Spontaneous particle transport through a triple-fluid phase boundary

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We present the first report of spontaneous transport of a spherical particle through an air-water-oil triple-fluid phase boundary, which is formed by placing a thin oil lens on a water surface. We find two distinct transport regimes: a particle accelerates upon its spontaneous adsorption to the triple phase boundary (capillarity regime), and subsequently decelerates after detaching from the triple phase boundary (relaxation regime). The driving force for the acceleration in the capillarity regime is attributed to the gradient in the attachment energy of the particle to multiple fluid-fluid interfaces present around the triple phase boundary. The particle slows down in the relaxation regime due to the drag force of the surrounding fluids. We demonstrate via experimental and numerical approaches that the transport behaviors of particles through the triple-fluid phase boundary depend on the particle size, fluid viscosity, and the shape of the oil lens. Such a phenomenon has practical importance in oil-spill remediation and enhanced oil recovery, in which particles are destined to come in contact with a triple-fluid phase boundary between air, oil and water.