Key Factor Identification for PM2.5 Formation in China: The Role of NH$_3$ in Atmospheric New Particle Formation

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Abstract

PM2.5 (particulate matters with aerodynamic diameter smaller than 2.5 µm) pollutions with adverse effect on human health and global climate has occurred frequently and caused widely concern in China. The main chemical compositions in PM2.5, i.e., SO$_4^{2-}$, NO$_3^-$, NH$_4^+$ and organic compounds, are converted from SO$_2$, NO$_x$, NH$_3$ and volatile organic compounds (VOCs), respectively. In order to find out the key factor for PM2.5 generations to help to relieve the air pollution, formation characteristics of PM2.5 is investigated. A property of electric neutrality of PM2.5 is proposed according to the least-energy principle and verified through electricity-charge calculation in this paper. As the only cation in the main chemical compositions of PM2.5, NH$_4^+$ is vital for anions (such as SO$_4^{2-}$ and NO$_3^-$) to aggregate together and is a key factor for PM2.5 formations. The major source of PM2.5 is secondary new particulate formations (NPF) in atmosphere. Herein, to identify the role of NH$_3$ in atmospheric NPF, a new kinetic model, combining the oxidation of SO$_2$/NO$_2$ in SO$_2$/NO$_2$/NH$_3$/H$_2$O/air system and the aggregation of clusters in H$_2$SO$_4$/HNO$_3$/NH$_3$/VOC system, is established based on gas-kinetic theory. From the modeling analysis, it is found that NH$_3$ can enhance PM2.5 formations not only by facilitating conversions of SO$_2$ and NO$_2$ indirectly, but also by promoting aggregations of H$_2$SO$_4$, HNO$_3$, NH$_3$ and VOCs directly. And the enhancement of conversion fractions for SO$_2$ and NO$_2$ during oxidation processes is the major effect of NH$_3$ on PM2.5 formations. In addition, the presence of NH$_3$ can particularly promote the contribution of HNO$_3$ in NPF process. Therefore, in order to relieve PM2.5 pollutions in China, the control strategies for NH$_3$ as current restrictions on SO$_2$ and NO$_x$ are suggested to be enhanced by government, such as decreasing the amount of nitrogenous fertilizer utilization, or changing the fertilizing environment from dry condition to wet condition.

Keywords: PM2.5, NH$_3$, new particle formation, modeling studies, haze mitigation