Low temperature gas-phase kinetics studies related to molecular growth in space

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Abstract

The CRESU (Cinétique de Réaction en Ecoulement Supersonique Uniforme, or Reaction Kinetics in Uniform Supersonic Flow) technique has enabled us to show that many neutral-neutral reactions may be rapid down to the temperatures of dense interstellar clouds (10-20 K), as well as proving an exacting test for theory [1,2]. Rate coefficients have been measured as low as 6 K for the reaction S(1D) + H2 [3] and 11 K for the prototypical reaction F + H2 → HF + H [4].
A series of fast barrierless reactions related to the formation of long chain cyanopolyyne molecules H(C2)nCN [5] of interest in both interstellar clouds and Titan's atmosphere, have been studied both experimentally and theoretically, and our latest results involving reactions of CN, C2H and C3N radicals to yield HC5N will be presented.

One of the current principal challenges in chemical kinetics is the determination of absolute product-channel specific rate constants for elementary reactions. This is particularly the case at low temperatures, and I will also present current efforts in Rennes (ERC CRESUCHIRP project) in collaboration with leading groups (Arthur Suits, U. Missouri, Robert Field, MIT) to use a promising new technique to determine product branching ratios at low temperatures in combination with the CRESU technique, namely Chirped Pulse microwave spectroscopy in Uniform supersonic Flow (CPUF) [6].

IR Sims, JL Queffelec, A Defrance, C Rebrion-Rowe, D Travers, P Bocherel, BR Rowe, IWM Smith, Ultralow temperature kinetics of neutral-neutral reactions - the technique and results for the reactions CN + O2 down to 13 K and CN + NH3 down to 25 K, J. Chem. Phys. 100 (1994) 4229-41.

H Sabbah, L Biennier, IR Sims, Y Georgievskii, SJ Klippenstein, IWM Smith, Understanding reactivity at very low temperatures: The reactions of oxygen atoms with alkenes, Science 317 (2007) 102-05.

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C Berteloite, M Lara, A Bergeat, SD Le Picard, F Dayou, KM Hickson, A Canosa, C Naulin, JM Launay, IR Sims, M Costes, Kinetics and Dynamics of the S(1D2) + H2 → SH + H Reaction at Very Low Temperatures and Collision Energies, Phys. Rev. Lett. 105 (2010) 203201.

M Tizniti, SD Le Picard, F Lique, C Berteloite, A Canosa, MH Alexander, IR Sims, Measurement of the rate of the F + H2 reaction at very low temperatures Nature Chemistry 6 (2014) 141-45.

S Cheikh Sid Ely, SB Morales, JC Guillemin, SJ Klippenstein, IR Sims, Low Temperature Rate Coefficients for the Reaction CN + HC3N, J. Phys. Chem. A 117 (2013) 12155-64.

C Abeysekera, B Joalland, N Ariyasingha, LN Zack, IR Sims, RW Field, AG Suits, Product Branching in the Low Temperature Reaction of CN with Propyne by Chirped-Pulse Microwave Spectroscopy in a Uniform Supersonic Flow, J. Phys. Chem. Lett. 6 (2015) 1599-604.