MSU Fen Bil. Dergi., Cilt 6, Sayı 1, s 529-532 *Araştırma Makalesi/ Research Article*
MSU J. of Sci., Volume 6 , Issue 1, p 529-532 DOI : 10.18586/msufbd.422592

The change of the collision parameters of '$O^+ + N_2 \rightarrow NO^+ + N$' reaction according to geomagnetic activity days in the ionosphere

Mehmet YAŞAR[1]🖉, Ramazan ATICI[2], Selçuk SAĞIR[3]
[1]Department of Physics, Faculty of Science, Firat University, Elazığ, Turkey
[2]Faculty of Education, Mus Alparslan University, Muş, Turkey
[3]Department of Electronic and Automation, Technic Science Vocational School, Mus Alparslan University, Muş
✉: mehmetyasar@firat.edu.tr

Received (Geliş): 10.05.2018. Revision (Düzeltme): 22.05.2018 Accepted (Kabul): 29.05.2018

ABSTRACT

A plasma is a medium containing a large number of charged particle interactions. For this reason, it is common and appropriate to examine the plasma in terms of kinetic theory. In this context, the collision dynamics of the **'$O^+ + N_2 \rightarrow NO^+ + N$'** reaction for geomagnetically quiet day (04/09/2017) and disturbed day (08/09/2017) were calculated for ionospheric altitudes with the help of kinetic theory. As a result of the calculation, it was seen that the mean free path values were less on the disturbed day, as expected. The total collisions number was seen to reach maximum at the height of hmF2 on both quiet and disturbed days, and the disturbed day values were greater. It was seen that the collision frequency decreased exponentially with altitude.

Keywords: Collision dynamics, ionosphere, geomagnetic storm, kinetic theory

İyonkürede jeomanyetik aktivite günlerine göre '$O^+ + N_2 \rightarrow NO^+ + N$' reaksiyonunun çarpışma parametrelerinin değişimi

ÖZ

Bir plazma çok sayıda yüklü parçacık etkileşimlerini içeren bir ortamdır. Bu nedenle plazmayı kinetik teori açısından incelemek yaygın ve uygundur. Bu bağlamda jeomanyetik olarak sakin gün (04/09/2017) ve tedirgin gün (08/09/2017) için **'$O^+ + N_2 \rightarrow NO^+ + N$'** reaksiyonuna ait çarpışma dinamikleri kinetik teori yardımıyla iyonküresel yükseklikler için hesaplandı. Hesaplama sonucunda ortalama serbest yol değerlerinin beklenildiği gibi tedirgin günde daha düşük olduğu görüldü. Toplam çarpışma sayısının ise hem sakin hem de tedirgin günde hmF2 yüksekliklerinde maksimuma ulaştığı ve tedirgin gün değerlerinin daha büyük olduğu belirlendi. Çarpışma frekansının ise üstel olarak azaldığı görüldü.

Anahtar Kelimeler: Çarpışma frekansı, jeomanyetik fırtına, iyonküre, kinetik teori

INTRODUCTION

The geomagnetic storm refers to the intense energy input from the magnetosphere into the Earth's upper atmosphere [1]. This energy input leads to the changes in the complex morphology of the electric field, temperatures, winds and media components, and affects all ionospheric parameters [2]. During geomagnetic storms, the quite increasing energy of the magnetospheric flux is spent at the high-latitude of the ionosphere and causes ionospheric disturbances expanding into the equator [3]. Perturbations occurred at ionospheric F region heights in association with the geomagnetic storm, (termed ionospheric storms) last for several days, including the recovery period [2,4]. The energy that enters the upper atmosphere from the magnetosphere in a geomagnetic storm causes to heat up.

Mehmet YAŞAR orcid.org/0000-0002-2758-3635
Ramazan ATICI orcid.org/0000-0001-7884-0112
Selçuk SAĞIR orcid.org/0000-0002-5698-0154

As the heating changes the rates of the chemical reactions and the atmospheric components at that point, it increases the thermospheric circulation and produces traveling ionospheric disturbances (TIDs), disturbance dynamo electric field (DDEF) [3]. Since the changes in the chemical dynamics of the ionosphere lead to the phenomena above mentioned during the period of geomagnetic storm, the investigation of the dynamics of these chemical reactions may lead to a clearer understanding about these events. The kinetic theory for classical gases consists of a combination of mechanics and statics. The theory states that the motions of molecules are determined by probabilities rather than their own directions [5]. In plasma kinetic theory, the change in particles is defined by the distribution functions expressed by kinetic equations [6]. For kinetic theory used in obtained the plasma convection flux and the conservation laws, the identification of either the cross section or the interaction potentials between gases is one of the main problems [7]. Despite the difficulty of quantum mechanical or plasma physical calculations of reaction dynamics such as reaction cross-section and rate constant associated with reactive collisions, which have an important place in ionospheric plasma, the importance of the work to be done on this subject is emphasized [8, 9].

In this study, the change of collision dynamics of the $O^+ + N_2 \rightarrow NO^+ + N$ reactive reaction occurring at the ionospheric altitudes (150-600 km) over Elazığ / Turkey (38 41' N and 39 13' E) was investigated by means of kinetic theory. The investigation was conducted for active (08.09.2017) and quiet (04.09.2017) days of the geomagnetic storm, which is an effective on the ionosphere.

MATERIAL and METHOD

The density and temperature values used to investigate the collision dynamics of the present reaction in the study was obtained by the IRI and MSISE-90 model for Elazığ, Turkey coordinate at Local Time (LT) 02:00.

The kinetic theory for gases includes statistical approaches as well as dynamic-based methods. With these approaches, kinetic theory allows the identification of a large number of individual molecules [5]. The distance traveled between two consecutive collisions of a single molecule is defined as the mean free path. The mean free path is defined as the inverse of the multiplication of the collision cross section by the particle density [5,9]:

$$\lambda = \frac{1}{\sigma n} \qquad (1)$$

where, σ is the cross section and n is the density of the molecule.

Collisions play a fundamental role in the dynamics and energy of the ionosphere, as they are responsible for the production of ionization, the diffusion of plasma from high -density regions to low -density regions, heat transfer from hot regions to cold regions, energy exchange between different species, and other processes [10-12].

In this study, it was assumed that the ion was mobile and the molecule was stagnant in the reaction "$O^+ + N_2 \rightarrow NO^+ + N$". It is assumed that all other molecules move at the same $\bar{v}$ velocity and that the relative velocity of the others relative to the particle fraction is $\bar{g}$ (where $\bar{g}$ and $\bar{v}$ denote the relative and average velocities of the molecules, respectively). Considering the number of collisions at the time dt with the immobile molecule, these particles, which collide with the N_2 molecule at time t = 0, have a circular cylinder with a volume of $\sigma\, \bar{g}\, dt$ and a length of $\bar{g}\, dt$. Thus, the number of collisions of the N2 molecule (at time dt) is equal to the product of the density of the colliding molecules and the cylinder volume, $n\, \sigma\, \bar{g}\, dt$ [5,11]. Therefore, the number of collisions of a single molecule at per unit time,ν, is given by

$$\nu = \sqrt{2} n\, \sigma\, \bar{v} \qquad (2)$$

Where, v is the velocity of the moving particle and n is the density of the immobile molecule.

Total Collision Number

The total collisions number of a moving particle on a particle that is stationary in the environment is defined as the collision frequency. The total collisions number between two particles Z_{12} is given by

$$Z_{12} = 4\pi \kappa_{12} \sigma n_1 n_2 \left(\frac{m^*}{2\pi kT}\right)^{3/2} \int_{g_0}^{\infty} dg\, g^3 e^{-\frac{m^* g^2}{2kT}} \qquad (3)$$

where k is Boltzmann constant, m^* is reduced mass, n_1 and n_2 is particles density and g is relative velocity. This equation applies to both forward and reverse reactions. Reversible reactions involve the collision of two similar molecules, while forward reactions involve the collision of different molecules. As a result, κ_{12} is ½ for reversible reactions and κ_{12} is 1 for forward reactions [5].

NUMERICAL RESULTS and DISCUSSIONS

In this study, **'$O^+ + N_2 \rightarrow NO^+ + N$'** reaction represents a reactive collision. The changes of the collision parameters for this reaction according to ionospheric altitudes for days, expressed as quiet day and disturbed day according to geomagnetic activity values, are shown in Figure 1. The parameters between (b) and (e) in both panels show the mean free path, collision frequency, total collision number, and collision cross section of the reactive ionospheric reaction "$O^+ + N_2 \rightarrow NO^+ + N$" respectively. (f) - (h) are the input parameters used to calculate the dynamics of this reaction and denote the density of the oxygen ion, the density of the nitrogen molecule, and the reaction temperature, respectively. Reaction temperature is defined as the arithmetic average of ion and neutral temperatures. (a) shows the change in ionospheric electron density for comparison. It is seen that the change of parameters according to altitude is showing differences in the numerical values of the parameters due to their height-dependent changes in active and quiet days while it is showing curvilinear similarities. It can be seen that the average temperature values obtained for the disturbed day are higher than the quiet day values ranging from about 57-73 K.

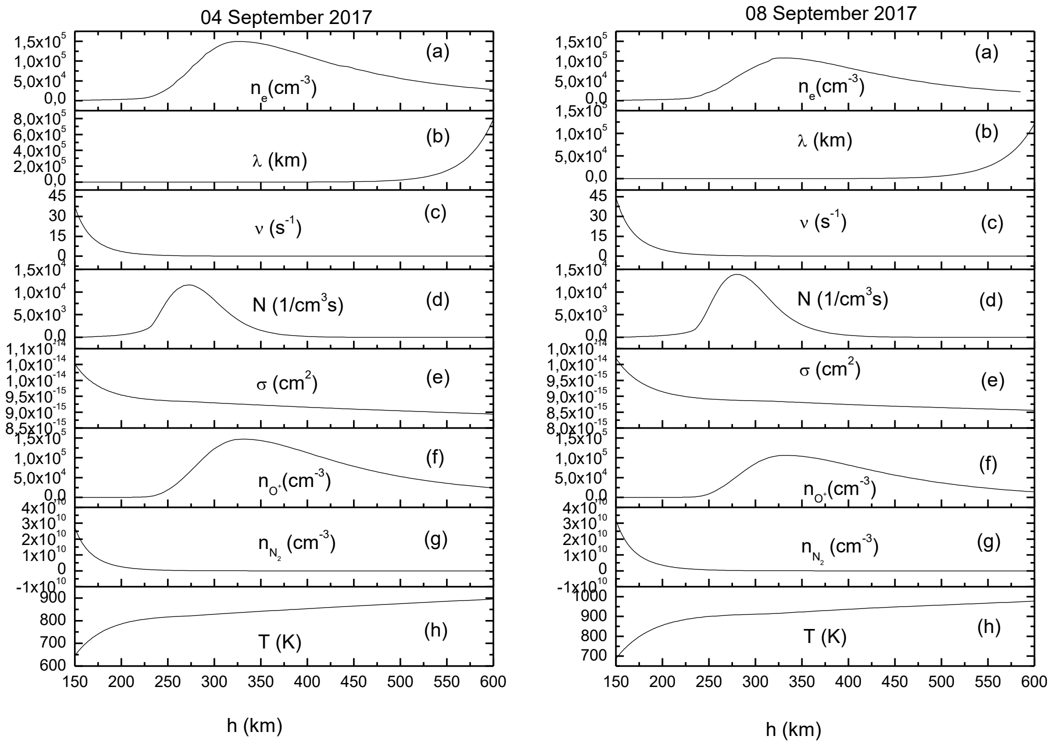

Figure 1. Change with altitude of the parameters of the present reaction for quiet (04 September) and disturbed (08 September) days of geomagnetic activity. While the left panel shows the changes in the geomagnetically quiet day, the right panel shows the changes in the disturbed day.

The mean free path values (curve indicated by (b) in the graphs) show a similar exponential distribution with altitudes on both quiet and disturbed days. However, it appears that the disturbed day's values are lower and the mean free-path increases in quiet days begin at lower altitudes. This can be attributed to the increase in the total collision numbers (the curves indicated by (d)) due to the lower value of the electron density during the disturbed days. The sudden increase, which starts at approximately 475 km in both days, may be related to the low values of electron, O^+ and N_2 intensities at these altitudes. The fact that N_2 density (the curves indicated by (g)) is the maximum at lower altitudes and shows a continuous decrease with increasing altitude has affected the collision frequency reaching its maximum value at the initial height and then decreasing. The total collision number (curves indicated by (d)) reached the maximum value at hmF2 altitudes at both disturbed and quiet day. The steady increase in Z_{12} from its initial height to its maximum value can be explained by the increase in the O^+ concentration (the curves shown in (f)) and the thermal rate, despite the increase in electron density up to hmF2 heights as well as the small-scale decrease in N_2 density. The declining trend from the maximum point to 600 km is due to the effect of decreasing the N_2 and O^+ density and the cross section (curves indicated by (e)).

REFERENCES

[1] Fuller-Rowell T., Codrescu M., Roble R., Richmond A. How does the thermosphere and ionosphere react to a geomagnetic storm? Magnetic storms**,** 203-225, 1997.

[2] Buresova D., Lastovicka J. Changes in the F1 region electron density during geomagnetic storms at low solar activity. Journal of Atmospheric and Solar-Terrestrial Physics, 63, 537-544, 2001.

[3] Polekh N., Zolotukhina N., Kurkin V., Zherebtsov G., Shi J., Wang G., Wang Z. Dynamics of ionospheric disturbances during the 17-19 March 2015 geomagnetic storm over East Asia. Advances in Space Research, 60, 2464-2476, 2017:

[4] Ratcliffe J.A., Weekes K. The ionosphere. Disturbances and storms in the ionosphere. In: Ratcliffe, J.A. (Ed.), Physics of the Upper Atmosphere. The University Press Aberdeen, Great Britain. 1960.

[5] Yaşar M. Investigation of the O++H2 → OH++H reaction by quantum mechanical approach in the ionosphere, Firat University, Institute of Science. 2017.

[6] Kirk J.G., Melrose D.B., Priest E.R. Plasma Astrophysics: Saas-Fee Advanced Course 24. Lecture Notes 1994. Swiss Society for Astrophysics and Astronomy. Vol. 24, Springer Science Business Media. 2006.

[7] Graille B., Magin T.E. Massot M. Kinetic theory of plasmas: translational energy. Mathematical Models and Methods in Applied Sciences, 19, 527-599, 2009.

[8] Rees M.H. Physics and chemistry of the upper atmosphere. Vol. 1, Cambridge University Press. 1989.

[9] Aydogdu M., Güzel E., Yesil A., Özcan O., Canyilmaz M. Comparison of the calculated absorption and the measured field strength of HF waves reflected from the ionosphere. Nuovo Cimento C Geophysics Space Physics C 30, 243-253, 2007.

[10] Schunk R., Nagy A. Ionospheres: physics, plasma physics, and chemistry. Cambridge university press.Sen M., Cakar O., Experimental modal analysis of a polyurethane sandwich panel, International Conference on Engineering and Natural Science (ICENS), Sarajevo, Bosnia. 2016, 2009.

[11] Yaşar M., Canyılmaz M. Investigations of chemical processes of O^+ +H_2(V=0, J=0) reaction using thermal

variation in the ionospheric regions. Thermal Science**,** 270-270, 2017.

[12] Alisoy H., Yesil A., Koseoglu M., Unal I. An approach for unipolar corona discharge in N2/O2 gas mixture by considering townsend conditions. Journal of Electrostatics, 69:4, 284-290, 2011.