Surface tension of sulfur nanoparticles as determined from nucleation experiments

S.V. Valiulin[1], A.A Onischuk[1], S. di Stasio[2], S.V. Vosel[1], A.M. Baklanov[1], V.V. Karasev[1],

[1]Voevodsky Institute of Chemical Kinetics and Combustion SB RAS, Novosibirsk, 630090, Russia
[2]Istituto Motori C.N.R., Fluid Dynamics and Combustion Division, 80125 Napoli, Italy

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Presenting author email: valiulin@kinetics.nsc.ru

The surface tension of sulfur nanodrops (critical nuclei) is determined from the homogeneous nucleation investigation results. To this end a laminar flow nucleation chamber is used. The aerosol concentration and size distribution are monitored at the chamber outlet by the diffusion battery and gravitational sedimentation techniques.

The nucleation volume is evaluated by the "supersaturation cut-off" method. The region of aerosol formation is localized by the 90 degree light scattering approach. The nucleation rate is determined experimentally from the outlet aerosol concentration and the nucleation volume to be $I_{\text{exp}} \approx 2.3\times10^7$ cm^{-3}s^{-1} at nucleation temperature $T_{\text{exp}} \approx 310$ K and the total supersaturation (total vapor pressure to saturated vapor pressure ratio) $s_{\text{exp}} = 1.9\times10^3$. Using the rigorous formula for the nucleation rate (taking the translation-rotation correction factor into account) (Vosel et al., 2013) the surface tension of critical nucleus and its radius of the surface of tension is determined from I_{exp}, T_{exp} and s_{exp} to be $\sigma_{\text{exp}} = 72.11$ mN/m and $R_{S,exp} = 0.980$ nm, respectively.

To calculate the critical nucleus surface tension more exactly a numerical simulation of vapor to particles conversion is carried out. As a result the nucleation rate is determined to be in the range $3\cdot10^3$ - $2\cdot10^8$ cm^{-3}s^{-1} for the supersaturation of S_8 species to be in the range 4000 - 380 and nucleation temperature 300 - 350 K. The surface tension σ_S of the sulfur critical nucleus is calculated to be in the range 67 to 75 mN/m for the radius of the surface of tension 1.08 to 0.95 nm. These values of surface tension exceed by 2 to 5% the surface tension σ_∞ for flat sulfur interface (Fig. 1). Such a small deviation of σ_S from σ_∞ is in agreement with the author's assumption that the surface tension for non-metal elements is essentially independent of curvature as in contrast to the metal nanoparticles. The comparison with the nanodrop surface tension for other elements (Fig. 2) makes it possible to conclude that the larger is the group number in the Periodic Table the less is the absolute value of difference between the surface tension of critical nucleus and that of the flat surface.

It is important to note that to determine correctly the critical nucleus surface tension one should take into account the translation-rotation correction factor in the formula for the nucleation rate. Omission of this factor gives the error of about 30% in the surface tension.

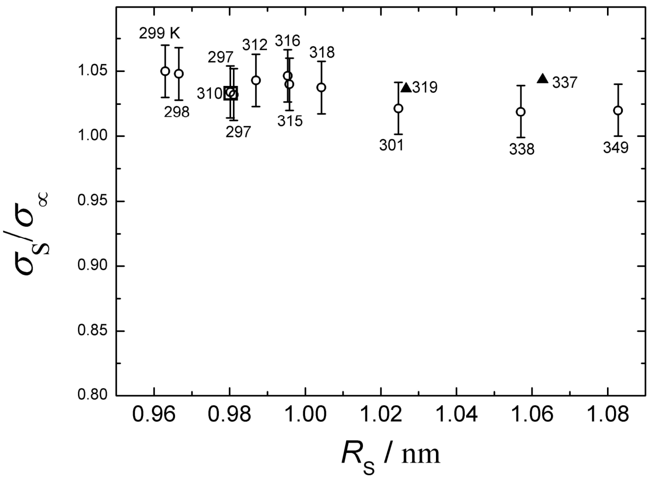

Figure 1. The ratio σ_S/σ_∞ vs. for different nucleation temperatures and values of the radius of surface of tension. The nucleation temperature is shown for each point.

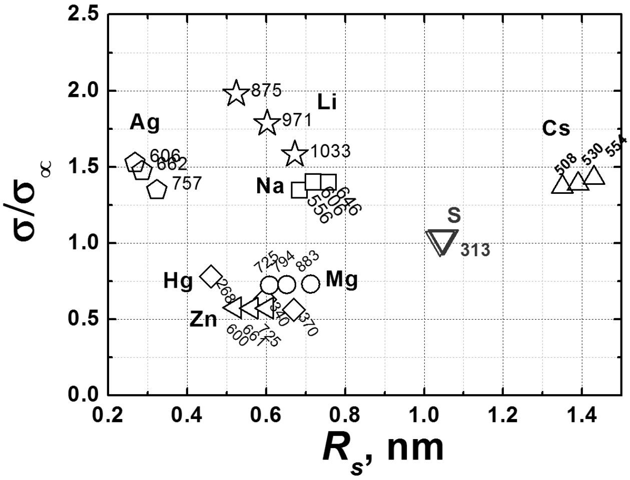

Figure 2. The ratio σ_S/σ_∞ for different elements. The nucleation temperature is shown for each point.

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