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Computer Simulation of Hydrogen Superfluidity through Binary Mixing

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Abstract : A superfluid is a fluid of bosons that flows without resistance. In order to be a superfluid, a substance's particles must behave like bosons, yet remain mobile enough to be considered a superfluid. Bosons are low-temperature particles that can be in all energy states at the same time. If bosons were to be cooled down, then the particles will all try to be on the lowest energy state, which is called the Bose Einstein condensation. The temperature when bosons start to matter is when the temperature has reached its critical temperature. For example, when Helium reaches its critical temperature of 2.17K, the liquid density drops and becomes a superfluid with zero viscosity. However, most materials will solidify -and thus not remain fluids- at temperatures well above the temperature at which they would otherwise become a superfluid. Only a few substances currently known to man are capable of at once remaining a fluid and manifesting boson statistics. The most well-known of these is helium and its isotopes. Because hydrogen is lighter than helium, and thus expected to manifest Bose statistics at higher temperatures than helium, one might expect hydrogen to also be a superfluid. As of today, however, no one has yet been able to produce a bulk, hydrogen superfluid. The reason why hydrogen did not form a superfluid in the past is its intermolecular interactions. As a result, hydrogen molecules are much more likely to crystallize than their helium counterparts. The key to creating a hydrogen superfluid is therefore finding a way to reduce the effect of the interactions among hydrogen molecules, postponing the solidification to lower temperature. In this work, we attempt via computer simulation to produce bulk superfluid hydrogen through binary mixing. Binary mixture is a technique of mixing two pure substances in order to avoid crystallization and enhance super fluidity. Our mixture here is KALJ H2. We then sample the partition function using this Path Integral Monte Carlo (PIMC), which is well-suited for the equilibrium properties of low-temperature bosons and captures not only the statistics but also the dynamics of Hydrogen. Via this sampling, we will then produce a time evolution of the substance and see if it exhibits superfluid properties.

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