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THOLINS AND OTHER CARBONACEOUS MATERIALS FORMATION IN HYPERSONIC FLOWS

Abstract

Tholins are a class of organic molecules known for their relatively brownish or reddish color, which essentially stems from their specific ability to absorb and scatter light. Generally speaking, these substances should not be seen as a specific chemical compound but rather as a relatively broad category of organic materials with wide-ranging chemical compositions and a set of certain properties in common. These substances have attracted much attention as their formation is a complex and fascinating process involving the interaction of simple organic molecules and energy sources commonly found in space environments, which therefore makes their study a subject standing at the intersection of chemistry, geophysics, astrobiology and aerospace engineering. Most recently, a completely new research path has been originated from the remarkable discovery that tholins have been detected in environments as dynamic as those resulting from the interaction of a high-Mach number stream with a solid body (hypersonic flow). In this paper we will report on a tholins formation mechanism relying on the high energies typically available in hypersonic flows. The considered conditions are representative of vehicle or meteorite entry in atmospheres containing the required "precursor" molecules. It is shown that the involved high temperatures can break the chemical bonds in methane molecules, thereby releasing carbon atoms in the gas mixture. These can combine with the other species and form various compounds with a variable degree of carbon depending on the local conditions in which the reaction takes place. Notably, the variability in composition also depends significantly on the catalytic behavior of the solid surfaces where the carbonaceous material tends to accumulate and the related temperature (according to whether they are cooled or not). The specific path followed by molecules in the gas flow also plays a significant role. The presence of localized shock waves in the gas stream and the ensuing variations in pressure and temperature also contributes to determining the nature of the organic residues. These phenomena are explored over a range of conditions intended to mimic entry in the atmospheres of most of the planets and moons of the external Solar System. The residues are characterized in terms of analytical techniques and some effort is provided to correlate them with the thermochemical and fluid-dynamic conditions occurring in the hypersonic wind tunnel used for the experiments. Overall, such results suggest a novel possible route to the formation of tholins, which has been rarely investigated in earlier studies.