ION CHARGE STATES OF THE SOLAR NOBLE GASES IN THE LUNAR ILMENITES.
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Introduction: The solar wind (SW) and the solar energetic particles (SEP, 1-50 MeV/n), being two distinguishable components of the solar corpuscular emanation, provide the direct clue to the processes in the corona and chromosphere. Indeed, the chromosphere and the lowest layers of the corona are the likely regions of the atom-ion separations, depending on the first ionization potential (FIP) of the elements; the charge states of the ions are eventually formed in the equilibrium with the local electron temperatures $T_e(r)$ and density $n_e(r)$, and they remain unaltered in further processes. Thus, the physical conditions above the photosphere can be studied by deriving the charge states of SW and SEP. Both the components are distinguished by their isotopic and elemental abundances. SEP, associated with the solar flares, are considered to be shock wave accelerated before injection from the corona and/or during propagation in the heliosphere. This leads to the SEP fractionation in proportion to $A/Z$ or $(A/Z)^j$ (to $A/Q$ or $(A/Q)^j$, where $Q$ is the ion charge, if the ionization is incomplete [1]. In the case of $i$ and $j$ isotopes of the same element the fractionation is proportional to $A/A'$ or $(A/A')^j$, i.e. to the common mass-fractionation. In the stony meteorites, enriched with the solar noble gases, the $(A/Z)^j$ regularity for the SEP component has been first detected, apparently, in [2].

Lunar Ilmenites: The SEP fractionation is strongly variable from event to event, so that its long-time average values provided with implanted noble gases in lunar samples are of paramount importance. The closed system stepped etching (CSSE) data [3,4] in the lunar ilmenites 71501 (I71) with the exposure age ~100 Ma and 79035 (I79) with that of ~1 Ga, are especially valuable. The solar noble gases, released by CSSE from the initial I71 (1) and I79 (3-4) steps of etching, turned out to be unfractonated SW noble gases, and those from the deep I71 (13) and I79 (16-17) steps were noticeably heavier, like the SEP noble gases. The recorded effects of higher diffusion losses of lighter gases during the first etching steps are easily corrected, indeed, in accordance with the self-diffusion coefficients of the gases [5].

The unexpected “paradox” that ratios of light gases ($^{4}$He/$^{36}$Ar and $^{20}$Ne/$^{36}$Ar) grow with the depth, whereas the $^{84}$Kr/$^{132}$Xe ratio remains essentially constant, turned out to be resolved in the light of the shock wave acceleration mechanism if the ionization of the SEP gases was incomplete [5]. Our modeling with respect to the charge states of the noble gas ions in the SW and with respect to the shock wave acceleration of the SEP in proportion to $(A/Q)^j$ leads to the average charge states of $Q = 8$, 14, 18-19 and 18 for the ions of Ne, Ar, Kr and Xe, respectively, in I71 (13), and to the ones of $Q = 8$, 16, 21-23 and 23 for the same ions in I79 (16-17). The obtained charge states are rather higher than those for the modern SW, the average charge states for ~1 Ga being rather higher than those for ~100 Ma, but, on the whole, they all lie in the temperature range of 2-4 MK, in which the solar activity variation may be expected over that time scale.