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Thermodynamics of Sphere Packings at Small N: Experiments and Theory[1]

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We study the formation and structure of equilibrium colloidal clusters at small particle number ($N \leq 10$) using optical microscopy. Our experimental system consists of an ensemble of isolated groups of colloidal microspheres interacting through a short-ranged depletion attraction. For $N < 6$ we observe only a single configuration at each N, but as N increases we observe an increasing number of coexisting configurations. We find that highly symmetric clusters are strongly suppressed by rotational entropy, and many of the clusters with the lowest free energy are subsets of close-packed crystal lattices. We compare our results for the cluster structures to those from a geometrical theory that enumerates all possible finite sphere packings for $N \leq 10$. The geometrical model may give some insights into how phase transitions emerge as N approaches the bulk limit.

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