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PARAMETERIZATIONS FOR THE KELVIN (SURFACE TENSION) EFFECT ON THE EQUILIBRIUM RADIUS AND ASSOCIATED OPTICAL PROPERTIES OF A HYGROSCOPIC AEROSOL PARTICLE

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ABSTRACT

The equilibrium size of an atmospheric aerosol particle is a key property, affecting its light-scattering coefficient and asymmetry parameter, and hence its radiative influence. For a hygroscopic particle of given composition this size is determined by the particle dry mass (which can alternatively be expressed as the volume-equivalent dry radius $r_{\rm dry}$) and the fractional relative humidity h (≡RH/100). Surface tension also affects this equilibrium size (Kelvin effect) and thus the associated properties. We have examined the dependence of the equilibrium size of a particle with given $r_{\rm dry}$ at given relative humidity on surface tension and found that to good approximation the decrease in equilibrium radius at a given fractional relative humidity h resulting from the Kelvin effect is independent of $r_{\rm dry}$ and approximately equal to $\Delta r/\mathrm{nm} = -h/3/(1-h)$, with only a weak dependence on solute and on temperature. This expression also yields a relationship between h and $r_{\rm dry}$ (or radius at a given h) describing when neglect of the Kelvin effect results in a specified error in calculated particle radius. For example, the value of the volume-equivalent dry radius below which the Kelvin effect results in more than a 5% decrease in the equilibrium radius of a solution drop at a given relative humidity h is given approximately by $r_{\rm dry,5\%}/\mathrm{nm} = [8h/(1-h)^{2/3}]$. The Kelvin effect also influences the hygroscopic growth factor g of an aqueous solution drop between two different relative humidities, resulting in a decrease in g between a low relative humidity and $h = 0.9$ of approximately $\Delta g = -3\ \mathrm{nm}/r_{\rm dry}$, again with only a weak dependence on solute and on temperature. These findings, all of which are presented for fractional relative humidity as the independent variable, allow the magnitude of the Kelvin effect and its consequences on the properties of an aqueous solution drop to be readily assessed.