Viscosity of Liquid ^{4}He and Quantum of Circulation: Why and How Are They Related?

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Following the 1953 Lars Onsager's Introductory talk at Int. Conf. of Theor. Phys. in Kyoto and Tokyo, we examine the relationship between the apparently unrelated physical quantities – kinematic viscosity of liquid ^{4}He, ν, and quantum of circulation, $\kappa = 2\pi\hbar/m_4$, where $\hbar$ is the Planck constant and m_4 denotes the mass of the ^{4}He atom – in the vicinity of the superfluid transition occurring at (pressure dependent) T_λ temperature in liquid ^{4}He due to Bose-Einstein condensation. A model is developed, leading to the surprisingly simple relation $\nu \approx \kappa/6$. We have critically examined the experimental data on the transition to superfluidity at various external pressures and found that in the relevant region of parameters ($T \simeq T_\lambda$ and at low applied pressures) the agreement is $\approx 10^3$ times better then one may expect from dimensional analysis. One can estimate the probability of this agreement, $\approx 10^{-3}$, as totally accidental. This raises many questions, for example: (i) Why does it happen? (ii) Why do ideal-gas considerations work so well for the real liquid? (iii) Could it be thanks to cancelation of effects of some as yet not known factors, which are definitely ignored in our suggested approach? (iv) Are these cancelations accidental or are there some deep physical reasons yet to be discovered? We also predict that the relation $\nu \approx \kappa/6$ ought to hold even better for the metastable stretched liquid along the λ–line at negative pressures.