Diffusion of charged particles in a DMA with inclined electric field

J. Salm and U. Hõrrak

Institute of Environmental Physics, University of Tartu, 18 Ülikooli St., 50090, Tartu, Estonia

Keywords: DMA, size analysis, diffusion, measurement errors.

In general lines, a differential mobility analyser (DMA) has air inlet(s), air outlet(s), electrodes, and collector(s) of electric current. Diffusion distortions in a simple DMA have been studied in (Salm, 2000). We will demonstrate that the method developed in the above paper is applicable also for a more complicated DMA. In particular, we consider the design of DMA with inclined electric field, which has certain advantages with respect to resolution (Loscertales, 1998; Tammet, 1999). The principle of inclined velocities was developed in an analyser by Tammet (2003).

In this abstract we systematically refer to the paper (Salm, 2000) and the corresponding equation numbers. Figure 1 of this paper is retained, only the traverse electric field strength \( E \) is replaced by two components \( E_x \) and \( E_y \), where \( E_x \) is directed against the airflow \( u \).

![Figure 1. Schematic representation of the DMA.](image)

Thus the horizontal velocity of charged particles is

\[ u = Z_1 E_x, \]

where \( Z_1 \) is the mobility of entering aerosol particles.

Equation (12) for the characteristic (limiting) mobility is replaced by a modified equation

\[ Z_0 = \frac{u}{E_y} \frac{d}{L + kd}. \]

We will consider here the case \( E_x \propto E_y \). Let us express \( E_x = kE_y \), where \( k \) is the coefficient of proportionality.

The following derivation of equations is quite similar to that in (Salm, 2000), with understandable replacements. In Equation (14) the flow velocity \( u \) is retained, since the horizontal electric field \( E_x \) does not influence the inlet. The entering aerosol is characterized by the differential distribution of polar charge density of particles by mobility or the mobility spectrum \( \rho(Z_1) \). In Equation (15) the electric field strength \( E \) is replaced by \( E_y \) etc. The derivation results in the normalized apparent spectrum \( w^*(Z,Z_1) \). Equation (27) in (Salm, 2000) is replaced by the following equation:

\[ w^*(Z,Z_1) = \frac{\rho_0 Z_1}{2\pi Z^2} \times \exp \left\{ \frac{\rho_0}{2} \left( \frac{L}{d} + \frac{E_y}{L + kd} Z_1 \right) \right\} \times K_0 \left( \frac{\rho_0}{2} \left( \frac{1}{L + kd} Z_2 \right) \right) \times \left( 1 \pm \frac{l^2}{a^2} \right), \]

where \( Z \) is the variable mobility, \( \rho_0 \) is the Peclet number, \( K_0(\zeta) \) is the Macdonald’s function.

Rough estimations of the influence of diffusion on the resolution of mobility spectrometers are possible also by means of simpler methods. However, a precise knowledge of the apparent spectrum opens a way to the improvement of resolution by calculations.

If we know the normalized apparent spectrum \( w^*(Z,Z_1) \) for one mobility \( Z_1 \), then the apparent spectrum \( \rho^a(Z) \) for any general case is expressed as

\[ \rho^a(Z) = \int w^*(Z,Z_1) \rho(Z_1) dz_1. \]

(*)

In many cases the apparent spectrum \( w^*(Z,Z_1) \) depends on the ratio \( Z/Z_1 \). Then, using a simple exponential transformation, it is possible to express Equation (*) in the shape of convolution, and to solve the convolution equation by means of the Fourier transform.

This work was supported by the Estonian Science Foundation under grants 6223 and 6988.


