Effect of Adsorbable Foreign Gas on Evaporation of water from Porous Aerosol Particles

Levdansky, V.V.
2013

EFFECT OF ADSORBABLE FOREIGN GAS ON EVAPORATION OF WATER FROM POROUS AEROSOL PARTICLES

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INTRODUCTION

Adsorption of molecules of a foreign gas on the surface of nanoscale objects can influence phase transitions in the heterogeneous systems with nanoobjects. Some problems related to adsorption of foreign molecules on the surface of nanoscale particles (clusters) were considered in (Luijten et al., 1997; Levdansky et al., 2006). Here we discuss the effect of the adsorbable foreign gas on water evaporation from porous aerosol particles with nanoscale pores.

RESULTS AND DISCUSSION

It is known that in a number of cases micro- and nanoscale pores can be inside solid aerosol particles (Fukuta, 1966). The aerosol particle in this case can be considered as the solid skeleton with fine (nanoscale) pores that are often filled with water (e.g. due to capillary condensation of the water vapor). The removal of water from the porous aerosol particles can be realized by water evaporation from pores, e.g. with increasing the particle temperature under the effect of solar radiation. Let us consider the influence of the adsorbable foreign gas on water evaporation from the fine cylindrical capillary in the free-molecular flow regime. Adsorption of molecules of a foreign gas on the water meniscus in the capillary can affect the surface tension of water as well as can block phase transitions on the meniscus surface. We consider for simplicity evaporation from the capillary with the fully wettable wall. The resulting flux of vapor molecules J passing through the capillary in water evaporation from the concave hemispherical meniscus can be written as

$$J = \frac{\pi d^2}{4} \frac{P_e}{(2\pi mkT)^{1/2}} QW.$$ (1)

Here d is the diameter of the capillary that is assumed to be equal to the diameter of the meniscus, P_e is the saturated vapor pressure of water over the pure meniscus (without adsorbed foreign molecules), m is the mass of the water molecule, k is the Boltzmann constant, T is the temperature, W is the transmission probability of vapor molecules passing through the capillary, the value of Q in view of (Luijten et al., 1997) is given by

$$Q = \frac{1}{1 + K_{am}P_a}\left[\left(\frac{1}{1 + K_{am}P_a}\right)^{-G} - H\right],$$ (2)

where $G = 4Vn_0/d$, $H = P_1/P_e$, n_0 is the number density of molecules of the adsorbable foreign gas in the fully filled monolayer, P_1 is the partial pressure of the water vapor at the exit end of the capillary, K_{am} is the Langmuir adsorption constant in adsorption of foreign molecules on the

meniscus, P_a is the partial pressure of the adsorbable foreign gas, V is the volume per molecule in the water.

Figure 1 shows the dependence of Q on $\varphi_m = K_{am}P_a$. It is seen from Fig. 1 that depending on H the value of Q in some range of φ_m can both decrease and increase with a rise in φ_m. Moreover, the introduction of the adsorbable foreign gas into the equilibrium at $P_a = 0$ system can induce the resulting flux of water molecules (the line 3 in Fig. 1). It is also shown that adsorption of foreign molecules on the meniscus surface can affect the critical (equilibrium) diameter of the meniscus at which the resulting flux of water molecules on the meniscus surface is equal to zero.
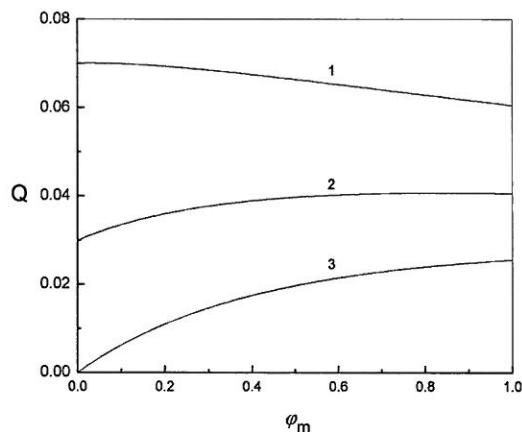

Fig. 1.: Dependence of Q on φ_m in water evaporation from the cylindrical capillary at $d = 10^{-8}$ m, $T = 293$ K, $n_0 = 6 \cdot 10^{18}$ m^{-2} and different values of H; 1: $H = 0.93$, 2: $H = 0.97$, 3: $H = 1$.

It is worth noting that the value of W in the general case can also depend on the pressure of the adsorbable foreign gas due to the effect of adsorbed foreign molecules on scattering of vapor molecules by the channel wall.

CONCLUSIONS

It is shown that the influence of the adsorbable foreign gas on water evaporation from the porous aerosol particle with fine pores (capillaries) is related to a change in the flux of water molecules evaporating from the meniscus in the capillary as well as to a change in the transmission probability of water vapor molecules passing through the capillary due to the influence of adsorbed foreign molecules on scattering of water vapor molecules by the capillary wall.

ACKNOWLEDGEMENTS

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