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A multi-component lattice Boltzmann method in consistent with Stefan-Maxwell equations: derivation, validation and application in porous medium. (English) Zbl 1391.76641

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Summary: In this paper, a multi-component lattice Boltzmann method (LBM) with different lattice speeds and multiple linearized collision terms is improved. The molecular weights, viscosities of each component and the diffusivities can be tuned separately. An exact calculation for relaxation times of the cross-collision terms is derived, which makes the model to be consistent with the Stefan-Maxwell equations. The derivation also demonstrates that the tuning-molecular-weight strategy is only available for the ternary diffusion. The expressions of the fluxes and the boundary conditions are proposed. A simulation of the one-dimensional diffusion demonstrates that the second-order interpolation is better than the first-order one to deal with the different lattice speed. The simulation of Couette flow shows that the model behaves like a single fluid with high Schmidt number, and the components tend to flow independently with small Schmidt number. The model is validated by the simulation of one-dimensional diffusion and two-dimensional opposed jet flow, where the LBM results coincide well with the results of the Stefan-Maxwell equations. Finally, the diffusion in a porous media is simulated as an example of the application of the model. This lattice Boltzmann model is suitable for simulating multi-component convection-diffusion problems with complex boundary conditions.

MSC:

76M28 Particle methods and lattice-gas methods
76Txx Multiphase and multicomponent flows

Keywords:

lattice Boltzmann method; multi-component simulation; Stefan-Maxwell equation; second-order interpolation; tuning molecular weights; porous medium

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