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Transport coefficients calculation using Inference the Momentum-Transfer and Inelastic-Collision Cross Sections of Electrons in Carbon Dioxide

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Abstract
In this work, we were calculate the electron diffusion coefficients, such as, the drift velocity, characteristic energy, and collision frequencies using the cross sections of the momentum transfer and inelastic for electrons in CO_2 from figure(1) after solving the Boltzmann transport equation numerically using the Finite-Difference Method in gas medium through applied electric field at 300 ^oK.
The theoretical predictions were obtained in agreement with the experimental values was publishered.
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Keywords: CO_2 lasers, Boltzmann Transport Equation, RF Discharges, Transport coefficients, Plasma discharge, Drift velocity.

الخلاصة
في هذا العمل ، تم حساب معاملات انتشار الالكترونات مثل سرعة الانجراف، الطاقة المميزة و ترددات التصادم باستعمال المقاطع العرضية المرنة وغير مرنة للالكترونات في غاز ثاني أوكسيد الكاربون CO_2 من شكل (1) خلال حل معادلة الانتقال لبولتزمان عددياً باستخدام طريقة التفريق المحدد في وسط غازي بعد تسليط مجال كهربائي عليه عند درجة حرارة 300 كلفن . النتائج التي تم الحصول عليها تنبأ بأنها متوافقة مع النتائج العملية المنشورة.

Introduction

The determinations of momentum transfer and inelastic cross sections for electrons in CO_2 from experimentally measured values of transport coefficients.
The analyses were most accurate for the calculation of the cross sections for momentum-transfer and vibrational excitation, in addition the electronic excitation in CO_2. These results were an extension of previous calculations of cross sections in Hydrogen [1], [2], and [3], Deuterium [2], Nitrogen [1],[4], and the rare gases [5].The time-and space-independent Boltzmann transport equation were solved for distribution function of electron energies ε in a neutral gas using an initial set of elastic and inelastic cross sections. The calculations of the transport coefficients were done by taking averages [1], [2], [6], and [7] over this distribution function and were compared with experimental values of the same transport coefficients. When the calculated values were match the experimental values to within 5% over an extended range of the ratio of the electric field strength E to gas density N, the cross section were considered satisfactory [8].

Carbon Dioxide

The very large energy exchange frequency at very low characteristic energy ε_k, and availability the ε_k and the recent time-of-flight drift velocity; these leading were to undertake on an analysis of the coefficient data of the electron transport in CO_2. Because of the CO_2 lasers development, the interest in excitation cross sections for electrons in CO_2 was increased.

Boltzmann transport equation:

The electrons swarms were undertaken the applied electric filed considering the steady state f^o distribution as [9][10]:

$$\frac{1}{2v^2\partial v}\left[G v_m v^3\left\{f^0+\left(\frac{kT_g}{m}+\frac{2}{3G}\left(\frac{eE}{mv_m}\right)^2\frac{\partial f^0}{v\partial v}\right)\right\}\right]+\frac{\partial}{3\partial Z}$$

$$\left\{\frac{eE}{mv_m}v\frac{\partial f^0}{\partial v}+\frac{1}{v^2\partial v}\left(\frac{eE}{mv_m}v^3 f^0\right)\right\}+\frac{v^2}{3v_m}\nabla_r^2 f^0=0 \ldots\ldots\ldots(1)$$

whereas G represents the energy loss factor, ν represents the electron velocity, ν_m represents the momentum transfer collision frequency; ^oT_g represents the gas temperature, K represents the Boltzmann factor. e represents the electron charge, and E represents the electric strength a long the negative Z - axis direction.

Solution of transport equation:

After we were preparation the cross sections for vibration excitation, electronical excitation, ionization and momentum transfer in CO_2 would be feeding to the computer program [11]. Hence solves the Boltzmann transport equation numerically.

Determination of transport parameters:

The transport coefficients ν_d, D/μ, ν_m and ν_u were obtained by solving the transport equation numerically (1) as above according to:

(a): the momentum transfer collision frequency ν_m which was defined by [12][13]:

$$\frac{\nu_m}{N}=\frac{e}{m}\frac{E}{N}\frac{1}{V_d}\ldots\ldots\ldots(2)$$

this parameter ν_m was primarily sensitive to the cross section for momentum transfer.

(b): the energy exchange collision frequency ν_u which was defined by:

$$\frac{\nu_u}{N}=\frac{e\ V_d\ \ E/N}{\varepsilon_k-kT}\ldots\ldots\ldots(3)$$

this parameter ν_u was primarily sensitive to the inelastic cross section.

(c): the drift velocity ν_d, defined by [14]1[5]:

$$\nu_d=\mu E\ldots\ldots\ldots(4)$$

$$\mu=-\frac{1}{3}\left(\frac{2e}{m}\right)^{1/2}\int_0^\infty\frac{u}{\sum_k N_k\ Q_m^k(u)}\frac{df^o}{du}du\ldots\ldots\ldots(5)$$

(d): $\varepsilon_k=e\dfrac{D}{\mu}\ldots\ldots\ldots(6)$

where, e represents the electron charge 1.6×10^{-19} columb, m represents the electron mass, 9.109×10^{-28} gm, E represents the applied electric filed, V/cm, N represents the gas number density cm-3, ν_d represents the drift velocity, cm/sec, ε_k represents the characteristic energy (eV), K represents the Boltzmann constant,1.3805×10^{-23} j/^{o}k, ^oT_g represents the gas temperature in unit of Kelvin (^{o}K), μ represents the mobility of electron (cm^2 sec^{-1} V^{-1}), u represents the electron energy (eV), N_k represents the total number density cm^{-3}, $Q_m^k(u)$ represents the momentum transfer cross section (cm^2) for elastic collisions of electrons of energy u(eV), D/μ represents the ratio of the diffusion coefficient to the mobility (eV).

Results and Discussion:

The electron transport coefficients were analyzed used in terms of elastic and inelastic cross sections as presented in Figure 1 [16], which was showing that many interesting conclusions can be reached regarding the magnitude and energy dependence of the cross sections.

Figure 1 represents the cross sections for momentum transfer Q_m, vibrational excitation Q_v, electronic excitation Q_x and ionization Q_i [16].

The curves were show the cross sections derived in your analyses of the data of Figure 4 and have a resonance nature with energy losses and the thresholds at 0.3, 0.6 and 0.9 eV and high energy tail of the 0.3 eV process. The magnitudes of these cross sections, the magnitudes of the resonance portion of the 0.083 eV energy loss process and the $Q_m(\varepsilon)$ curve were adjusted to give a good fit to ν_m and ν_u curves calculated from the 300 ^{0}K data.

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Figure 2 was show the drift velocity of the electron as a function of the applied electric filed to the gas number density ratio E/ N, which was increased proportionally with E/N and appeared agreement with experimental data [16].

Figure 3 appeared the characteristic energy was stable between $(2\times10^{-19}< E/N <2\times10^{-17})$ V cm^2 but proportionally increasing with E/N.These data was agreement with experiment values [16]. From Figure 4 was note that the our procedure of fitting to the ν_m and ν_u curves leads to rather satisfactory agreement between the calculated and experimental ν_d, and D/μ values show in Figures 2 and 3, further experimental and theoretical investigations of this E/N range are necessary in order to resolve this discrepancy.

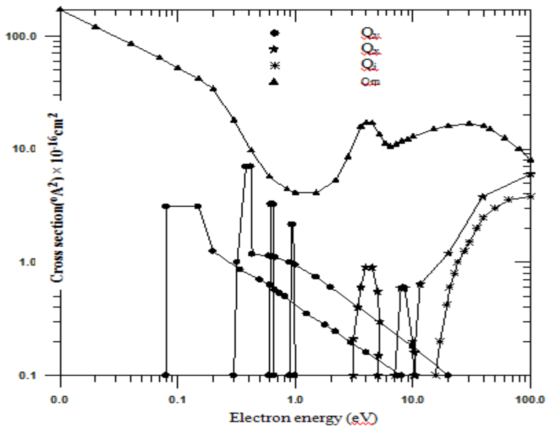

Figure 1: The inelastic scattering Q_v, Q_x, Q_i and momentum transfer Q_m cross sections versus the electron energy in Co_2 [17].

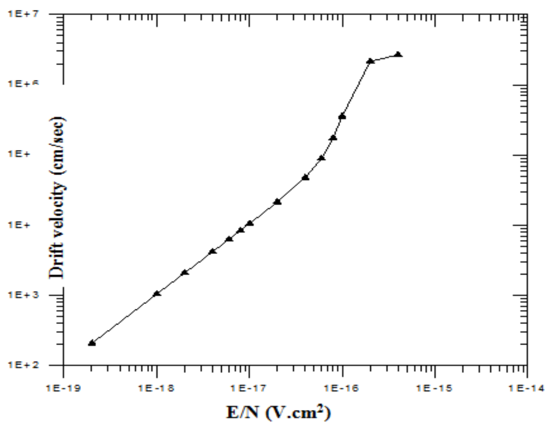

Figure 2: The drift velocity Vd of the electrons versus the applied electric field to the gas number density ratio, E/N in Co2.

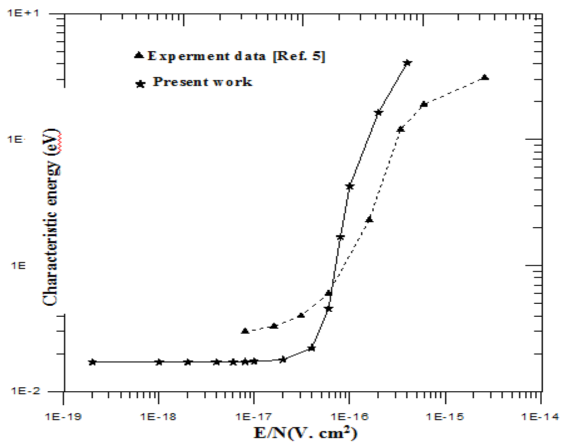

Figure 3: The characteristic energy D/μ of the electrons versus the applied electric field to the gas number density ratio, E/N in Co2.

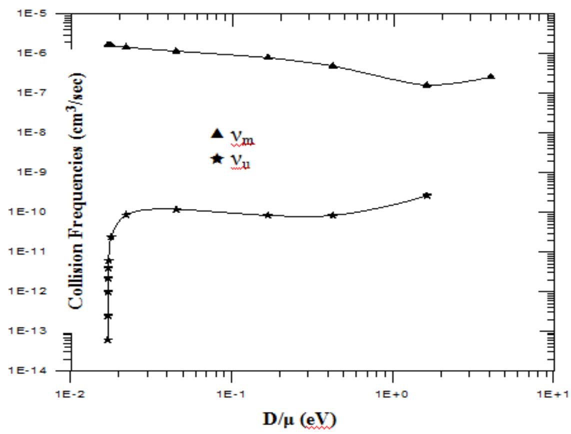

Figure 4 :The momentum transfer ν_m and energy-exchange ν_u collision Frequencies per molecule versus the characteristic energy, D/μ for electrons in Co2 at 300ok.

Conclusions

The high quality experimental electron transport coefficient data was worthwhile. From the above the various gases and gas temperatures were to fill in the many gaps and check the questionable data evident. Such data were available for gases such as CO_2, H_2O and Ch_4 over a wide range of E/N values.

References

[1] L. S. Frost and A. V. Phelps , "Rotational Excitation and Momentum Transfer Cross Section for Electrons in H_2 and N_2 from

Transport Coefficients", Phys. Rev. Vol. No.127, PP. 1621, 1962.

[2] A. G. Engelhard and A. V. Phelps, " Elastic and Inelastic Collision Cross Sections in Hydrogen and Deuterium from Transport Coefficients", Phys. Rev., Vol. 131, PP. 2115, 1963.

[3] Ibrahim Kaittan Fayyadh, Farhan Lafta ashid, Nada Mohamed Hassen, Saadallah Taha, " Determination of Radio-Frequency Electromagnetic Wave in Isothermal Plasmas: By Using Collision Cross Section of Helium, Argon Atoms and Ions for Electrons proceedings " 2nd International Conference on Mathematical Applications in Engineering.

[4] A. G. Engelhardt, A. V. Phelps, and C. G. Risk, " Determination of Momentum Transfer and Inelastic Collision Cross Sections for Electrons in Nitrogen Using Transport Coefficients " Phys. Rev., Vol. 135, PP. A1566, 1964.

[5] Z. D. Nikitovic, V. D. Stojanovic, J. P. Booth, and Z. L. Petrovic," Electron Transport Coefficients in Mixtures of CF (4) and CF (2) Radicals, Plasma Sources " Science & Technology, Vol.18, No.3, 2009.

[6] Farhan Lafta Rashid, Ibrahim Kaittan Fayyadh. Mohammed Izat Ismaeel," of Townsend Energy Factor and Drift Velocity for Air in terms of L, G and E/P " Journal of Babylon University Engineering Science, Vol.21, No.5, 2013.

[7] Jasim Mohammed Salih, Mohammad Mohsen Shneter, Saadallah Taha Idan, Ahmed Ibrahim Alwan and Ibrahim Kaittan Fayyadh," Determination of Mean Free Path Elixir Int. J. Elixir Chem". Phys. Letters, Vol.97, PP.42214, 2016.

[8] Hien P. X., D. A. Tuan, B. H. Jeon, " Electron Collision Cross Section for the TMS Molecule and Electron Transport Coefficients in TMS-Ar and TMS-O-2 Mixtures" , Journal of the Korean Physical Society, Vol.61, No.1, pp.62-72, 2012.

[9] Ibrahim G. Faiadh, Muhammed I. Ismaeel, Faisal G. Hamudy , " magnetic Deflection Coefficient Investigation for Low Energy Particies " Baghdad Science Journal, Vol.8, No. 2, PP.302,2011.

[10] S. D. Rockwood, and A. E. Greene, " Numerical Solutions of the Boltzmann Transport Equation " Computer Physics Communications. Vol.19, pp.377-393, 1980.

[11] Muhammed I. Ismaeel, Ibrahim Kaittan Fayyadh,Qasim Rahmaatallah Ali, Karim ghulf muhammed, " Collision Freqency Evaluation of Electron Argon-Helium Gas Mixture" J. College of Education, Al-Mustansiriyah University, No.6, PP.17, 2011.

[12] Ibrahim Kaittan Fayyadh, Kareem Khalaf Mohammad,Ali Hussein Jawad and Mohammad Mohsen Shneter, " Evaluation the Drift Velocity to Diffusion Coefficient Ratio for Low Energy Electrons in Air and He Gas Elixir Nuclear&Radiation " Phys.Vol.67, PP. 21637, 2014.

[13] D. Stephen Rockwood, " Elastic and Inelastic Cross Sections for Electron-Hg Scattering from Hg Transport Data " ,Phys. Rev. A, Vol.8, No.5, and PP.2348, 1973.

[14] C. J. Baker, D. R. Hall and A. R. Davies, "Electron Energy Distributions, Transport Coefficients and Electron Excitation Rates for RF Excited CO_2 Lasers" , J. Phys. D: Appl.Phys.Vol. 17, pp.1597-1606, 1984.

[15] F. L. Rasheed, Ibrahim Kaittan Fayyadh, Hamid B. Mahood, " Calculation of the Characteristic Electron Energy for Mercury-Argon Mixture" , Um-Salama Science, J. Vol.2,No.3,PP.477-483, 2005.

[16] R. D. Hake, JR. and A. V. Phelps, " Momentum –Transfer and Inelastic-Collision Cross Sections for Electrons in O_2, Co, and Co_2 " , Phys. Rev.,Vol. 158,No. 1, pp. 70-84, 1967.

[17] H. S. W. Massey, E. H. S. Burhop and H. B. Gilbody, " Electronic and Ionic Impact Phenomena" , Second Edition, in Four Volumes, Vol.II, Oxford University Press, Great Britain,1969.