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LETTER TO THE EDITOR

Electron impact ionization of neon and argon

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Abstract. Measurements of absolute total ionization cross sections and first ionization coefficients for electron molecule collision ionization in gases, previously reported in hydrogen and deuterium, have been extended to neon and argon.

In a recent paper, (Cowling and Fletcher 1973), the authors reported their results of measurements of the ionization parameters of electron–gas molecule collision ionization in both electron beams and electron swarms in hydrogen and deuterium. This work has now been extended to include the rare gases neon and argon. The situation regarding the total ionization cross sections in neon and argon is confused. Keiffer and Dunn (1966) have commented that 'The rare gas (ionization) cross sections are generally regarded as well known; . . . this opinion is not well founded unless one considers 20–30% as a small uncertainty'. The present work aims to reduce that uncertainty.

The apparatus and method used is the same as that described previously, (Cowling and Fletcher 1973), with the exception of the gas preparation. In the present set of experiments the rare gases used were obtained from one litre pyrex flasks of spectroscopically pure gas prepared by the British Oxygen Company. The gas was admitted directly into the vacuum system via a Granville Phillips variable leak valve.

The present values of Q_i as $f(\epsilon)$ in neon and argon are presented in table 1 where they are compared with the data of Rapp and Englander-Golden (1965). Errors in the present results over most of the energy range are estimated at $\pm 4\%$ and when this is considered with the error of $\pm 4{\cdot}5\%$ estimated by Rapp and Englander-Golden it can be seen that in both gases considered here the two sets of data agree to within the combined error. The exception to this is the data taken in the first 10 eV above threshhold. In this low energy region as Q_i tends to zero the ion current becomes very small and errors in I_i, which are normally very small, become important. For this reason alone the uncertainty in Q_i increased in this region. More important however is the fact that this uncertainty in Q_i introduces a possible error in the observed threshold potential, which is the true threshold potential plus contact potentials, and which is obtained by extrapolating the observed Q_i against ϵ curve back to $Q_i = 0$. The energy scale must be adjusted so that $Q_i = 0$ at the true threshold and since the variation of Q_i with ϵ in this region is very rapid any misadjustment will give large percentage errors in the final values of Q_i as $f(\epsilon)$. This uncertainty is reflected in the

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increased discrepancy between the present results and those of Rapp and Englander-Golden at low electron energies.

Table 1. The present values of total absolute ionization cross sections compared with those of Rapp and Englander-Golden (1965).

$Q_i \times 10^{16}$ cm^2	Helium		Argon	
ϵ(eV)	1	2	1	2
16			0·035	0·020
17			0·198	0·134
18			0·367	0·294
19			0·530	0·460
20			0·695	0·627
22	0·006	0·004	0·994	0·933
23	0·017	0·015		
24	0·026	0·026	1·28	1·18
25	0·040	0·037		
26	0·058	0·050	1·54	1·41
27	0·070	0·063		
28	0·088	0·076	1·75	1·60
29	0·106	0·089		
30	0·124	0·102	1·94	1·80
35	0·197		2·39	
40	0·257	0·227	2·62	2·39
50	0·375	0·338	2·80	2·53
60	0·474	0·436	2·91	2·66
70	0·554	0·514	3·01	2·77
80	0·615	0·577	3·07	2·84
90	0·660	0·628	3·07	2·86
100	0·695	0·667	3·05	2·85
110	0·728	0·700	3·01	2·83
120	0·748	0·725	2·97	2·80
130	0·764	0·743		
140	0·774	0·757		
150	0·779	0·773	2·82	2·68
160	0·783			
170	0·785			
175			2·69	
180	0·785			
190	0·781			
200	0·776	0·781	2·56	2·39
250	0·748	0·757	2·34	2·17
300	0·714	0·722	2·15	1·98
350	0·681	0·686	2·00	1·82
400	0·644	0·628	1·86	1·68
500	0·582	0·587	1·62	1·55

Column 1: present data; column 2: Rapp and Englander-Golden.

In table 2 values of Q_i at ϵ = 30, 50, 100 and 300 eV are extracted from table 1 and compared not only with the Rapp and Englander-Golden (1965) data, but also with the data obtained by Smith (1930), Assundi and Kurepa (1963) and Tozer and Craggs (1960). It may be seen that the present results tend to substantiate the Rapp and Englander-Golden values and to disagree with the earlier data.

Table 2. Comparison of present values of Q_i with other determinations.

ϵ(eV)	$Q_i \times 10^{16}$ cm^2				
	1	2	3	4	5
			Neon		
30	0·124	0·102	0·135	0·104	
50	0·375	0·338	0·416	0·425	
100	0·695	0·667	0·752	0·771	
300	0·714	0·722	0·766		
			Argon		
30	1·94	1·80	2·40	2·27	2·29
50	2·80	2·53	3·33	3·19	3·34
100	3·05	2·85	3·68	3·61	3·59
300	2·15	1·98	2·44		

Column 1: present values; column 2: Rapp and Englander-Golden (1965); column 3: Smith (1930); column 4: Assundi and Kurepa (1963); column 5: Tozer and Craggs (1960).

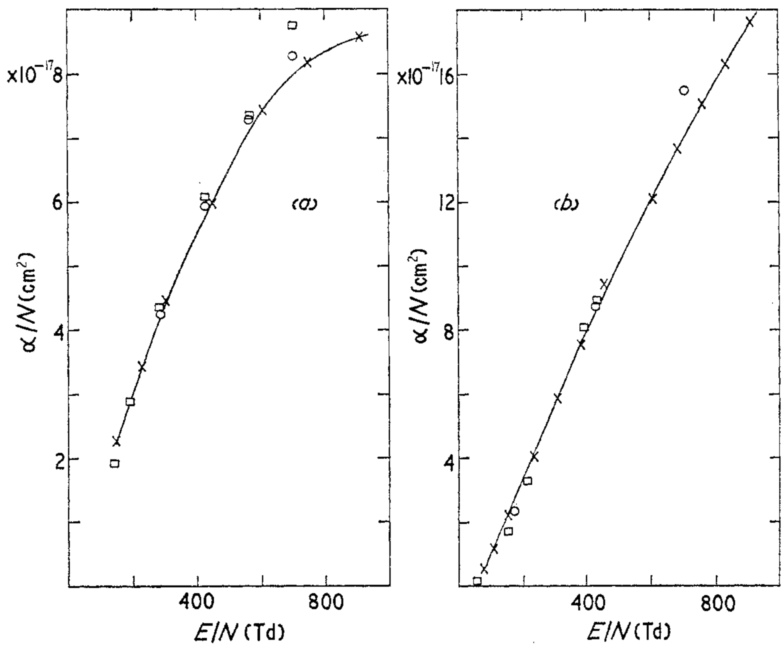

Figure 1. α/N as a function of E/N in (*a*) neon and (*b*) argon. —×— present results; ○ (*a*) Kruithof and Penning (1937) and (*b*) Davies and Milne (1959); □ (*a*) Chanin and Rork (1963) and (*b*) Heylen (1968).

The ionization coefficients in neon and argon, as a function of E/N are presented in figure 1 ((*a*) and (*b*) respectively). The maximum estimated error in this data is $\pm 3\%$. The present results agree with previous determinations of Kruithof and Penning (1937) and Chanin and Rork (1963) in neon and of Davies and Milne (1959) and Heylen

(1968) in argon at all but the highest values of E/N investigated. At these very high values of E/N the electron swarm is no longer in equilibrium with the applied electric field and the mean swarm energy becomes position dependent. Values of α/N at these high swarm energies must be treated with caution since it is not understood how the electron swarm behaves under these conditions. An attempt was made by Chanin and Rork (1963) in neon to measure how α/N varies with gap distance, at constant gas pressure, in this non-equilibrium regime. The method used however was crude and involved considerable error. A detailed analysis of the behaviour of α/N in this range of E/N is a most complex problem since all the various parameters which contribute to α/N, eg the ionization frequency, the electron drift velocity, the lateral and longitudinal diffusion coefficients, will also vary with mean swarm energy and hence position, each in its own, at present mostly unknown, manner.

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