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Investigation of Interfacial Mass Transfer During Dropwise Condensation Using the Navier-Stokes-Korteweg Equations with a van der Waals Fluid

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Dropwise condensation is a phenomenon that is widely present both in nature (e.g. morning water condensation on grass leaves) and in engineering systems such as condensators, water desalination systems and water harvesting systems to name a few. However, despite its commonality, dropwise condensation mechanisms and thermodynamics are not thoroughly understood and there are plenty of open challenges. One of this challenges is the modelling and prediction of the mass transfer rate and distribution between phases. It is often assumed that the mass transfer between the phases is homogeneously distributed on the interface. Nevertheless, experimental and numerical observations of the droplet's temperature gradients indicate that higher heat and mass transfer rates are expected to be allocated near the triple contact line. Measuring such flows in the laboratory can prove to be almost impossible due to the involved characteristic lengths and the complexities of the system. Computational methods offer a solution to this by reducing the complexity of the studied system and partially handling the necessary characteristic lengths. Thus, computational methods become a powerful tool in the study and development of more accurate models for phase transfer. This work examines the interfacial mass transfer of a condensing droplet resting on a cooled surface. Different cooling temperatures and surface wettabilities are considered. To simulate the droplet, the Navier-Stokes-Korteweg (NSK) equations are utilized to solve a van der Waals fluid. The NSK equations are a set of 3rd order partial derivative equations for mass, momentum and energy which present hyperbolic, parabolic and elliptic behaviours. As a consequence of the complexity of this system of PDEs, a robust Least-Squares Spectral Elements Method with Hermitian basis functions is employed utilizing C^1 cartesian elements. Neumann boundary conditions on the density are used to impose the contact angle between the droplet and the surface. The results obtained show that the mass flux is higher near the contact line and that it decreases as we move away from it along the liquid-vapor surface, opposed to the homogeneous assumption. Moreover, a small outwards mass flux can be observed at the top of the droplet for hydrophobic surfaces.