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Editorial: Transport phenomena in microgravity

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Editorial on the Research Topic
Transport phenomena in microgravity

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It is in fluids that the effects of gravity—and its absence, microgravity—mainly matter. Fluids are essential in the functioning of spacecrafts and satellites and for sustaining life in crewed missions. It happens that the phenomena of transport in fluids and mixtures of fluids are specially affected by the absence of Earth gravity. On Earth, the variations of mass density under the action of temperature or concentration indeed lead to stratification and/or convection phenomena due to buoyancy effects. Transport phenomena related to other causes, e.g., thermal or mass diffusion, can be thus misleadingly minimized or even ignored. The question that arises when the buoyancy-induced convection and sedimentation effects are canceled is therefore how altered are the transport phenomena. The latter is concerned with different processes and can be classified into three main classes: transport of heat, mass, and momentum.

In the absence of forced convection, the transport of heat under microgravity conditions becomes only due to a diffusion process, natural convection under the action of buoyancy forces being canceled. This effect becomes particularly important near the critical point of fluids. Here, due to the critical anomalies in compressibility and thermal expansion, heat transport becomes very unstable on Earth even for minutes temperature gradients. Microgravity allows a very close approach to the critical point and the detailed study of thermal diffusion processes without spurious gravity-induced convection flows (Oprisan et al. contribution).

Other phenomena, however, become important. It is the case of the isentropic heating or cooling of a fluid by the expansion or contraction of a thermal boundary layer (the "Piston Effect"). This phenomenon, which provokes a slight motion of the fluid near the edge of the boundary layer, is all the more pronounced that the fluid is close to its critical point (Beysens et al. contribution). It is present on Earth but is masked by the natural convection flows; it was detected thanks to microgravity.

Mass transport in a phase separation process under weightlessness is no more dominated by the denser constituent going down and the lighter going up. The effects of diffusion and surface tension lead to only two specific patterns and growth evolution. Boiling, which is a liquid-vapor transition, has been the object of many studies under weightlessness. Close, but below the critical point, interesting behavior concerning the nature of the boiling crisis can be clearly evidenced. The above processes are reviewed by Beysens et al.

The transport of momentum deals with fluid flows. Under microgravity conditions, convection in absence of forced flows can be induced by gradients in surface tension, temperature or concentration. Thermal or solutal gradients in a two-phase fluid can lead to a pronounced capillary motion due to the temperature or concentration variation of the interfacial tension. This effect is classically observed in microgravity, where buoyancy forces are canceled. The contribution of Prud'homme et al. deals with related instabilities in a spherical liquid drop.

The study of viscous flows is also concerned with the transport of momentum. It is, for instance, encountered very near a critical point in the measurement of viscosity (Beysens et al. review) or deals with instabilities in a spherical liquid drop in an external flow of uniform velocity at infinity (Prud'homme et al. contribution).

Transport of momentum is also considered when an external vibrational force is present. This is generally the case in all practical situations of weightlessness. Vibrations of high frequency (with respect to typical fluid inverse times) and small amplitude (with respect to sample size) have many effects and exhibit a rich phenomenology. For instance, a vibrated gas-liquid interface flattens and orientates perpendicular to the vibration direction. Instabilities of thermal boundary layers are detected in relation to a vibrational Rayleigh number. Faraday instabilities on one single vapor-liquid interface or on a pattern of interfaces are observed. Kelvin-Helmholtz-like frozen wave instabilities are identified, transforming near a critical point in a band pattern. Transport of momentum and mass can couple to, e.g., modify the process of phase separation when external vibrations are present. The above phenomena are addressed in the Beysens et al. review.

A rich phenomenology therefore arises for transport phenomena in microgravity. The latter permits us to understand various behaviors which were misunderstood or ignored on Earth or misleadingly attributed to buoyancy effects. More generally, these investigations give us the possibility to predict and better understand the complex and, in some aspects, still unexplored behavior of fluids in the spatial ambiance of weightlessness and time-dependent accelerations and vibrations. This understanding is especially important while ambitious programs of space exploration are launched.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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