe and ^{136}Xe abundances of noble-gas components of alternative composition are determined by normalizing to the measured of ^{130}Xe/^{132}Xe, ^{134}Xe/^{132}Xe and ^{136}Xe/^{132}Xe ratios for xenon in the NRF of meteorites.

$$x+z+s = ab$$
$$Ax+Bz+Ds+Ey = b$$
$$Nx+Lz+Ts+My = tb$$
$$Fx+Rz+Is+y = db$$

The use Xe isotopic compositions of noble-gas components are shown in the Table 1. The Xe-(H+L) composition was obtained assuming that all content of ^{130}Xe in Xe-HL is caused by Xe-P3. It's note, the use of the Xe-HL composition is caused by only the more accurate values of its isotopic ratios. The same composition of Xe-(H+L) will be obtained for any point on the mixing line between Xe-P3 and Xe-HL.

For calculations we used the ^{132}Xe contents and the Xe compositions in the NRF of Orgueil (CI), Allende (CV3) and Indarch (EH3-4) meteorites according to data in [1]. These meteorites are used because they belong to different chemical classes and have undergone thermal metamorphism under various conditions.

Results and discussion. According to the obtained results, the P3 component of noble gases in NRF of meteorites is the dominant component (Table 2). The kinetics of low-temperature ^{132}Xe-P3 release (Fig. 1) is corresponds to the tendencies of its change depending on the conditions of thermal metamorphism [2]. As it's seen, a larger amount of the ^{132}Xe-P3 is released at T ≤1000 °C during pyrolysis of the NRF of least thermally metamorphosed the Orgueil meteorite, while almost all of the ^{132}Xe-P3 is released at T≥1000 °C from NRF of thermal metamorphosed the Allende and Indarch meteorites. Almost the entire ^{132}Xe-(H+L) is released at T≥1000 °C, which also corresponds to the release kinetics of ^{132}Xe-(HL) on the data in [2]. However, according to our data, a low-temperature peak is clearly appeared in the ^{132}Xe-P6 release histogram for NRF of Orgueil (Fig. 1), whereas the ^{132}Xe-P6 release has only a high-temperature peak on data in [2]. The low-temperature peak of ^{132}Xe-P6 releasing, as well as of ^{132}Xe-P3, is not observed for NRF of the Allende and Indarch meteorites (Fig. 1).

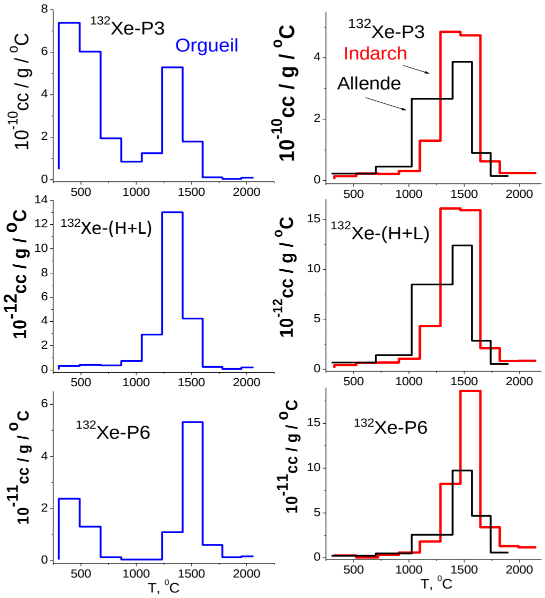

Figure 1

The kinetics of ^{132}Xe-P3 and ^{132}Xe-(H+L) release at T≥1000 °C are practically the same for NRF of each meteorite (Fig. 1). Therefore, the calculated ^{136}Xe/^{132}Xe ratios according to the released Xe-P3 and Xe-(H+L) have a plateau at T≥1000 °C (Fig. 2a).

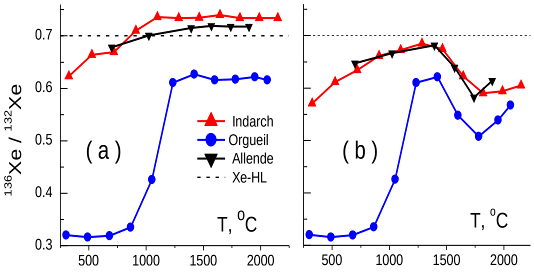

Figure 2

As it's seen, the ^{136}Xe/^{132}Xe plateau values are the differenced for NRF of meteorites that underwent different thermal metamorphism. Therefore we suppose the following: (a) Xe-P3 and Xe-(H+L) are contained in individual populations of nanodiamond grains and these populations are similar by grain-size distributions; (b) the population grains with Xe-(H+L) were more resistant to destruction during thermal metamorphism than the population grains with Xe-P3. It is obvious that any the xenon mixture from these two population grains will always be on mixing line between Xe-P3 and Xe-(H+L) on three-isotope plots.

Low-temperature peaks of the Xe-P6 and Xe-P3 release from the NRF of Orgueil meteorite (Fig. 1) are due-to probably surface-bound state of the some Xe part of P6 and P3 components. The maximum temperature of the second peak of ^{132}Xe-P6 release is higher than that for ^{132}Xe-P3. Besides, the isotopic compositions of Xe-P6 and Xe-P3 are different (Table 1). Probably, the noble gases of the P6 component are also contained in the individual population of nanodiamond grains. The higher temperature of ^{132}Xe-P6 release relative to that for ^{132}Xe-P3 (Fig. 1) may be due to lesser defect of the P6 population grains. Thus, the NRF of meteorites consist the three populations of nanodiamond grains with different both noble-gas components and thermal-oxidation resistance. Therefore, the dependence of ^{136}Xe/^{132}Xe ratios from temperature for Xe from all of the nanodiamonds in NRF (Fig. 2b) essentially differs from shown on Fig. 2a. It is obviously, that on three- isotope plots the released Xe during step pyrolysis of all nanodiamonds in NRF will be in the region bounded by the mixing lines between Xe-P3 and Xe-(H+L), and between Xe-P6 and Xe-(H+L) (e.g., Fig. 3a). As NRF contains the Xe-S, then the calculated dependencies only for the nanodiamonds of NRF (Fig. 3a) differ from those for whole of Xe of NRF (Fig. 3b). These differences are minimal for NRF of the Allende and maximal for NRF of the Indarch in accordance with the content of Xe-S in NRF of these meteorites (Table 2).

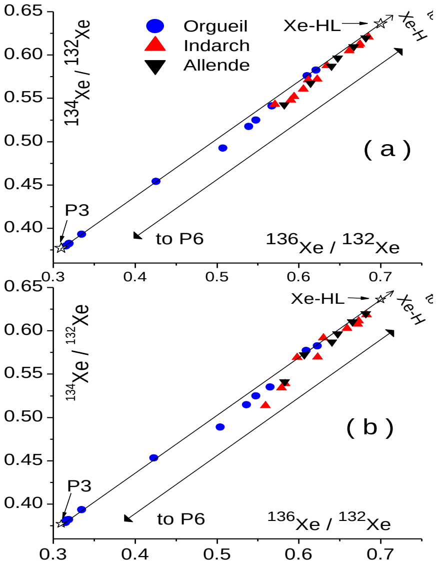

Figure 3

Conclusion. The use of Xe isotopic composition of *p*- and *r*-processes instead of Xe-HL in calculation of the contents of noble-gas components in NRF meteorites has shown the following. The component P3 of noble gases is the dominant component. The xenon of *p*- and *r*-processes, as well as the noble gases of P3 and P6 components are contained in individual populations of nanodiamond grains. These the grain populations are different in thermal stability during stepped pyrolysis. The thermo-oxidative stability of grain populations during thermal metamorphism of different meteorites was also different, which led to a change of initial their relation.

References: [1] Huss G.R. and Lewis R.S. (1994) *Meteoritics*, 29, 791–810. [2] Huss G.R. and Lewis R.S. (1994) *Meteoritics*, 29, 811–829.

Table 1. Xe isotopic compositions of noble-gas components

Xenon	^{124}Xe	^{126}Xe	^{128}Xe	^{129}Xe	^{130}Xe	^{131}Xe	^{132}Xe	^{134}Xe	^{136}Xe
Xe-P3*	0.02835	0.02539	0.5066	6.549	≡1	5.174	6.285	2.370	1.948
Xe-HL*	0.00842	0.00569	0.0905	1.056	0.1544	0.844	≡1	0.636	≡0.7
Xe-S*	0	0.00068	0.4474	0.244	≡1	0.385	2.072	0.046	0.007
Xe-P6*	0.02686	0.02674	0.5337	6.691	≡1	4.970	6.046	2.033	1.899
Xe-(H+L)	0.0101	0.0044	0.0308	0.112	≡0	0.114	0.074	0.677	≡1

* Xe isotopic composition of components is on data in [1]

Table 2. Total the ^{132}Xe abundances (in 10^{-8}cc/g) of noble-gas components

NRF sample	^{132}Xe*	^{132}Xe-P3	^{132}Xe-(H+L)	^{132}Xe-P6	^{132}Xe-S
Orgueil	49.79	47.3	0.415	2.06	0.042
Allende	25.12	20.7	0.654	3.76	0.007
Indarch	30.91	23.5	0.78	6.44	0.167

*Total the ^{132}Xe amount in NRF is on data in [1]