Generation and growth of aerosol particles on nucleus of radioactive decays

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Aerosol particles could grow on charged ions nuclei. Such nuclei could be produced by different processes occurring in a gas phase, including chemical and photo-chemical reactions and radioactive decay. In particular, appearance of ions in the gas phase could be related to alpha, beta and gamma radiation. Moreover, it is common belief that radiation, both natural and anthropogenic, is the main contributor of ions to the atmosphere. It was shown (Freidlander, 2000) that presence of oversaturated vapor does not always ensures particle growth on charged ions. The reason is based on a fact that, according to the classic theory of nucleation, there is a Coulomb's barrier exists for charged nuclei, preventing small particle growth up to the point where substantial oversaturation is reached. Considering that the size of the critical cluster is small (few dozens of molecules), the surface tension could not be considered, as almost all molecules are located on the surface. In this situation, a kinetic approach ought to be used to describe the mechanism of the particle growth on charged ions.

Cloud (Wilson) chambers and diffusion chambers are commonly used for detecting ionizing radiation by visualised particle growth on the ion nuclei produced by radioactive decay. Diffusion chambers have some important advantages as (1) they are self cleaning from alien nuclei, (2) allow identifying a nature of radioactive particle, and (3) could operate continuously. Figure 1 shows some traces of radioactive decay products.

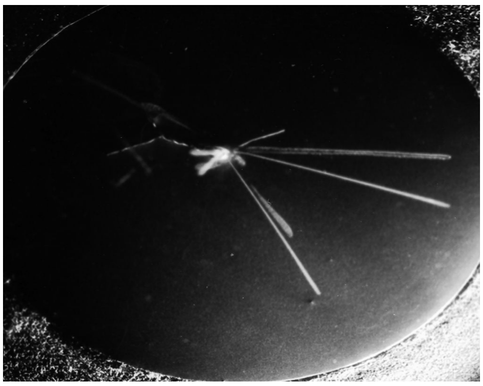

Figure 1. Decay of ^{239}Pu observed by diffusion chamber

Similar process is used for growth of clusters and nanoparticles in CNCs, where ions could also act as nuclei for particle growth. On this basis, the Diffusion Aerosol Spectrometer (DAS) equipped with CNC could be used for measuring particles grown on both ion and molecular cluster nuclei. To distinct these types of particles, it is crucial to separate ones produced on ion nuclei and carrying its charge from others which acquired charge as the result of collision with gas ions. Let c_0 be a concentration of light ions, c_n - concentration of particles containing n molecules, ion concentration - c_{in} , a rate of ion generation in a unit of volume per unit of time - I, rate of collision of ions carrying k and n molecules - α_{kn} , and velocity of collision of neutral particles containing n molecules and light ions is K_{1n} . Then, the following equations could be written to describe rates of variation of concentrations of light ions and particles:

$$\frac{\partial c_{i1}}{\partial t} = I - \alpha_{11}c_{i1}^2 - \sum_n^G \alpha_{1n}c_{i1}c_{in} - \sum_n K_{1n}c_{i1}c_n \,, \quad (1)$$

$$\frac{\partial c_{in}}{\partial t} = K_{1n}c_{i1}c_n - \alpha_{1n}c_{i1}c_{in} \,, \quad (2)$$

Solving these equations enables determining of concentrations of neutral particles, unity charged particles and light ions. In a case of stationary regime, the left hand side of equations could be taken as 0 and $c_{i1} \gg c_{in}$ and $c_{i1} \gg c_n$. Then, for these conditions, Eq. (2) provides the following relation $\frac{c_{in}}{c_n} = \frac{K_{1n}}{\alpha_{1n}}$. For small particles causing main interest, K_{1n} and α_{1n} could be taken from Lushnikov and Kulmala (2004):

$$\alpha(a) = \frac{4\pi D l_c}{1 - e^{-\frac{l_c}{R(a)}}} \,, \quad (3)$$

where D - diffusion coefficient, $l_c = \frac{e^2}{kT}$ - Coulomb's distance of interaction, $R(a) = \frac{4D}{v_T}$, e - electron charge, k - Boltzmann's constant, and v_T is a rate of heat motion.

Concentrations of charged and neutral particles were experimentally obtained with the aid of a condenser placed at the entry to the DAS. The results enabled to separately identify concentrations of charged and neutral particles. Additional experiments with radioactive sources with different power enabled to identify a rate of atmospheric particle generation.

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