Experimental study of homogeneous nucleation from the sulfur supersaturated vapor: Evaluation of the surface tension of critical nucleus.

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The surface curvature dependence of surface tension is a central problem in the surface thermodynamics. There are many theoretical contributions in the literature where the surface tension $\sigma(R_s)$ of a small drop was calculated as a function of its radius R_s. It is hardly possible to measure directly the curvature dependence of surface tension. However, the nucleation rate is a function of surface tension and therefore experimentally measured parameters of the homogeneous nucleation (rate, temperature, supersaturation) can be used to determine $\sigma(R_s)$. In a work [1] new formula for the nucleation rate was proposed. This formula is based on the Kusaka's theory, the theory of Reiss accounting the translational movement of the mass center of the drop, and Frenkel's kinetic theory of liquids. Thus we have a rigorous formula accounting both the $\sigma(R_s)$ dependence and translation-rotation correction factor which allows us to calculate the dependence of the surface tension on radius from the experimental nucleation rate.

In present work the homogeneous nucleation of sulfur supersaturated vapor is studied in a laminar flow nucleation chamber. The experimental setup is shown in Fig. 1. The concentration of outcoming aerosol particles is analyzed by an Automatic Diffusion Battery coupled with a condensation nucleus counter. The rate of sulfur evaporation from crucible and rate of sulfur wall deposition is measured by direct weighing of the wall deposits and crucible. The axial and radial temperature profiles are measured by a thermocouple. The radial profiles of sulfur vapor concentration and supersaturation are determined solving the mass transfer equation. Based on the rigorous formula and experimental data the surface tension of sulfur critical nuclei resulting from the nucleation has been calculated. The surface tension $\sigma(R_s)$ of the sulfur critical nucleus is found to be 72.5 ± 1.1 dyne/cm for the radius of the surface of tension $R_s \approx 10.6$ Å at temperature 312 – 319 K. The value of $\sigma(R_s)$ proved to be 5 % higher than the surface tension of a flat surface.

The "supersaturation cut-off" method for to find approximate confines of the nucleation zone was developed. The idea of this method is in inserting a stainless steel grid inside the nucleation region. The vapor to grid deposition results in the suppression of nucleation downflow which is observed as a decrease of outlet aerosol concentration. The outlet concentration vs. axial grid position curve has a dip which gives approximate confines of the nucleation zone. It was shown that the "supersaturation cut-off" method was in a good agreement with the calculations of the nucleation region, Fig. 2.

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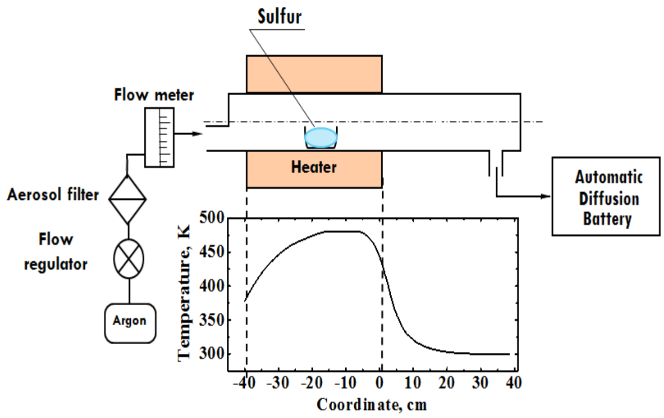

Figure 1. The schematic of experimental setup.

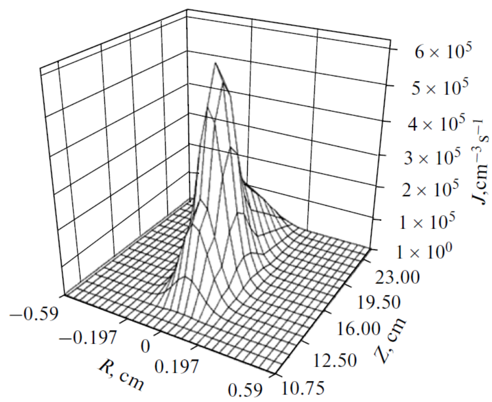

Figure 2. Calculated field of nucleation rate.