Adsorption Mechanism of the Escape of the Lunar Atmosphere

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At present it is generally accepted that the Earth' s hydrosphere and atmosphere are the result of its geological development and that their formation is connected with the melting and degassing of mantle material ([1]). In recent years E. K. Markhinin ([4]) has succeeded in estimating the quantity of water vapor and other gases ejected into the atmosphere. These data have shown that, over the geological history of the Earth, the release of volatile components by volcanoes (assuming an intensity of volcanic activity close to the present one) is quite sufficient for the formation of the hydrosphere and atmosphere. One may suppose that analogous processes of volatile release are also characteristic of the Moon. This is confirmed by direct observations of the Moon ([2,3]).

American investigators ([11]) have recently systematized all the "nonstationary" points on the visible side of the Moon, which testify to endogenous activity on the lunar surface. At the same time, the data on the geology of the Moon accumulated by the present time convincingly attest to the long duration of the formation of its surface structures and, consequently, to the long duration of its geological history ([6,9,12]). The similarity of structures of different ages makes it possible to assume a long duration of volcanic activity on the Moon as well. In addition, one may suppose that there are other processes on the Moon leading to the generation of gases. These should first of all include impacts of meteorites on the lunar surface. The corresponding calculations, showing the role of these processes in local heating of its surface and in evaporation of its material, were carried out by K. P. Stanyukovich and V. V. Fedynskii ([7]). Some role may also be played by the decay of radioactive elements contained in the lunar crust.

However, as the results of optical and radio-astronomical observations show, the concentration of gases in the lunar atmosphere at the present time is vanishingly small (it is smaller than the concentration of air at sea level at the Earth's surface by at least a factor of 10^{12}). To explain the absence of an atmosphere on the Moon, the mechanism of thermal dissipation of gases from the lunar surface is chiefly invoked. Owing to the small mass of the Moon, the escape velocity is comparatively small ($v_k = 2.38$ km/sec). The mean velocity of thermal motion of molecules of gases with small molecular weight at temperatures that occur at the lunar surface in the daytime (300—400°K) has a value of the same order as the escape velocity, and the dissipation time of such gases as H_2, He, on the Moon is very small. However, for a gas typical of the Earth' s atmosphere such as N_2, the time of thermal dissipation, if estimated by Jeans' formula, is of the order of 10^7 years. By Shklovskii' s more exact formula, an even longer dissipation time is obtained ([10]). For such gases as SO_2, the dissipation time is greater than the age of the Moon.

Thus, thermal dissipation of gases cannot explain the practically complete absence of an atmosphere on the Moon. Therefore, to explain dissipation, other mechanisms are invoked: the ionizing action of ultraviolet solar radiation, the transfer of energy to molecules

of the lunar atmosphere by particles of the corpuscular radiation of the Sun (the solar wind), and the formation, at some height above the Moon, of an ionized layer analogous to the terrestrial exosphere, with a temperature of 1000-1500°C. There is no mathematical analysis in the literature of the action of these mechanisms. Qualitative estimates are insufficiently substantiated. Thus, for example, the cross section for the process of energy transfer to molecules by protons with an energy of 2 keV is taken to be 10^{-15} cm^2. For these energies, which exceed many times the energy of ionization and dissociation, the cross section of molecules is many orders of magnitude smaller.

It appears that, in order to explain the absence of an atmosphere on the Moon, it is necessary to take into account the process of adsorption of gases by the lunar surface. The adsorption capacity of the lunar surface must be considerable, owing to its high porosity ([5,8]). The settling of cosmic dust, fresh lava covers, and new surfaces formed after particles produced by meteorite impacts settle onto the surface of the Moon—all this should restore the adsorption capacity of the lunar surface. However, the most important aspect of the process of absorption of gases by the porous material of the lunar surface is the thermodiffusion of adsorbed molecules into the depth of the porous layer under the action of the temperature gradient. During the day the temperature decreases inward from 300-400°K at the very surface to 200-250°K at a depth of 0.5-2 m ([8]). Since the coefficient of surface diffusion of adsorbed atoms depends very sharply on temperature, this should cause a diffusion flux into the porous layer. The reverse flux, which, generally speaking, will occur at night, when the temperature gradient is directed outward, may be neglected, since the low temperature of the surface layer will lead to an almost complete cessation of diffusion processes. If the heat of adsorption of gas molecules exceeds the activation energy of surface diffusion of the gas along the surface of the adsorbent, the probability of desorption of molecules is less than the probability of their migration into the porous layer. The adsorptive escape of such gases will predominate over thermal dissipation. The phenomenon considered should lead to the accumulation of many chemical substances at a small depth within the surface layer of the lunar crust.

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REFERENCES

1. A. P. Vinogradov, *Izv. AN SSSR, ser. geol.*, No. 4 (1967).
2. N. A. Kozyrev, in: *New on the Moon*, Publ. House of the Academy of Sciences of the USSR, 1963.
3. Yu. N. Lipskii, M. M. Pospergelis, Bureau of Astronomical Communications, *Astronomical Circular*, No. 389, 1–2 (1966).
4. E. K. Markhinin, *The Role of Volcanism in the Formation of the Earth' s Crust*, "Nauka," 1967.
5. *The First Panoramas of the Lunar Surface*, "Nauka," 1966.
6. A. L. Sukhanov, V. G. Trifonov, *Geotektonika*, No. 4 (1967).
7. K. P. Stanyukovich, V. V. Fedynskii, *DAN*, 57, No. 2 (1947).
8. V. S. Troitskii, *Izv. vyssh. uchebn. zaved., ser. Radiofizika*, 9, No. 10 (1967).
9. A. V. Khabakov, in: *The Moon*, Moscow, 1960.
10. I. S. Shklovskii, *DAN*, 76, No. 2 (1951).
11. B. M. Middlehurst, P. A. Moor, *Sci.*, 155, No. 3761 (1967).
12. J. E. Spurr, *Geology Applied to Selenology*, 1945.

Note: Figure translations are in progress. See original paper for figures.