

Scavenging of Gaseous Pollutants by Falling Liquid Droplets in Inhomogeneous Atmosphere

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Concentration measurements of CO_2 , SO_2 , NH_3 and other gases in the atmosphere revealed altitudinal dependence of the concentrations. In this study we analyze mass transfer during absorption of soluble atmospheric gases by falling rain droplets with internal circulation taking into account altitudinal dependence of concentrations of soluble trace gases and temperature distribution in the atmosphere. Concentration of soluble gas and temperature distribution in the droplet are governed by a system of unsteady convective diffusion and energy conservation equations with time-dependent boundary conditions (Elperin et al. 2007; 2008, 2009). It is shown that gas absorption by falling droplets is described by a system of Volterra integral equations (Elperin and Fominykh 2005) that are solved numerically. We compare the results obtained using the model of gas absorption in the case of uniform distribution of soluble gases and temperature with those obtained when concentration of soluble gases and temperature vary with altitude. The comparison showed that vertical concentration and temperature profiles in atmosphere have a profound effect on mass transfer during gas absorption by a falling rain droplet. When concentration of soluble trace gases in the atmosphere is assumed constant, their content in the droplet attains saturation after a certain time elapsed, and at the final stage of their fall droplets do not absorb soluble trace gases. When concentration of soluble gases in the atmosphere decreases with altitude, droplets absorb trace gases during all the fall period. Consequently, concentration of soluble gases inside droplets at the ground which fall in the atmosphere with a homogeneous distribution of trace gases is lower than the concentration inside the droplet falling in the atmosphere with altitude dependent concentrations. When concentration of soluble gases increases with altitude, after a certain time interval droplets begin to release the dissolved gases. Consequently droplets have a lower concentration of trace gases at the ground level as compared with droplets falling in an atmosphere with a homogeneous distribution of trace gases. Dependence of the concentration of the dissolved gas in the bulk of a water droplet vs. time for absorption of CO_2 by water (average concentration of CO_2 in the atmosphere is 300 ppm) is shown in Fig. 1. Calculations are performed for a case when initial concentration of dissolved gas in a

droplet is negligibly small and for different values of gradients of concentration of a soluble gas. The derived solution can be used in calculations of scavenging of hazardous gases in atmosphere by rain or gas absorption in spray absorbers and incorporated into the computer codes. The simple form of the obtained solutions allows to use them to analyze the dependence of the rate of mass transfer on different parameters, e.g., upon a radius of a droplet, diffusion coefficient, gradient of absorbate concentration in a gaseous phase etc. The obtained solution can be used for validating modeling procedures for solving more complicated problems of gas absorption by falling liquid droplets.

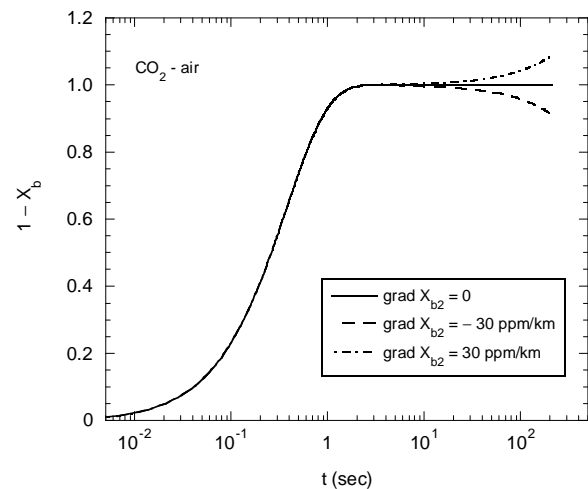


Figure 1. Dependence of the concentration of the dissolved gas in the bulk of a water droplet vs. time.

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