

where α is the first Townsend ionisation coefficient. Substitution of (11) in to (4) and (6) gives

$$v_z = \Gamma_z/n = w \left(1 - \frac{\alpha D_{||}}{w} + \frac{\alpha^2 \Gamma^{(3)}}{w} + \dots \right), \quad (12)$$

$$\alpha(W - \alpha D_{||} + \alpha^2 \omega^{(3)} + \dots) = \nu \quad (13)$$

respectively, from which α and v_z may (at least in principle) be found to the desired accuracy by taking sufficient terms in the expansions. Problems of convergence of these series could arise if α were not sufficiently small. Thus, just as in the Cavalleri experiment, it appears that a kinetic theory treatment (Phelps and Pitchford 1985) based on the hydrodynamic limit but avoiding a density gradient expansion is desirable. However, unlike the Cavalleri experiment, there appears to be no obvious empirical means of extracting any of the transport coefficients appearing in parentheses in (12) and (13) as a limiting case, e.g. at high pressure. This is because α scales as n_0 and all terms in the series (12) and (13) are therefore independent of n_0 . Of course, α itself may be found by direct comparison of (11) with the empirical density profile, and v_z could, in principle, be obtained if the flux Γ were measurable in some way which did not disturb the free-space density distribution (11). We must therefore regard this experiment as furnishing quantities v_z and α which occupy a unique position in the hierarchy of transport coefficients.

3. Discussion

We firstly observe that the reactive correction $S^{(1)}$ of equation (7) is given by the approximate relation (Robson 1986)

$$S^{(1)} = -\frac{kT_{||}}{e} \frac{\partial \nu}{\partial E}, \quad (14)$$

so that if the collision frequency for nonconservative collisions is independent of energy, and the average production rate ν is consequently independent of E/n_0 , W and w are identical (but different from v_z). If collisions are conservative, $\nu = 0$, $\alpha = 0$ by (13) and consequently $W = w = v_z$. In general, however, all three differ. Notice that $S^{(1)}$ can be either positive or negative. Similar corrections for diffusion coefficients are given by Robson (1986). This multiplicity of transport coefficients in nonconservative conditions (ionisation, attachment, etc.) can give rise to difficulties in interpretation unless care is taken in the definition, measurement, calculation and reporting of drift velocities. The sort of difficulties which can arise otherwise are apparent in a recent paper of Ingold (1989) who effectively compared v_z (w_0 in the notation of Ingold) with w of Robson (1986). As these are fundamentally different quantities, it is not surprising that such significant discrepancies are observed, even in the case of a constant momentum-transfer collision frequency. The criticisms contained in Ingold's paper are therefore quite misplaced. Robson (1986) and Robson and Ness (1988) did not 'overlook' the importance of the density gradient, as claimed by Ingold, but rather we have expanded in terms

of it, as in equations (4) and (5), and identified transport coefficients in the manner described above. There is no reason to doubt the validity of any of the results reported by Robson (1986) or Robson and Ness (1988). Braglia *et al.* (1990) have introduced further 'conventional' transport coefficients, but these are artificial constructs, inconsistent with any conventional definition that we know of and not measurable in any case (Ness and Brennan 1992).

Blevin (1988) suggested that a transport property can be usefully defined only if:

- (i) it is *measurable* and not an artifact of a particular theoretical model or method of analysis;
- (ii) it is a *universal* quantity, independent of the method of measurement or the particular experimental arrangement. The SST parameters v_z and α do not appear to qualify, since they are related to a specific experimental arrangement.

In principle, the 'flux' or PT drift velocity w also satisfies these conditions, but its determination also requires an independent measurement of the number of electrons in a swarm. Only the 'bulk' quantities W , v , $D_{||}$ and D_{\perp} satisfy the above stipulations. Looked at from another perspective, only these parameters appear in the diffusion equation (9), which is used to analyse the majority of experiments. We therefore suggest that W be designated as *the* drift velocity and $D_{||}$, D_{\perp} as *the* diffusion coefficients, as these are the parameters which are in fact measured. The corresponding flux-derived parameters w , $\mathcal{D}_{||}$ and \mathcal{D}_{\perp} are not measured in present-day experiments.

These considerations should also be taken into account wherever transport processes are accompanied by reactive effects, in fluid mechanics, plasma physics, micrometeorology, engineering applications and so on. The scope for discussion is very broad.

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