VOF based sharp interface methods for the multi-phase incompressible flows with multi-component phase change and complex geometries

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In many natural and industrial applications, solid-liquid-gas phase change processes, such as multi-component solidification and evaporation, play a crucial role. These processes involve complex interactions between flow dynamics, heat transfer, and concentration fields, which influence the flow patterns and interface morphology. In this study, we present a novel 3D sharp interface method developed to model these phenomena in the presence of complex geometries. The contact line motion is captured through a sharp, conservative approach, ensuring strong coupling between flow, temperature, and concentration fields at the interfaces. The method combines the volume-of-fluid (VOF) technique and the embedded boundary method (EBM) to represent sharp interfaces, with geometric reconstruction used to define the distinct phases and enforce accurate jump conditions across the interfaces. The accuracy and robustness of the proposed method are rigorously validated through a comprehensive set of benchmark test cases.

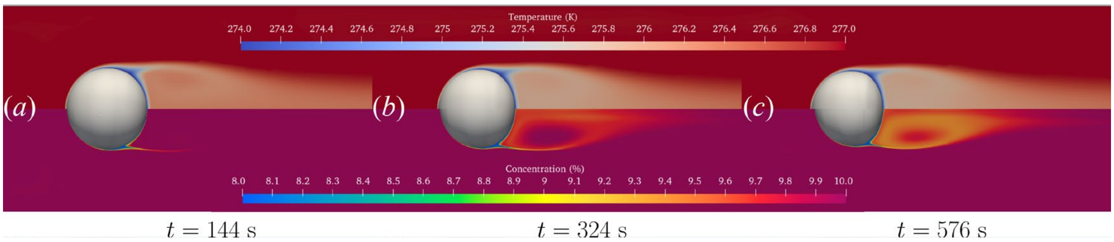

Figure 1: Snapshots of the temperature field (upper half) and the concentration field (lower half) for the melted ice sphere in pure water (upper half) and NaCl solution (lower half) at different moments.