Homogeneous Nucleation and the Microscopic Theory of Droplet Growth

The two theories underpinning condensing flow calculations are the theory of the homogeneous nucleation of liquid droplets from supersaturated vapours, and the theory of droplet growth. From both a practical and a scientific viewpoint, it is important that these processes be modelled as accurately as possible. The two theories are strongly interconnected, although this is not particularly evident from the very extensive literature. Viewed together, however, a number of inconsistencies become evident.

Droplet growth theory is the more reliable although there are still areas which need attention. For example, at the surface of a condensing droplet, the zero temperature-slip boundary condition, normally applied for growth or evaporation in the low Knudsen number or continuum regime, is incorrect. The true condition can only be established by solving the Boltzmann equation close to the surface. Using approximate methods, a theory has been developed [1991, 1993] which successfully predicts the ‘reversed temperature gradient phenomenon’ thought to occur in this region.

Homogeneous nucleation theory is still highly controversial after almost a century of research. The review [2005] assesses the current situation and includes some new ideas and insights. The weakness of the classical theory, ignored by all but a handful of papers, is the importance of energy transfer (as opposed to mass transfer) along the chain of growing molecular clusters. A non-isothermal theory which models this process is currently under development, the objective being a single uniform approach, valid all the way from the formation of microscopic liquid-like clusters through to the establishment of the macroscopic droplet size distribution. This work has not yet been completed but some preliminary results for isothermal nucleation have been published [2008].

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