can cause local damage to the crystal at low temperatures, such as observed by Krivokhizha at al. [1] In addition, at large values of R a purely longitudinal wave cannot exist and shear stresses arise, which under certain conditions can reach large values. These stresses can also cause crystal damage.

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FEATURES OF SCATTERING OF FAST BEAMS OF H, N, AND O ATOMS IN MOLECULAR GASES (N_2, O_2)

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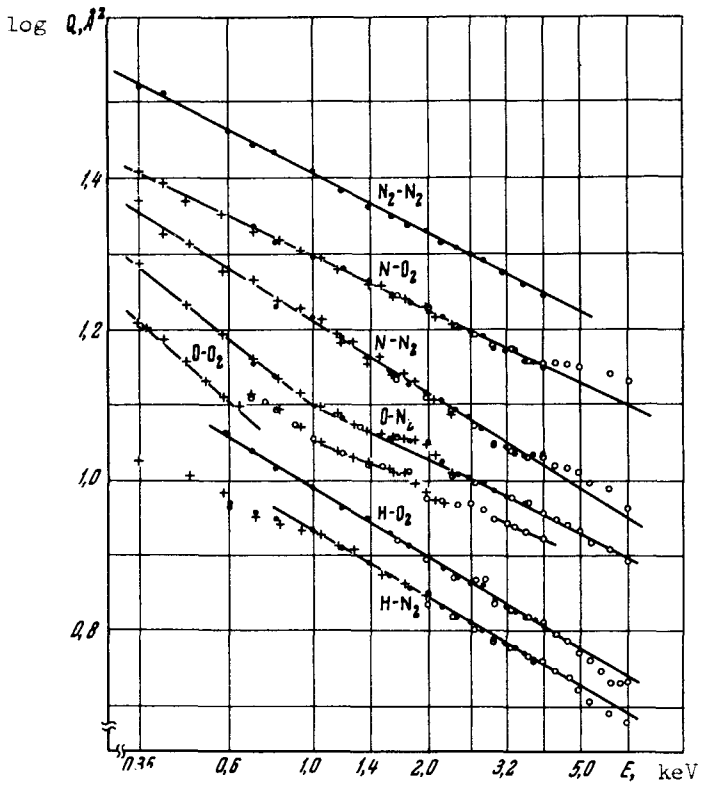
Exact knowledge of the surfaces of the potential energy of interaction (or potential curves for spherically symmetrical systems) is essential for a theoretical calculation of both elastic and inelastic processes accompanying atom-molecule collisions. A reliable method of obtaining the corresponding information is to scatter fast beams by gas targets. In particular, scattering of beams of energy ~1 keV at small angles (~10^{-3} rad) yields information on the interaction of colliding particles in the energy region ~1 eV [1].

The experimental setup and the measurement procedure were described in the papers by the authors and Kamnev et al. [1] Measurements of the total scattering cross sections were made with the aid of beams with energies from 0.6 to 4 keV, using three different detector angular apertures (θ_0). The relative error of the measured values of $Q(\theta_0, E)$ lies in the range 1 - 1.5%, and the error of the absolute measurements does not exceed ±8%.

The figure shows a log-log plot of the measured cross sections against the beam energy. The cross sections are given relative to the value for O-N_2, and to obtain the true cross sections the values from the figure must be multiplied by 1.19 for H-N_2 and O-O_2, by 0.91 for H-O_2, by 0.81 for N-N_2, and by 0.76 for N_2-N_2 and N-O_2.

From the initial linear sections of the plotted curves we can determine the parameters K and n of the effective spherically-symmetrical potential $V = K/r^n$ of the investigated systems. These values and the ranges of the closest-approach distance within which they are valid are summarized in the table.

System	K, eV $Å^n$	n	Δr, Å
$O - N_2$	22.5	5.0	2.48 - 2.00
$O - O_2$	13.25	4.4	2.46 - 2.05
$N - N_2$	76.6	6.31	2.54 - 1.76
$N - O_2$	362	8.3	2.49 - 1.84
$H - N_2$	34	6.9	1.81 - 1.46
$H - O_2$	17.4	6.53	1.84 - 1.46



From the figure we see that, unlike the case of N_2-N_2 scattering given as an example in [1], the experimental plots of $Q(\theta_0)$ against E for systems with unclosed shells have several kinks, the magnitudes of which greatly exceed the limits of possible experimental errors. Comparison of the data for N-N_2 and O-N_2 and also for N-O_2 and O-O_2 indicates that the observed singularities of the scattering, in the energy region ~1 keV (see the figure), cannot be attributed to the nonsphericity of the molecules, since the closest-approach distances are approximately the same in all cases. We can therefore assume that these singularities reflect the sharp change in the character of the interaction of the particles over a very short interval of atom-molecule distances.

Such a change can be the consequence of the crossing of the levels of the electron energy for symmetrical configurations of three identical atoms (for example, N_3) [3].

The interpretation of the elastic-scattering data usually calls for the a priori knowledge of the qualitative (attraction-repulsion) potential interaction curves of the systems in the investigated range of distances, and also of the possibility of nonadiabatic electronic transitions in the collision process. In this sense, the most unambiguous interpretation can be obtained for the results of a study of the scattering of the $O-N_2$ system, to which we confine ourselves in the analysis.

The high accuracy of the determination of the closest-approach distances makes it possible to fix two successive kinks on the $Q(\theta_0, E)$ curve for the $O-N_2$ system (see the figure), which can be readily attributed to nonadiabatic transitions from one potential interaction curve to another during the collision process. Such transitions are possible, inasmuch as the repulsion terms $^3\Pi$ and $^3\Sigma$ of the states of the system $O(^3P)-N_2(^1\Sigma)$ cross the potential curve of the $^1\Sigma$ state of the system $O(^1D)-N_2(^1\Sigma)$ [4]. The relative maximum of the dependence of the cross section $Q(\theta_0)$ on E in the energy region ~2.0 keV can be naturally related with the "rainbow effect," which is known for scattering in the case of a nonmonotonic potential of interaction [5]. The probability of nonadiabatic transition to the state $^1\Sigma$ can be roughly estimated, from the magnitude of the "rainbow" peak, at 0.07, and the cross section of this process can be estimated at 0.8 $Å^2$.

The experimental data for elastic systems can be interpreted with the aid of similar considerations.

Let us summarize the main results of the work.

1. We measured the absolute values of the total cross sections for elastic scattering of H, N, and O atoms by O_2 and N_2 molecules as functions of the energy.

2. From these data we obtained the parameters of the effective spherically-symmetrical potentials describing the interaction of the investigated systems in the energy region ~1 keV.

3. We observed singularities in the energy dependence of $Q(\theta_0)$ for the scattering of atoms with unclosed electron shells by molecules.

4. For the $O-N_2$ system, we attempted to explain the observed scattering singularities and to estimate the probability of nonadiabatic electronic transition.

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