The radiation transfer in a vibrationally nonequilibrium diatomic gas is described by a system of equations which can be reduced to one integrodifferential equation for the vibrational energy density. A method for the numerical solution of this equation by using the theory of Markov chains is proposed in the paper. The investigation of radiation transfer in nonequilibrium gases is closely associated with such areas of application as spectroscopy, low-temperature plasmas, molecular gasdynamic lasers, radiation gasdynamics, and physics of the upper layers of a planetary atmosphere. In the general case, the problem reduces to solving a system of equations of Boltzmann type for material particles and photons [1, 2]. Obtaining concrete results by direct integration of the system of equations is hence a very complex mathematical problem. Hence, examination of such physical situations when the problem allows of specific simplifications is of interest. The present paper is devoted to an investigation of radiation energy transfer in nonequilibrium diatomic heteronuclear gases (CO, HCl, NO, etc., for example) both because of the relative simplicity of configuration of diatomic molecules and the practical importance of such gases for radiation gasdynamics and atmospheric optics problems. Radiation processes exert a substantial effect, together with inelastic collisions on the population of the vibrational–rotational molecule levels at reduced pressures of the radiating medium \( p \sim 10^{-4} - 10^{-5} \).
and the temperatures $T \sim 1-3 \times 10^{3} \text{K}$ when the maximum of the Planck functions is in the frequency range corresponding to vibrational-rotational transitions. The emergence of radiation outside the boundaries of the emitting volume in this case results in spoilage of the local thermodynamic equilibrium. However, a representation about the local equilibrium within separate degrees of freedom [3, 4], and particularly, about the vibrational temperature $T_v(r)$ which differs from the translational $T(r)$ (the temperature of the rotational degrees of freedom also equals $T(r)$), can be introduced for a broad class of problems. The radiation characteristics of such a partially equilibrium medium are determined by the radiation transfer equation in which the source function depends on $T_v(r)$ or the equivalent parameter $\varepsilon(r)$, the gas vibrational energy density. In turn, a kinetic equation must be written for $\varepsilon(r)$, where besides the relaxation term, a term describing the influence of the radiation transitions should be present.

Considering the diatomic molecules in the "quantum oscillator-rigid rotator" approximation, the following system of equations can be written for the gas vibrational energy density $\varepsilon(r)$ and the spectral intensity $I(k, r)$:

\[
\eta_\nu I(k, r) = k_\nu(r)(I^0_\nu(r) - I(k, r)),
\]

\[
\left( \frac{\partial}{\partial t} + \nu(r) \gamma \right) \varepsilon(r) = \frac{\varepsilon^0(r) - \varepsilon(r)}{\tau^0(r)} - \frac{1}{\rho(r)} \nabla \int_{(\nu v)} S_\nu(r) dv,
\]

where

\[
k_\nu(r) = \frac{\hbar \nu N(r) B}{\pi} \sum_{j=0}^{\infty} \sum_{\alpha=0}^{\infty} S_{j\alpha}(r) \Phi_{j\alpha}(\nu, r),
\]

\[
B = \frac{2\pi}{3 \hbar^2 c} \frac{B_e^2}{\omega_e} \left( \frac{\partial \mu}{\partial r} \right)^2 \rho \nu_0,
\]

\[
\Phi_{j\alpha}(\nu, r) = \frac{1}{\nu_0} \gamma_{j\alpha}(r),
\]

\[
S_{j\alpha}(r) = (j + \alpha) \left( \frac{\hbar c B_e}{k_B T(r)} \right)^{3/2} \exp \left\{ -i (j + 1) \frac{\hbar c B_e}{k_B T(r)} \right\},
\]

\[
\gamma_{j\alpha}(r) = \nu_{j\alpha} \left( \frac{2k_B T(r)}{mc^2} \right)^{3/2}, \quad \nu_{j\alpha} = \nu_0 + 2(1 - 2\alpha)(j + \alpha) c B_e,
\]

\[
\varepsilon(r) = \frac{\hbar \nu_0}{m} \left( \exp \left( \frac{\hbar \nu_0}{k_B T_0(r)} \right) - 1 \right)^{-1}, \quad I_0^\nu(r) = \frac{2m \nu^3}{c^2 \nu_0} \varepsilon(r).
\]

For simplicity in the writing, the time argument in the functions is omitted here.

Integrating (1) with respect to the solid angle results in the relation:

\[
\varphi S_\nu(r) = 4\pi \nu_\nu^3 k_\nu(r) \varepsilon(r) - k_\nu(r) \int_{(4\pi)} I(k, r) d\Omega,
\]

where according to (1), $I(k, r)$ has the explicit form

\[
I(k, r) = \int k_\nu(r') I_0^\nu(r') \exp \left\{ -\tau_\nu(r, r') \right\} ds' + \gamma_\nu(r_n, n) \exp \left\{ -\tau_\nu(r, r_n) \right\},
\]

\[
\tau_\nu(r, r') = \int_{0}^{r-r'} k_\nu(s) ds, \quad q = \frac{2m}{c^2 \nu_0}.
\]

Substituting (3) into (2) results in an integrodifferential equation for the vibrational energy density [2].