455-10

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No.NAS-5-12487

N69-15513

ST — SP — ACH — 10794

CASE FILE COPY

JAN 1969
RECEIVED
NASA STI FACILITY
INPUT BRANCH

THE ROLE OF ELECTRON IMPACT IN THE DESTRUCTION OF CARBON MONOXIDE MOLECULES ON THE SUN

by

A. P. Sarychev
& G. F. Sitnik

(USSR)

FACILITY FORM 602

(ACCESSION NUMBER)
(THRU)
6 (PAGES)
1 (CODE)
CR#99139 (NASA CR OR TMX OR AD NUMBER)
30 (CATEGORY)

8 JANUARY 1969

ST-SP-ACH-10794

THE ROLE OF ELECTRON IMPACT IN THE DESTRUCTION OF CARBON MONOXIDE MOLECULES ON THE SUN*

Astronomicheskiy Zhurnal
Tom 45, No.6, 1303-1305
Izdatel'stvo "NAUKA", 1968

by A. P. Sarychev
& G. F. Sitnik

SUMMARY

The rate is estimated of carbon monoxide (CO) molecule dissociation by electron impacts in the upper layers of the solar photosphere on the basis of the results of experiments on the collision of electrons with molecules obtained in [2—4]. Comparison of this rate with those of photodissociation and dissociation at collisions with hydrogen atoms, computed in [1], shows that the electron collision plays practically no significant role in the destruction of CO molecules on the Sun.

* * *

Analysis is pursued in this paper of mechanisms of CO molecules' decay in the transitional layer between the Sun's photosphere and chromosphere. Two elementary processes of CO destruction were investigated in [1]: the thermal dissociation at collisions with hydrogen atoms and the photodissociation. It was established by way of comparison of these reaction rates that dissociation at radiation absorption is somewhat more effective that the decay under the influence of hydrogen atom impacts. Besides photons and hydrogen atoms, free electrons are also part of actively acting components of solar atmosphere on molecules. The present work is devoted to ascertaining the role of electron impact in the destruction of CO molecules on the Sun.

The dissociation of molecules into neutral atoms as well as ions can be the result of inelastic collisions of electrons with molecules. In experiments on dissociation into atoms one is compelled to meet with difficulties in detecting and identifying the neutral products of the reaction, but the dissociative

---

*ROL' ELEKTRONNOGO UDARA V RAZRUSHENII MOLEKUL CO NA SOLNTSE ionization is quite successfully studied by the method of retarding (counter) potential and the method of mass-spectrography. In particular, the following processes are revealed during the bombardment of carbon monoxide by electrons (the numerals standing to the left show the minimum kinetic energy required for reaction onset) [2, 3]:

$$9.6 \text{ ev} \quad CO + e \rightarrow C + O^-, \tag{1}$$

$$20.9 \text{ ev} \quad CO + e \rightarrow C^+ + O^- + e, \tag{2}$$

$$22.8 \text{ ev} \quad CO + e \rightarrow C^+ + O + 2e, \tag{3}$$

$$23.2 \text{ ev} \quad CO + e \rightarrow C^- + O^+ + e. \tag{4}$$

It is easy to see that among the above written four reactions, the first is the most advantageous. This reaction, which is the process of dissociative capture of the electron by CO molecule, has been investigated in detail by Schultz [4]. In the aggregate of careful experiments with an electron beam, he succeeded in determining the effective capture cross section σ as a function of electron's kinetic energy E. The dependence $\sigma(E)$ has a peak, characteristic in form for resonance processes, whereupon the maximum value, $\sigma = 1.6 \ 10^{-19}$ cm^2 is reached at E = 10.1 ev. The knowledge of $\sigma(E)$ allows us to compute the rate of CO dissociation by means of electron capture, or, to be more precise, the reaction rate factor α, entering into law of reagents' concentration variation, is

$$\frac{dN(\mathrm{CO})}{dt} = -\alpha N(\mathrm{CO}) N(e),$$

where N(CO) and N(e) are respectively rhe concentrations of CO molecules and electrons, t is the time. If we assume the Maxwellian distribution of electrons by velocities and consider that the velocities of molecules are negligibly small by comparison with those of electrons, we have

$$\alpha = 4(2\pi m_e)^{-1/2}(kT)^{-3/2} \int_0^\infty E\sigma(E) \exp\left(-\frac{E}{kT}\right) dE; \tag{5}$$

m_e being the mass of the electron, T — the temperature and k the Boltzmann constant. Substituting the values of $\sigma(E)$ from the graph of [1] into formula (5) and integrating numerically for T = 5000°K, we found the rate of CO molecules' decay as a consequence of reaction (1) in conditions of molecular layer of the photosphere:

$$\frac{dN(\mathrm{CO})}{dt} = -2.7 \cdot 10^{-20} N(\mathrm{CO}) N(e)\, \text{см}^3 \cdot \mathrm{sec}^{-1}. \qquad (6)$$

We shall now show that the destruction of CO in the photosphere as a consequence of reactions (2) - (4) is insignificant by comparison with reaction (1). This stems from the fact of the participation in reactions only of electrons having energies much higher than the thermal energy, that is, of the "tail" of Maxwellian distribution. For the temperature of T = 5000°K, the mean energy of electron's therma; motion constitutes only $^3/_2$ kT = 0.65 ev, while the initial potentials of the reactions are respectively E(1) = 9.6 ev, E(2) = 20.9 ev, E(3) = 22.8 ev, E(4) = 23.2 ev. The sharp curtailing, according to the Maxwell law, of the number of reacting electrons at transition from the dissociation threshold according to scheme (1) to threshold of (2) - (4), may be only compensated by the increase of effective cross sectioss. For examples, in order that reactions (1) and (2) be identical, the cross section $\sigma(2)$ must be greater than the cross section $\sigma(1) \sim 10^{-19}$ cm^2 by

$$\frac{\sigma(2)}{\sigma(1)} \approx \frac{E(1)}{E(2)} \exp \frac{E(2) - E(1)}{kT} \approx 10^{11}$$

times (the given estimate is obtained from the condition of equality for these reactions of the values of α, determined by formula (5); for simplicity we considered here the cross sections as independent of the energy of the electron when the latter exceeds the dissociation threshold). Since there is no basis of any kind for expecting in reactions (2) - (4) such high values of σ, we are compelled to recognize the dissociative capture of the electron (1) as the predominant dissociation mechanism with molecule CO ionization in the photosphere.

With respect to molecule CO dissociation by electron impact into neutral atoms

$$\mathrm{CO} + e \rightarrow \mathrm{C} + \mathrm{O} + e \qquad (7)$$

direct data are not available. However, the small probability of process (7) may be qualitatively forecast by utilizing an analogy between CO and N_2 molecules. These molecules are isoelectronic and quite similar in their physical properties. But, inasmuch as at N_2 bombardment by electrons the dissociation into neutral atoms was not experimentally observed [2], we conclude that the reaction (7) itself is apparently little probable.

Thus, we have discussed all the possible variants of CO dissociation by electron impact and ascertained that in conditions of molecular photosphere layer, the most active will be the dissociation by way of electron capture. Therefore, the rate of reaction (1), provided by formula (6), will be close to the aggregate rate of CO decay under the action of collisions with electrons. In order to compare the rate of CO dissociation by electron impact with the photodissociation rates computed in [1]:

$$\left[\frac{dN(\mathrm{CO})}{dt}\right]_{h\nu} = -3.6\cdot10^{-4}N(\mathrm{CO})\ \mathrm{sec}^{-1} \qquad (8)$$

and the dissociations at collisions with hydrogen atoms:

$$\left[\frac{dN(\mathrm{CO})}{dt}\right]_{\mathrm{H}} = -4.0\cdot10^{-6}N(\mathrm{CO})\ \mathrm{sec}^{-1} \qquad (9)$$

we shall substitute in formula (6) the value of electron concentration

$$N(e) \approx 10^{12}\ \mathrm{cm}^{-3}$$

in the region of the molecular layer

$$\left[\frac{dN(\mathrm{CO})}{dt}\right]_{e} = -2.7\cdot10^{-8}N(\mathrm{CO})\ \mathrm{sec}^{-1}\ . \qquad (10)$$

As may be seen from relations (8) - (10), for one act of CO destruction by electron impact corresponds on the average about

$$\frac{4.0\cdot10^{-6}}{2.7\cdot10^{-8}} \sim 10^{2}$$

acts of destruction by atomic hydrogen impacts and

$$\frac{3.6\cdot10^{-4}}{2.7\cdot10^{-8}} \sim 10^{4}$$

photodissociation acts. Consequently, in conditions of transition layer between the photosphere and chromosphere of the Sun the electron impact plays no practically noticeable role in the destruction of CO molecules.

*** THE END ***

The Shternberg's State
Astronomical Institute

Received on 21 May 1968

References follow../..

REFERENCES

1. G. F. SITNIK, M. CH. PANDE. Astronom. Zh. 44, 732, 1967
2. H. S. MASSEY & E. H. S. BURHOP. Electronic and Ionic Impact Phenomena. London, 1952.
3. J. D. CRAGGS & H. S. W. MASSEY. Handb. Physik, 37, 314, 1959.
4. G. J. SCHULZ. Phys. Rev. 128, 178, 1962.

CONTRACT No.NAS-5-12487
VOLT INFORMATION SCIENCES, INC.
1145 - 19th St.NW
WASHINGTON D.C. 20036.
Tel: 223-6700 (X-36)

Translated by ANDRE L. BRICHANT
on 8 January 1969