PHENOMENOLOGICAL EXCITATION FUNCTIONS OF Xe ISOTOPES WITH PROTONS ON NUCLEI OF Cs, La AND Ce;
G. K. Ustinova, Institute of Geochemistry and Analytical Chemistry, Russian Academy of Sciences, Moscow 119991 Russia; e-mail: ustinova@dubna.net.ru

Introduction: Production cross sections of isotopes in nuclear reactions with high energy particles represent an actual problem of the modern cosmochemistry. To analyze formation of the isotopic content of cosmic matter and its evolution under different radiation conditions, the knowledge of isotope excitation functions on all nearby target nuclei for large energy spectra of nuclear-active particles of cosmic radiations is required. Experiment is unable to provide all the plenitude of the necessary information. In this connection, some semi-empirical systematics of nuclear reactions are elaborated, among which the Rudstam systematics [1] should be assessed as the best one. Reflecting correctly, on the whole, the main regularities of the processes, they, nevertheless, do not always fit satisfactorily experimental data. The essentially better exactness can be reached if our approach (elaborated earlier [2, 3]), based on the possibility of separation of the Rudstam parameters, depending on mass A_t of the target nucleus and on mass A_i of the product isotope, is used.

Phenomenological approach: Indeed, the Rudstam generalized formula may be presented as follows:

$$\sigma(A_iZ_i)=146f(A_t)f(E)P(A_t)A_t^{0.367}(1-0.3/P(A_t)A_t)^{-1}\cdot$$
$$\exp[-P(A_t)(A_t-A_i)]\cdot\exp[-R(A_i)|Z_i-SA_i+TA_i^2|^{3/2}] \quad (1)$$

It describes the production cross section of the isotop i on the target nucleus t and contains some free parameters determined experimentally:

$$f(A_t) = \exp(-0.25+0.0074A_t) \quad (2)$$

$$f(E)=\begin{cases}\exp(1.73-0.0071E), & E<240 M эB\\ 1, & E>240 M эB\end{cases} \quad (3)$$

$$P(A_t)=\begin{cases}40A_t^{-0.1725}E^{-0.77}, & E<2100 M эB\\ 0.112A_t^{-0.1725}, & E>2100 M эB\end{cases} \quad (4)$$

$$R(A_i) = 11.8\, A_i^{-0.45} \quad (5)$$

A formula similar to (1) may be written for the experimentally known production cross section of the isotop i on the target nucleus t', so that the ratio of both the cross sections leads to

$$\sigma_t^{\,i}(A_iZ_i)=(K_t/K_{t'})\exp\{[P(A_t)-P(A_{t'})]A_i\}\ \sigma_{t'}^{\,i}(A_iZ_i)_{exp.} \quad (6)$$

where all the parameters of (1-5), depending on t and t', are included into the coefficients K_t and $K_{t'}$. Substituting numerical values of the parameters, one may obtain a simple formula (7) to calculate the unknown production cross sections of the isotope i on the target nucleus 1, using its experimentally known production cross sections on the target nucleus 2:

$$\sigma_1^{\,i}(E)=(A_1/A_2)^{0.1945}\exp\{0.0074(A_1-A_2)-40E^{-0.77}\cdot$$
$$[A_1^{-0.1725}(A_1-A_i)-A_2^{-0.1725}(A_2-A_i)]\}\sigma_2^{\,i}(E)_{exp.} \quad (7)$$

· Analogously, it is easy to obtain another formula (8): for determination of the unknown production cross sections of the isotope i, using the experimental production cross sections of the isotope j on the same target, which is useful, for instance, for calculation of the excitation functions of the long-lived radionuclides (e.g., of ^{53}Mn, using the data of ^{52}Mn or ^{54}Mn):

$$\sigma_t^{\,i}(A_iZ_i)=\exp[P(A_t)(A_i-A_j)-R(A_i)|Z_i-SA_i+TA_i^2|^{3/2}+$$
$$R(A_j)|Z_j-SA_j+TA_j^2|^{3/2}]\sigma_t^{\,j}(A_jZ_j)_{exp.} \quad (8)$$

It is clear that, when $Z_i=Z_j$, the ratio of the exponents in (8) points out to the isotope relation on the isobaric curve.

Xe excitation functions: Production cross sections of the noble gases, in particular, those of Xe, represent a vital problem of cosmochemistry. The Xe excitation functions with protons are measured only on Ba at E_p=38-730 MeV [4,5]. Besides, there are measurements of the relative yields of Xe isotopes on Cs, Ce and REE at E_p=730 MeV [6]. Meanwhile, the analysis and interpretation of the isotopic anomalies in the 9-isotope system of Xe demand exact estimates of contributions of the different Xe sources, in particular, of its cosmogenic component. In Fig.1 the excitation functions of Xe isotopes on Cs, La and Ce, calculated according to (7) by using the experimental data [4,5] of Xe production on Ba, are shown. In spite of the strong differences of the Xe isotope production on the different targets, the ratios of the Xe isotopes turned out to be practically independent of the target, whereas the energy dependence of the ratios turned out to be very strong. The analysis shows that the observed spread of the Xe isotope ratios in the different lunar samples is due not to their various chemical composition, but, mainly, to the solar proton energy variations in the range of 200-400 MeV, where the maxima of the excitation functions lie.

References: [1] Rudstam G. (1966) // *Zts. Naturforsch.,21A*, 1027-1041. [2] Lavrukhina A.K. and Ustinova G.K. (1990) *Meteorites as probes for cosmic ray variations*, Moscow: Nauka, 262p. (in Russian). [3] Lavrukhina A.K. and Ustinova G.K. (1971)// *Nature, 232*, 462-463. [4] KaiserW.A. (1977)// *Phil. Trans. R. Soc. Lond., A, 285*, 337-362. [5] Funk H. and Rowe M.W. (1967) *// EPSL, 2*, 215-219. [6] Hohenberg C.M and Rowe M.V. (1970)*// JGR,. 75*, 4205-4209.

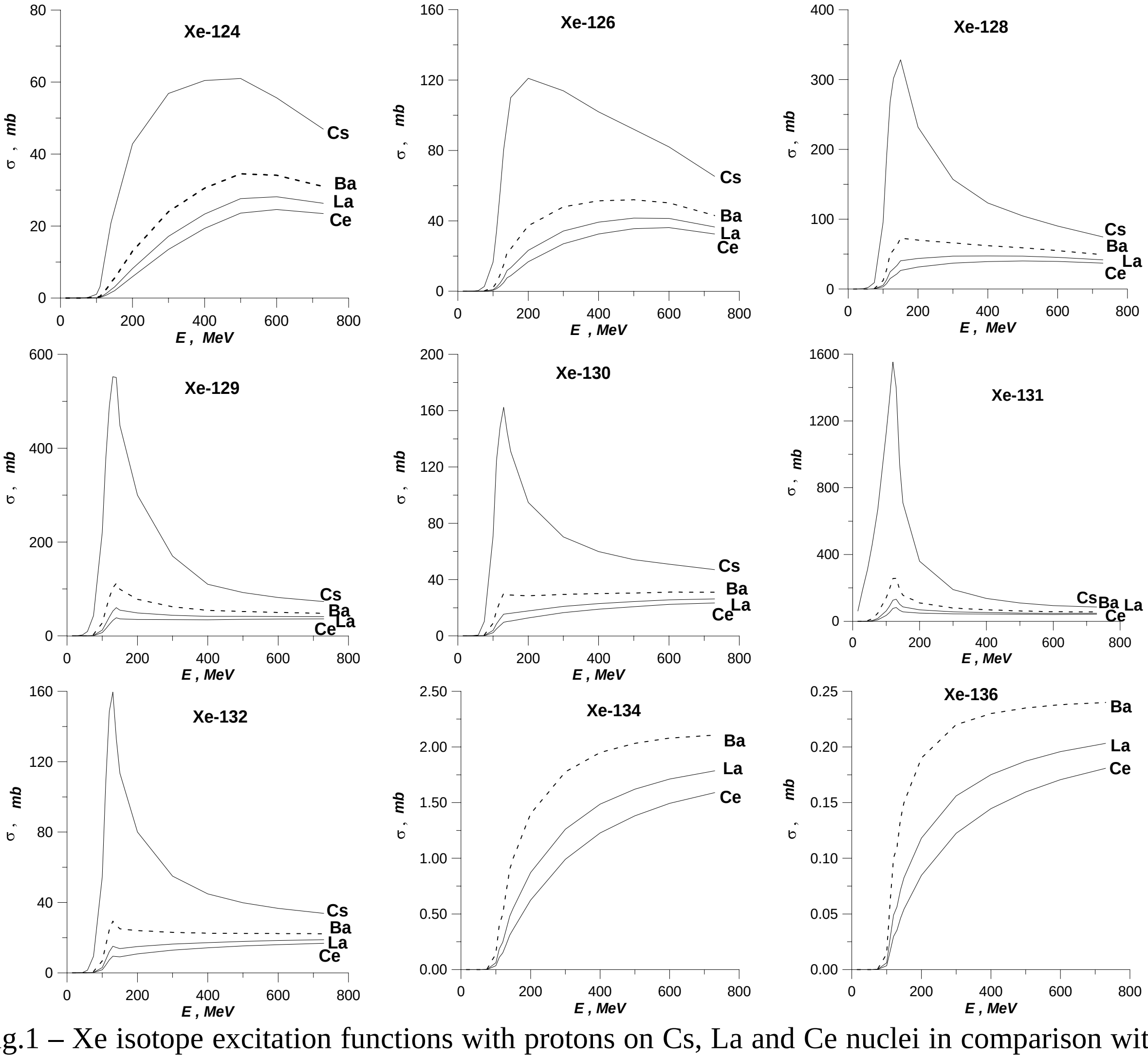

Fig.1 – Xe isotope excitation functions with protons on Cs, La and Ce nuclei in comparison with their experimental excitation functions (Kaiser, 1977; Funk and Rowe, 1967) on Ba