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Study of chemical composition of cosmic (meteoritic) material fragments by instrumental neutron activation analysis

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What is an object of examination?

Geological processes have strongly changed a primary chemical and mineral composition of the Earth. Its fingerprints of the pre-accretion history were destroyed. In contrast to terrestrial rocks, chondrites did not undergo chemical differentiation that attends igneous processes. They were kept practically without changes since time of planet formations and therefore the chondrites are the most important source of information about the primary material composition of the solar system and also about the initial stages of planetary material evolution. The study of the chemical composition of chondritic individual components and minerals allows to reveal the processes, which took place at the earliest stages of the solar system evolution and to obtain information about the P- T -fO_2 conditions in the solar nebula during their formation.

How fragments were separated?

Methods of separation of chondrite components from matrix were different, depending on chemical composition and (or) physical properties of analyzed samples. For example: 1) Refractory inclusions having a spherical form and size up to several mm have been identified visually and then separated from a matrix during crushing of samples (e.g., inclusion [U+FFFD]3, Efremovka CV3 chondrite). 2) The alien inclusions of one chondrite type in the chondrite of another type (for example, carbonaceous material in a ordinary chondrite) were identified according to their black color (inclusion K1 in the Krymka LL3.0 chondrite).

Ultra-refractory inclusions (with size of tens μm enriched in refractory siderophile and (or) lithophile elements up to 10^4 times relatively to C1 chondrites) have been identified in the samples with mass about 10 mg based on the induced activity ratios of elements, which differ in volatility but similar in their geochemical properties, such as Ir/Ni (Co) or Sc/Cr (inclusions K8, KS1, Kainsaz CO3 chondrite).

What method for determination of the fragment compositions was used?

The composition of fragments was studied by the INAA method. Its advantages and possibilities are: the low detection limits, the small sample mass (μg) needed for analysis, possibility of simultaneous determination the large number of elements, analysis without sample destruction, a simple scheme of analysis. Methodology of analysis and systematic approach to the study of material composition were developed.

Main results

The elemental composition of the separate components of chondrites is represented in table 1-4; the distribution of elements normalized to the average composition of chondrites is represented in Fig. It may be concluded that

a) distribution of the elements of different volatility in three types of inclusions testify about their isolation from interaction with the gaseous protoplanetary disc at different temperatures;

b) from the data on chemical composition of metal grains in Ca-Al inclusions of Efremovka chondrite (Fig., line 1) and grains of metal from the matrix (Fig., line 2) follows that the condensation of metal and the formation of refractory aggregates occurred in the same region of solar nebula , but in the different period of time;

c) from the data on composition (table) of Sc- containing minerals in chondrites and terrestrial mineral - thortveitite follows that in contrast to the latter the Sc-minerals of chondrites are enriched in refractory Ti, Al and Ca, and their rare-earth elements are fractionated on volatility, but not according to the crystallochemical properties of the elements. These minerals were formed at the extreme stages of the evolution planetary material - in the process of the condensation of elements in the solar nebula and in the terrestrial processes, which took place in the presence of water, respectively.

Conclusions

The basic representatives of micro-objects and specific features of a study of their chemical composition are considered. It is shown that the INAA method can be successfully used for studying the elemental composition of ultra small individual objects by a mass up to several micrograms and below it that is necessary for solving of many cosmochemical and geochemical problems. An error in the analysis of such samples is determined mainly by the unexcluded systematic error connected with determination of the sample masses at a level of the certified accuracy for the utilized micro balance. However, using the appropriate methods of the interpretation of the analytical results for micro samples, it is possible to avoid the influence of error the determinations of mass and to obtain information about nature of processes, responsible for observed fractionation of elements in the samples under investigation.