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Lightning-induced astrobiological potential of rare gas-grain medium

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Introduction

After Miller experiments [1] electric discharges are consider as one of energy sources for synthesis of biochemical compounds both in Earth's atmosphere [2] and in atmospheres of others bodies of Solar system [3,4]. The researches of gas-grain chemistry demonstrate that the chemical reactions on gas-grains boundary play a considerable role in changes of molecular composition of gas-grains mediums [5,6]. Electric discharges in such rare gas-grain mediums can be not only energy source for synthesis of biochemical compounds. For prebiotic chemistry will have the important consequences that plasma of these discharges will have properties of dusty plasma. First, it is the presence of the charged micron-size particles (0,1...10 μm) [7]. These grains can be charged up to values $10^3$10^5 elementary charges at sticking of high-energy electrons and ions ($\geq$1eV), which are produced at lightning discharge.

What is the real role of the electrical discharge in synthesis of biochemical compounds? What types of discharges, and in what conditions they can play a substantial role in synthesis of biochemical compounds? By what criteria it is necessary to evaluate an astrobiological potential of different types of discharges and mediums, in which they happen?

The purpose of this paper is the attempt to estimate the influence of parameters of gas-grain medium on such lightning-induced astrobiological potential. As basis for these

estimations are used the parameters of discharges (sprites) [8] in high layers of Earth's atmosphere (50...90km) and supposing that discharges with such properties happen in gas-grain medium.

Lightning-induced astrobiological potential of rare gas-grain medium in case of different types of discharges

The astrobiological potential of gas-grain mediums at influence of electric discharges can be realized by two ways:

- in gas-grain medium there are processes as a result of which is probably accumulation of charges on grains or drops, spatial separation of particles with opposite charges and consequent discharges between opposite charged volumes. On the Earth such situation will be realized at usual lightning or lightning's at volcano eruption.
- in region of discharges in a usual gaseous atmosphere ingress the gas-dusty cloud with the composition, in which is possible the synthesis of biochemical compounds. The similar case can be realized at interaction with comet and ingress the cometary's matter in region of sprites. In paper is evaluated quantity and composition of cometary's matter, which ingress in area of sprites at interaction of a comet with the Earth.

First, we should consider quantity of discharges, quantity of matter in the area of discharges and energy, which dissipates at discharges. It is evident that frequency of usual lightings and energy dissipates at discharges make their basic candidate for a role of an energy source for synthesis in atmosphere.

On the second place most likely, there will be sprites. Sprites occur randomly with only about one percent of lightning strokes. If a typical lightning strikes the Earth 100 times each second, that sprite happens 1 time per second. The brightest region disposes in the altitude range 65-75 km and extends to about 90 km. Sprites may extend across horizontal distances of 50 km or more and occupy atmospheric volumes about 10^4 km^3.

It is interesting to evaluate quantity of matter, which is located in the area of these discharges. The strongest usual lightings in the Earth's atmosphere take a volume less than 0,0001 cubic km. Even if to take into account fractal structure of sprites, it on 7 ... 8 orders is more, than volume of a usual lightning. Quantity of matter in a volume of a sprite constitutes approximately 10^5 ... 10^6 tons. At discharge of a usual lightning volume is contained approximately 10^2tons.

On my opinion, this difference gives the reason to speak about higher astrobiological potential of sprites in comparison with usual lightings.

Lightning-induced chemistry in gas-grain medium

Two factors arising at interaction of grain and ice with plasma of discharge introduce additional capabilities for synthesis of organic compounds on a surface of ice and grain:

- bombardment of particles by high-energy electrons and ions;
- the micron-size particle accumulate a charge about 10^3 e.

The first factor will promote formation of new species on a surface of all particles, including uncharged. The second factor will increase probability of collisions of ions with particles, subsequent recombination at their surface and formation of new species. For estimation of impact discharge on chemical reactions in gas-grain mediums will be necessary following parameters of plasma and dependence from altitude: temperature of electrons and ions T_e, T_i, mean velocity of electrons and ions v_e ,v_i , concentration of electron and ions n_e, n_i and charge of a grains Z_g (table 1). For these estimations are used the parameters of sprites on different altitudes (50 km, 70km, 90 km).

Table 1

		Earth atmosphere, altitude km		
		50	70	90
Pressure, Torr		0,6	0,04	0,0013
Free path, m		$0{,}07 \cdot 10^{-3}$	$0{,}8 \cdot 10^{-3}$	$20 \cdot 10^{-3}$
Electric field, V/m		$\sim$ 500	$\sim$ 200	$\sim$ 50
Electrons and ions temperature		$T_e \sim$ 0,35 eV $T_i \sim$ 0,04eV	$T_e \sim$ 1,3 eV $T_i \sim$0,15eV	$T_e \sim$ 8 eV $T_i \sim$ 1eV
Electrons velocity, cm s^{-1}		$v_e \approx 4 \cdot 10^{7}$	$v_e \approx 8 \cdot 10^{7}$	$v_e \approx 18 \cdot 10^{7}$
Electrons density, cm^{-3}		$0{,}1 \cdot 10^{5}$	$1 \cdot 10^{5}$	$0{,}1 \cdot 10^{5}$
Charge Z_g	0,1 micron	$\approx$ 1	$\approx$ 10	$\approx$ 3
	1 micron	$\approx$ 40	$\approx$ 800	$\approx$ 200
	10 micron	$\approx$ 1000	$\approx$ 8000	$\approx$ 20000

Further, we can estimate quantity potentially of possible formations of some compounds on a surface of grains, as the recombination of ions in dusty plasma take place on negatively charged grains.

Conclusion

The electric discharges in rare gas-grains mediums will serve not only power source for synthesis of biochemical connections. It is possible to tell, that the density rare gas-dusty atmosphere, which corresponds to density of the Earth's atmosphere at altitudes 70…90 km (pressure 0,04 … 0,001 Torr) will be the such density at which may be appear additional capabilities for prebiotic chemistry. The expediency of researching in similar atmospheres is called also by that in a history of the early Earth probably there were periods, when in high layers of atmosphere was more dust and ice.

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