Swarm of Electron Simulation in Carbon Dioxide Parameters for Intermediate E/N Values

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Abstract

The rotational excitation and transfer of low-energy electrons cross-sections in carbon dioxide have been obtained to compare in the theoretical & experimental values of the kinetic and diffusion coefficient. The transport coefficients theoretical values of were gained by calculating the delicate electron energy distribution functions using a putative elastic and inelastic cross-sections combination. The values for movement, drift speed, average electron energy, and power noticeable with experimental data were compared. Alteration were made to the default cross sections until obtaining good agreement. Transport coefficients were calculated for values between \( (6 \times 10^{-17} \text{ - } 6 \times 10^{-15}) \text{ V cm}^2 \) with energy zoning 0.035 eV at 300k\textdegree temperature.

Keywords: Basic swarm data, diffusion, electron swarm coefficients, electron transport, non-thermal plasmas applications, and swarm parameters.

Introduction

Information in details of the parameters transportation that organize the gas discharges development were necessary for optimum operating requirements for the CO\textsubscript{2} laser. Several researches were made to find out the leakage parameter in uncontaminated gases. The importance of these factors lies in providing a connection among the cross-sections of the electronic gas conflict, the decomposition and degradation observable fact. Swarm factors are calculated in a straight line from a the impact cross-sections utilizing Boltzmann numerical
transport solution. Calculations resulted were the allocation of the electron energy, that was a vital characteristic but hard to calculate empirically [1].

The electron swarm parameter for E/N drop where E denotes the applied electric field (V/cm) and N denotes the density number of the total gas (cm^-3) minutes until the start of ionization (~10^{-15}) Vcm^2. It was previously considered utilizing Boltzmann transport factor to be compared with the experimental values [2]. The work's aim is calculating the swarm of electron parameters in carbon dioxide and match the obtained values with investigational records utilizing an appropriately selected set of cross sections. [3, 4].

**Numerical solution**

By consider an electron's swarm drift during a gas subjected to a temperature (T) in the arrangement of the electric field influential (E) at (V/Centimetre). Stead-state distribution function is then given by the solution of the Boltzmann equation [5, 6 and 7]:

\[
\frac{\partial f}{\partial t} + v \cdot \nabla f + a \cdot v f = \sum_j \int \left[ f(v', r, t) f_j(v_j, r, t) - f(v, r, t) f_j(v_j, r, t) \right] v_{rj} \eta_{ij} (\theta, \varphi) d\Omega_j \tag{1}
\]

Where: \(\frac{\partial f}{\partial t}\) represent \(f(r, v, t)\) adjusts with point in time at \(v\) set values, \(r\) while \(v\) stands for the charged particles velocity, \(a\) represents charged particle acceleration, \(F_j\) being the velocity sharing occupation of the unbiased types \(j\), \(v_{rj} = |v - V_j|\) represents the charge particles' relative taking into account the unbiased gas types \(j\), \(V_j\) represents neutral types velocity \(j\), \(\sigma_j(\theta, v_j)\) represents the degree of difference charged particles microscopic cross-section that interacts through \(V_j\), and \(d\Omega = \sin \theta d\theta d\Phi\) represents the robust angularity, Where \(\theta\) and \(\Phi\) are the polar and azimuthally angles respectively.

The allocation purpose of electrons \(f(r, v, t)\) was approximated by \(f(v)\) because it was considered the electric filed \(E\), was not depend on the space and time and furthermore the interactions of electrons were specially
uniform [5, 8, 9 and 10]. Whether the velocity dependence distribution function is represented by the legendary sequence growth where:

\[ f(r, v, t) = f_0(r, v, t) + \sum_{k=1}^{\infty} f_k(r, v, t) P_k(\cos \theta) \quad (2) \]

**Calculation procedures and analysis**

The velocity distribution function for electrons diffusing in the gas temperature in \( (T) \) at the uniform electric filed controlling, \( (E) \) has been performed during the explanation of the numerical Boltzmann transport equation [11, 12]. According to the above, the detailed analysis of transfer coefficients It was calculated for comparison with experimental data and included the velocity of drift \( V_d \) \( (\text{cm} / \text{s}) \), the characteristic energy \( \varepsilon_k \text{ (eV)} \), the electron energy average \( <\varepsilon> \text{ (eV)} \), the electron mobility \( \mu \text{ (cm}^2/\text{V. sec)} \) and the diffusion coefficient \( D \text{ (cm}^2/\text{sec)} \). These parameters are [12 and 13]:

\[ V_d = \frac{\mathcal{E}_d}{E_n} \quad (3) \]

where:

\[ n_\sigma = \sum_k n_k \quad (4) \]

\[ \mu = \frac{\mathcal{V}_k}{E/N} \quad (5) \]

\[ D = \frac{1}{3} \left( \frac{2}{\pi} \right)^{1/2} \sum_k \frac{\varepsilon_k f_k \Delta \varepsilon}{\sum_{\varepsilon > \varepsilon} \sigma_k (\varepsilon_k)} \quad (6) \]

with:

\[ f_k = \frac{n_k}{\varepsilon^{3/2} \Delta \varepsilon n_\sigma} \quad (7) \]

finally:

\[ <\varepsilon> = 18.36 \left( \frac{\mathcal{E}_d}{\sigma_s} \right) \quad \text{with} \quad \sigma_s = \sigma \quad (8) \]

where
$E_g$ is the energy rate obtained by the dc filed electrons, $n_0$ represents the electron number density ($\text{cm}^{-3}$), $n_k$ is electrons number. Each unit has a volume, per unit of energy in space ($\epsilon_{k+1}^+ \epsilon_k^-$), $m$ denotes the mass of the electron (gm), $\epsilon_k$ is the energy of electron (eV), $f_k$ is the regularized distribution function, $\Delta \epsilon$ refers to the energy zoning (eV), $q_s$ is the types concentration $N_s$, $\sigma_s$ It is the elastic dispersion cross-section species (s), $<\epsilon>$ is the average energy electron (eV ), $\sigma$ represents the cross section.

**Numerical results and discussion**

Equation (1) is solved numerically in excess of a rage of E/N for carbon dioxide gas using the Finite-Difference Method and through the equations between 3 to 8 were obtaining the swarm parameters [12], which could be simply evaluated to the earlier authors. Figure-1 exhibits the computed electron energy allocation task, the electron energy allocation was powerfully affected by parameter change E/ N [14].

![Normalized distribution function of electron energy $f(\epsilon)$ (eV$^{-3//2}$) vs. the electron energy in CO$_2$ gas.](image)

Figure. 1- the relationship between the distribution function of electron energy $f(\epsilon)$ (eV$^{-3//2}$) for a variety of values of E/N including electron-electron interactions vs. the electron energy in CO$_2$ gas.
Figures (2 & 3) shows the computed results for mobility and drift velocity as the functional field of electric function to the ratio of gas number density. over 10 Td the investigational points go down under both theoretical calculations, while, the experimental and theoretical results agreement was excellent [15].

**Figure 2** - the relationship between the mobility of electron vs. the ratio of the applied electric field function to the total gas number density for CO$_2$ gas.

**Fig. 3** - the relationship between the electron drift velocity vs. the ratio of applied electric field to the total gas number density for CO$_2$ gas.
Figures (4, 5, 6 and 7) are plotted against E/N for pure CO₂. It must be mentioned that at below E/N values (100Td) the values of the diffusion coefficient, the electron energy average, the applied electric field and the characteristic energy are increased sharply with E/N but at the maximum E/N values (100Td) the values of the above parameters are stable with E/N. An agreement of these values appeared with experimental data [16].

**Figure 4** - the relationship between the diffusion coefficient of the electron vs. the ratio of the applied electric field to the total gas number density for CO₂.
Figure 5 - the relationship between the electron energy average vs. the ratio of the applied electric field function to the total gas number density for CO₂ gas.

Figure 6 - the relationship between the electric field applied as a function of the electric field applied to the ratio of the density of the number of gas to carbon dioxide.
Conclusions

- The electronic energy distribution functions calculations of $E/N = (8 \times 10^{-17} - 1 \times 10^{-16}) \text{ Vcm}^2$ have been shown to be Maxwellian but at $E/N = 4 \times 10^{-16} \text{ Vcm}^2$ have been shown to be highly non-Maxwellian.
- The results are compared with several experimental data, the general agreement between the computed and measured values was satisfactory.

Fig. 7- the relationship between the characteristic energy vs. the electric field applied to the ratio of the density of the number of gas to carbon dioxide.
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