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Abstract

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GEOPHYSICS

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ESTIMATE OF THE CONCENTRATION OF NEGATIVE IONS IN THE *D* REGION OF THE IONOSPHERE

(Presented by Academician E. K. Fedorov, February 18, 1967)

One of the most important questions in the modern study of the *D* region of the ionosphere is the question of the concentration of negative ions n_i^- . Rocket measurements of the electron concentration n_e at altitudes of 60–100 km make it possible to obtain, on the average, more or less reliable values of n_e ⁽¹⁾, in agreement with ground-based measurements. At the same time, the rocket-measured values of n_i^+ and n_i^- reported by different authors differ by as much as 2–2.5 orders of magnitude ^(1–5). In this connection the relative values n_i^+/n_e and n_i^-/n_e turn out ⁽⁵⁾ to be an order of magnitude higher than is given by the theory ⁽⁶⁾, based on allowance for the mechanisms of formation and destruction of negative ions. The conclusions of the theory ⁽⁶⁾ are disputed in a number of works ^(7,8). Below an attempt is made to estimate the value $l^- = n_i^-/n_e$, starting from ionospheric data on the effective recombination coefficient α' .

As is known, changes in the electron concentration in the *D* region of the ionosphere are determined by the equation

$$dn_e/dt = q/(1 + l^-) - \alpha' n_e^2. \quad (1)$$

The effective recombination coefficient α' is related to the dissociative recombination coefficient α^* and the coefficient of mutual neutralization of positive and negative ions α_i by the relation

$$\alpha' = \alpha^* + \alpha_i l^-. \quad (2)$$

Thus, starting from α' , one can determine the value l^- if the constants α^* and α_i are known. For the value α^* we use $(2-3) \cdot 10^{-7} \text{ cm}^3 \cdot \text{sec}^{-1}$, which, according to the latest data ⁽⁹⁾, corresponds to the atmospheric temperature at the altitudes under consideration. Let us consider in more detail the available data on α' .

A review of the results of experimental measurements of α' in the *D* region of the ionosphere was given by Mitra ⁽¹⁰⁾. We note that individual measurements may differ from the mean values, shown by crosses in Fig. 1, by a factor of 2–3, which also characterizes the accuracy of the mean values of α' . Fig. 1 also gives the values q/n_e^2 for daytime conditions ^(b) during solar flares according to

(¹¹), and for nighttime conditions (a) during polar blackouts according to (¹²). According to (1), for stationary conditions the quantity q/n_e^2 should be greater than α' by a factor of $1 + l^-$. Taking into account that the differences between the indicated quantities at altitudes of 60–80 km lie within a factor of 1.5–2.5, one may conclude that even at 60 km l^- is probably only slightly greater than unity. Apparently, more reliable estimates of l^- can be obtained from comparison of $\alpha'n_e^2$ (see Table 1) for quiet conditions (n_e taken from ground-based measurements (¹³)) at altitudes of 50–60 km with the value of q , which here is determined only by cosmic rays. We used the latest calculations (^{14,15}), which give values of q an order of magnitude higher than in (⁶). The values of l^- obtained for altitudes of 50 and 60 km are used to estimate the constant α_i , and then we determine l^- from α' for greater altitudes.

The excess of α' over α^* is equal to $\alpha_i l^-$. The dashed line in Fig. 1 gives the lower limit of α' . Hence, from the data on l^- for altitudes of 50–60 km we find $\alpha_i = (0.7-2) \cdot 10^{-6} \text{ cm}^3 \cdot \text{sec}^{-1}$, which is close to the value $\alpha_i = 1.6 \cdot 10^{-6} \text{ cm}^3 \cdot \text{sec}^{-1}$ obtained from data on ionization at low altitudes of 5–30 km (it is given in the handbook (¹⁶)). Using this value of α_i ,

one can obtain the values of l^- (and, taking into account n_e , the values of n_i^-) given in Table 1. It is seen that at heights of 50–70 km the values $n_i^+ = n_i^- + n_e$ are close to the new results of rocket measurements (²). The values of l^- are apparently determined to within a factor of 2–3. It is important to emphasize that the variation of l^- with height is determined only by the data on α' and α^* .

Thus, the use of data on the profile $\alpha'(h)$ makes it possible to estimate the relative concentration of negative ions at heights of 50–80 km.

Let us compare the obtained values of l^- with the theoretical values determined by the formula

$$l^- = \frac{1.5 \cdot 10^{-30} [O_2]^2}{\rho + kn}, \quad (3)$$

where n and $[O_2]$ are the concentrations of neutral particles and oxygen molecules, respectively; k may be regarded as an effective constant for reactions of electron detachment from negative ions as a result of collision processes. Using the data on the atmospheric model in (¹⁶), one can find that the values of l^- in Table 1 satisfy formula (3) for $\rho = 0.2-0.45 \text{ sec}^{-1}$ and $k = (3-10) \cdot 10^{-17} \text{ cm}^3 \cdot \text{sec}^{-1}$. We note that the value of ρ agrees with modern data (¹⁵), while the value of k is close to Bailey's estimates from independent data during PCA (¹⁷). Indeed, as is known, the diurnal variations of radio-wave absorption during PCA are equal to ~ 4 , whence it follows that $\rho + kn \approx 4k$. Taking into account that, according to rocket measurements, absorption occurs at heights of 65–75 km (¹), we obtain $k = (3-6) \cdot 10^{-17} \text{ cm}^3 \cdot \text{sec}^{-1}$. These conclusions are important for the photochemistry of the D region.

(Figure: Fig. 1)

Fig. 1

Table 1

	h , km			
	50	60	70	80
α' , $\text{cm}^3 \cdot \text{sec}^{-1}$ (¹⁰)	$2.5 \cdot 10^{-5}$	$8 \cdot 10^{-6}$	$2.1 \cdot 10^{-6}$	$4.7 \cdot 10^{-7}$
n_e , cm^{-3} (¹ , ¹³)	20	50	160	800
$\alpha' n_e^2$, $\text{cm}^{-3} \cdot \text{sec}^{-1}$	0.01	0.02	—	—
q , $\text{cm}^{-3} \cdot \text{sec}^{-1}$ (¹⁴)	0.35	0.1	—	—
l^-	35	4	1.1	0.1
n_i^- , cm^{-3}	700	200	180	240

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