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Simple models for ultracold molecular collisions

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A simple yet general model of reactive collisions having a quantum defect form is possible based on the separation of the collision dynamics into a long range and a short range part.[1] [2] The long range region governs the quantum transmission of the incident de Broglie wave into the short range region, where reaction occurs. The van der Waals interaction is characterized by a length scale on the order of 5 to 10 nm. Reactive chemical dynamics is characterized by a length scale less than 1 nm. The wave function in the entrance channel in the long range region beyond 1 nm is characterized by two dimensionless quantum defect parameters y and s, which respectively represent the probability of reaction in the short range zone and the phase of the reflected wave from this zone. We find universal collision rate constants in the "black hole" limit $y = 1$, for which there is a unit probability of loss from the entrance channel in the short range zone and no reflected wave back into the entrance channel. In this limit we get universal low temperature event rate constants depending only on the strength of the van der Waals potential for s wave collisions for bosons or unlike fermions and for p wave collisions of identical fermions. We find good agreement with the recent experimental measurements of the JILA group[3] for reactive collision rates for fermionic KRb molecules below 1 microkelvin, as well as for collisions of KRb with K atoms. The model is readily generalized to treat collisions in reduced dimensions and to include the effect of an electric field on polar molecules.

[1]P. S. Julienne, Faraday Disc. 142, 361 (2009).
[2]Z. Idziaszek and P. S. Julienne, arXiv:0912.0370.
[3]S. Ospelkaus, K. K. Ni, D. Wang, M. H. G. de Miranda, B. Neyenhuis, G. Qumner, P. S. Julienne, J. L. Bohn, D. S. Jin, and J. Ye, arXiv:0912.3854.