MEASUREMENT OF THE ATOMIC OXYGEN PARTICLE CONCENTRATION IN DISSOCIATED GASES

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Effects associated with the interaction of atomic oxygen and chemical detectors were previously described in [1]. From the degree of blackening of the chemical detector (measured photoelectrically) it is possible to judge the concentration of atomic oxygen in the medium. We now present the results of an experimental investigation of the possibility of using chemical detectors to measure the absolute concentration of atomic oxygen particles in dissociated gases.

The experimental apparatus was previously described in [1, 2]. The atomic oxygen was obtained by means of an electrodeless high-frequency discharge. As distinct from our previous experiments, on this occasion we were able to record the change in the transmittance of the detectors continuously during the experiment. The setup is illustrated in Fig. 1: light from a stabilized source 1, passing through the chemical detector 4 at the end of the discharge tube, falls on a FSK-1 photoresistor 5 connected to one of the arms of a bridge 6. The change in the transmittance of the chemical detector during a high-frequency discharge in molecular oxygen is registered by a microammeter inserted in the bridge diagonal 7 (2 denotes the discharge chamber, 3 the discharge coil).

From the values of the current flowing through the bridge diagonal it is possible to estimate the change in the transmittance of the chemical detector resulting from interaction with atomic oxygen particles.

The experiments were conducted at initial molecular oxygen pressures $P_0 = 10^{-2}$-10^{-3} mm Hg in the discharge chamber. The change in detector transmittance (at a fixed hf-generater voltage U = 5 V) was recorded as a function of the exposure time at various pressures, i.e., for different densities, determined from the degree of dissociation of the molecular oxygen and the initial pressure P_0.

The degree of dissociation was measured by the method described in [3-6], for which purpose two thermocouple lamps were attached to the discharge tube.

A fine silver mesh was introduced into the inlet opening of one of these lamps. This virtually prevented atomic oxygen from reaching the filament [3, 5, 6]. The distance from the discharge plasma to the filaments of the thermocouple lamps was so selected that the hf field of the high-frequency generator had practically no effect on the measurements. The hf discharge creates a temperature difference between the filaments of the thermocouple lamps that is determined from the thermocouple emf. The filament temperature of the thermocouple lamp without a silver insert increases as a result of the recombination of atomic oxygen particles from the discharge chamber with the particles adsorbed on the surface (i.e., O+O (adsorb) → $O_2 + q$, where q is the heat of the unit recombination event).

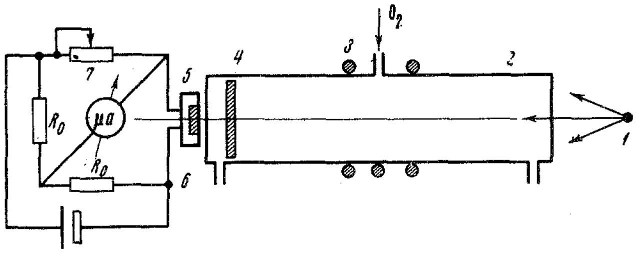

Fig. 1

Using the heat balance equation of the filament and the ratio $\alpha = n/N$ (where N is the total number of particles, and n the atom concentration), we can go over from the temperature difference to the degree of dissociation.

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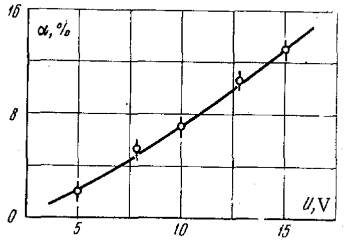

Fig. 2

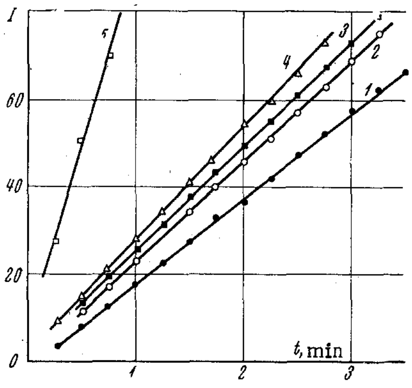

Fig. 3

$$\alpha = \frac{2qK\Delta T}{q}$$

Here ΔT is the filament temperature difference, K Boltzmann's constant, and a the accommodation coefficient for atomic oxygen at the filament surface. The accommodation coefficient $a \sim 1$ [7], while q can be determined from published data [8]. Thus, by experimentally measuring ΔT, we can determine the degree of dissociation of O_2 in the discharge chamber. The estimated measurement error is of the order of 15-20% of the measured value [3, 8, 5, 6].

In Fig. 2 the measured degree of dissociation is plotted against the hf-generator voltage for $P_0 = 2 \cdot 10^{-3}$ mm Hg. There is a tendency for α to increase with voltage.

In Fig. 3 the degree of blackening of the chemical detectors is plotted against exposure time; curves 1-5 correspond to the following density values: n = 3.0, 3.5, 4.0, 5.0, 15 particles/cm^3 10^{12}.

The relation obtained between DI/dt and atom concentration n is presented in Fig. 4. As may be seen from Figs. 3 and 4, the degree of blackening increases linearly with time, and dI/dt is directly proportional to n.

Hence from the slope of the curves tan β = dI/dt we can estimate the atomic oxygen concentration

$$\frac{n_1}{n_2} = \frac{(dI/dt)_1}{(dI/dt)_2}$$

and, having determined dI/dt for some concentration by other independent methods (for example, starting from the measured values of the degree of dissociation and the initial pressure), we can also determine the absolute concentration of atomic particles.

The measurement error of the method described is chiefly determined by the error in calibrating and measuring the degree of blackening of the chemical detectors. According to [1] the error in measuring the change of transmittance is of the order of 10-15%. Since the calibration error is 15-20%, the maximum scatter of the concentration data obtained by the method described should be of the order of 20-30%. However, the use of more accurate calibration methods will make it possible to reduce the error in measuring the atomic oxygen concentration.

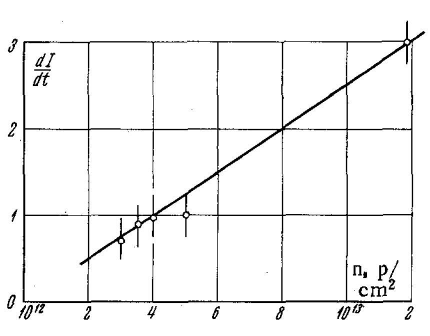

Fig. 4

Chemical detectors can be used to determine the relative concentration of atomic particles in another way. Since the degree of blackening depends linearly on the number of particles striking the detector, by determining the change in the degree of blackening at different pressures for the same measurement time, we can find the ratio and, after calibration, the absolute concentration of atomic particles.

$$\frac{n_1}{n_2} = \frac{I_1(t)}{I_2(t)}$$

and, after calibration, the absolute concentration of atomic particles.

Finally, we note that the results of the experiments confirm the possibility of using chemical detectors to measure the concentration of atomic oxygen particles in rarefied dissociated media. Despite certain disadvantages (limitation on the accuracy of the measurement time determined by the density of the medium, etc.), the method described has a number of good points: a) it is of independent value in connection with the surface interactions of atomic particles; b) as distinct from most spectroscopic methods it can be used to measure the concentration of atoms in dissociated gas flows not in thermodynamic equilibrium; c) as distinct from methods based on the use of thermal probes it possesses selectivity, i.e., it registers a particular species of particles, e.g., O; moreover, errors introduced by measuring the recombination coefficients at the sensitive elements of the thermal probe are eliminated. With further improvement (in methods of preparing the chemical detectors, calibration methods, methods of recording the degree of blackening, etc.) the ability of chemical detectors to change their transmittance upon interaction with O may provide a basis for the design of a rocket-borne instrument to measure the atomic particle concentration in the upper layers of the atmosphere.

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