Isotope separation in laser-stimulated chemical reactions

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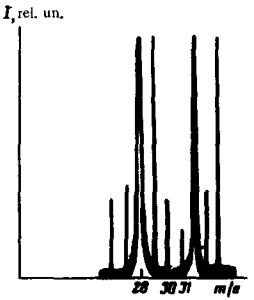
Isotopes of nitrogen were separated in the laser-stimulated reaction $N_2+O_2 \rightarrow 2NO$. An isotope separation coefficient $\beta \sim 100$ was reached for ^{15}N and ^{14}N. The reaction was stimulated in a cell with air, with simultaneous action of ruby-laser radiation and of the intense Stokes component obtained beforehand by SRS in liquid nitrogen.

1. It was shown in[1] that it is possible to separate effectively isotopes in chemical reactions stimulated by laser radiation in the IR band. Physically the effect is connected with the difference between the distribution functions of the isotopic molecules over the vibrational levels, due to $V-V$ exchange between molecules. It is shown in[1] that the isotope-separation coefficient $\beta = r/r' - 1$, where r' and r are the isotopic ratios before and after the separation, is determined by the relative isotopic shift $\Delta\nu/\nu$ of the frequency of the molecule vibrations, by the reaction activation energy ϵ^*, and by the temperature T of the translational and rotational degrees of freedom of the molecules:

$$\beta = \exp\left(\frac{\epsilon^*}{T}\,\frac{\Delta\nu}{\nu}\right) - 1, \qquad (1)$$

with β practically constant even if the molecule anharmonicity is comparable with the isotopic frequency shift.[2]

In the present study we separated the nitrogen isotopes in the laser-stimulated reaction $N_2 + O_2 \rightarrow 2NO$. The reaction calls for an activation energy not less than 3.3 eV,[3] and in the case of low "translational" gas temperature, the reaction products should, according to (1), be enriched with the isotope ^{15}N. Since the vibrational degrees of freedom of molecules without dipole moments cannot be excited by resonant IR radiation, the "hot" nitrogen molecules were obtained by simultaneously applying to the $N_2 + O_2$ mixture the laser emission and the intense Stokes component obtained in liquid nitrogen beforehand by stimulated Raman scattering (SRS).[4]



2. The ruby laser emission and its Stokes component were focused into a liquid-nitrogen-cooled cell with air at a pressure ~300 Torr. The nitrogen oxide obtained from the reaction $N_2 + O_2 \rightarrow 2NO$ was analyzed in an SN-8 mass spectrometer. The mass spectrum obtained after the irradiation is shown in the figure. The ratio of the peaks with $m/e = 30$ and 31, which is equal to ~2.5 (after subtracting the background), agrees with the ratio of ^{14}NO and ^{15}NO. Since the content of the isotope ^{15}N in natural nitrogen is ~1/250, we obtain for β a value ~100.

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