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Stationary diffusion among partially reactive sinks: from von Smoluchowski to recent advances

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In 1917, von Smoluchowski founded the first mathematical theory of diffusion-limited reactions by computing the diffusive flux towards a perfect spherical sink. In spite of many advances over the past hundred years, stationary diffusion in complex media with numerous sinks of various shapes and reactivities remains poorly understood. After a brief overview, we present a recently developed generalized method of separation of variables (GMSV) to solve boundary value problems for the Poisson equation in three-dimensional canonical domains (e.g., parallelepipeds, cylinders, spheres, spheroids, ...,
and their combinations). In particular, we derive a semi-analytical representation of the Green function for an arbitrary configuration of non-overlapping partially reactive spherical sinks. This is the key object to determine various characteristics of stationary diffusion such as reaction rate, escape probability, harmonic measure, residence time, and mean first passage time, to name but a few. Based on this solution, we introduce and investigate an effective reaction radius of individual sinks or their clusters that significantly generalizes the famous Smoluchowski formula by accounting for diffusion interactions between sinks and their mutual screening.

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