Effect of Particle Diffusion Loss on Coagulation in a Tube

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Particle concentration gradient and diffusion to the walls of the container are seldom considered in studies of aerosol coagulation, in spite that in the calculation of the coagulation rate constant diffusion is explicitly included. The objective of this work is to examine the effect of particle diffusion (i.e. radial and axial concentration gradient, and particle loss to the wall) in the coagulation process of an aerosol flowing laminarly in a circular tube.

Numerical calculations of mean size and geometric deviation for a cogulating aerosol with and without diffusion loss to the tube wall have been performed. The equation to be solved is

$$u_x \frac{\partial n_i}{\partial x} = \beta_i \left(\frac{\partial^2 n_i}{\partial r^2} + \frac{1}{r} \frac{\partial n_i}{\partial r} \right) + \frac{\Delta \ln d_p}{2} \sum_{j=1}^{i-1} K_{i-j,j} n_{i-j} n_j$$

$$- \Delta \ln d_p \sum_{j=1}^{\infty} K_{i,j} n_i n_j$$

where all the variables are dimensionless: u_x is axial flow velocity; $n_i \Delta \ln dp$, the number concentration of particles with size around $\ln dp_i$; β_i, their diffusion coefficient; $K_{i,j}$ the coagulation rate constant between particles of size indexes i and j; and r,x are the radial and axial coordinates. The total particle number concentration at the tube inlet is denoted as n_{T0}. At the tube inlet, $x = 0$, the aerosol is assumed to have a uniform concentration and a lognormal particle size distribution.

Illustrative results are shown in Figures 1 and 2. In the first drawing, the evolution of the aerosol geometric mean diameter along the tube is plotted taking as parameter the total particle number concentration at the entrance of the tube. This particular case was obtained for a tube radius of 5 mm, tube length of 100 cm, aerosol flow rate of 2 lpm, and initial particle size distribution with d_{pg} = 10 nm and σ_g = 1.20. Two curves are drawn for each value of n_{T0}: one taking $\beta_i = 0$ in the above equation (this is the case usually discussed in the literature); and another one considering the full equation, thus taking account of particle losses and of the existence of a radial concentration gradient in the tube. In this specific case, the effect of diffusion on the mean particle size starts to be noticeable for initial concentrations above 10^8 cm^{-3}; for example, at the highest concentration the mean particle size at the tube outlet is about 15% smaller when diffusion losses are considered.

Figure 2 shows the downstream evolution of the geometric standard deviation for the same example considered in the previous Figure. The effect of diffusion loss is less drastic in this case, but anyway it is observed that in general diffusion yields narrower size distributions.

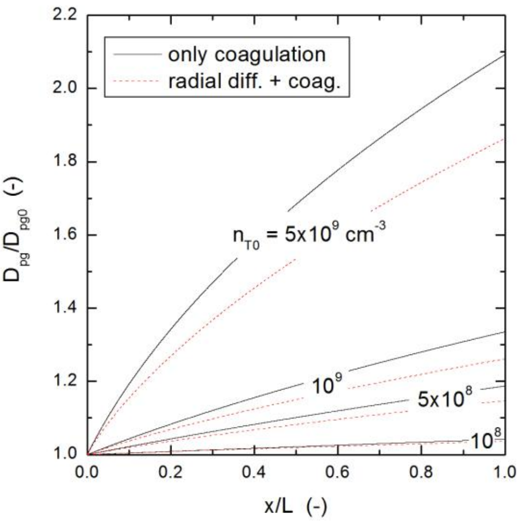

Figure 1. Mean particle size along the tube for the specific conditions cited in the text.

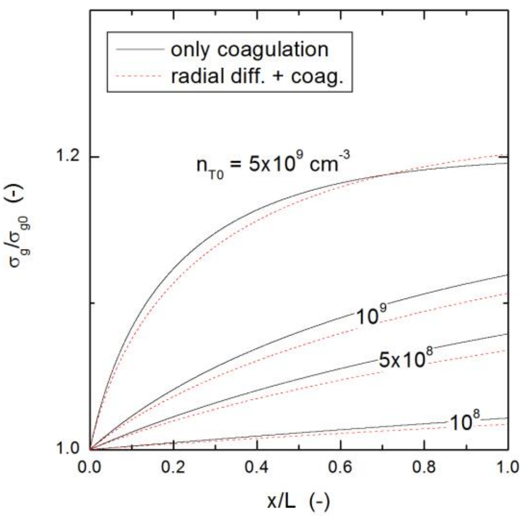

Figure 2. Geometric standard deviation along the tube for the same example of Figure 1.

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