Aggregation of discoidal particles due to depletion interaction

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Depletion forces are effective interactions of entropic origin ubiquitous in a large variety of colloidal systems. They arise when big colloidal particles are immersed in a solution of smaller non-adsorbing particles or polymers. To maximize the volume available to the smaller solutes and thus increase the entropy of the system, the aggregation of the larger colloids is favored, generating an effective interaction between them [1, 2].

Depletion interactions are of special relevance in biological systems, where the medium is often crowded with different types of polymers. A case where this interaction might play a crutial role is in the formation of aggregates in blood. Indeed, it has been long known that erythrocytes, with discoidal geometry, aggregate into columnar structures called rouleaux when blood is at rest. The driving force of such aggregation process is still controversial, being the depletion interaction generated by the presence of large concentrations of proteins in blood plasma a possible important effect [3].

In this contribution I propose a simple model to understand the equilibrium aggregation properties of a solution of disc-shaped colloids due to the depletion interaction. Built upon simple arguments borrowed from the theory of self-assembly of micelles, the model is analytically solvable, providing simple expressions to predict the equilibrium distribution of aggregates in terms of the relevant parameters of the problem (concentrations of discs and polymers, size of the discs and length of polymers). To validate the model, I also report the results of molecular dynamics simulations of a system of discs and polymers in contact with a thermal bath interacting solely via steric repulsive interactions; the agreement between both approaches, with no fitting parameters, is excellent (see Fig. 1). Corrections to the model and possible consequences in the formation of aggregates of red blood cells will be discussed.

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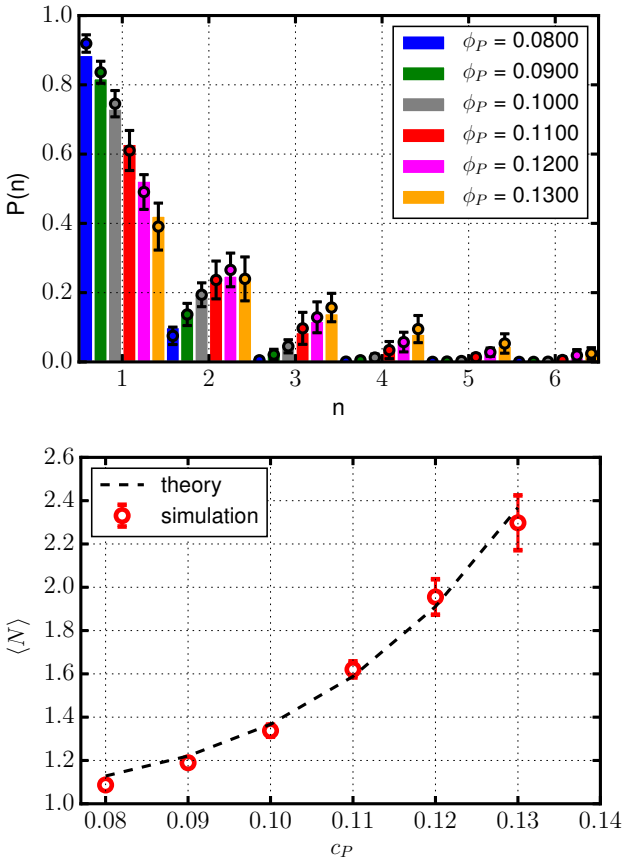

Fig. 1. Comparison between molecular dynamics simulations and analytical model. (Top) Probability of finding an aggregate of size n for different values of polymer concentration as obtained in theory (bars) and simulation (circles). (Bottom) Average number of discs per aggregate as a function of polymer concentration as obtained in theory (dashed line) and with simulations (circles).