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Statistical mechanics of Jammed Matter

The problem of sphere packings in crystalline and disordered geometries has intrigued scientists from Johannes Kepler some four centuries ago to Bernal in more recent years. Apart from its mathematical significance, this problem has found applications to very modern topics, such as the jamming in granular media and on the colloidal scale and the glass transition. Despite the vast progress that has been made in developing a new statistical mechanics for such systems, deriving analogies with glasses, and calculating the stress fields through particulate media, basic questions still remain unanswered. For instance, rigorous definition of the most common random packings (with the maximum, RCP, and minimum, RLP packing densities), the nature of their disorder and their uniqueness are still hotly debated. Here, we employ statistical mechanics of jammed matter originally proposed by Sam Edwards to (i) demonstrate the phase diagram of all available jammed configurations that (ii) provides a statistical definition of the RLP and RCP, (iii) predicts their density values in close agreement with experiments, and (iv) establish the concomitant equations of state relating observables such as the coordination number Z, entropy, and volume fraction . We show that the RCP state is not a unique point in the phase space but extends along a line of zero compactivity (a temperature-like variable) predicted to be at a constant =0.634, but with different Z. The lowest density of RLP appears as a line of infinite compactivity parameterized by Z, ending at the minimum possible density theoretically predicted to be =0.543. The nature of the disorder of the packings is statistically characterized by the entropy which is shown to be larger in the random loose case than in the random close case.

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