Ionic Liquids as Hypergolic Green Propellants

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Introduction

With the recent push for a more sustainable and economic space transportation infrastructure, it is a goal of NASA and other aerospace entities to target areas of potential cost reduction to promote space exploration, and to do so in a self-sustaining way. Due to the toxicity of hydrazine and its derivatives, Self-Contained Atmospheric Pressurized Ensemble (SCAPE) fueling procedures are in place for propellant loading, which aim to prevent any chance of human or environmental exposure to these substances. For satellites and in-space vehicles where hydrazine is employed, these procedures drive up the cost of the given mission. By finding a less toxic, more stable fuel to replace hydrazine, these costs may be significantly reduced and may contribute to the attainability of a more sustainable future for space exploration.

Ionic Liquids

An ionic liquid (IL), composed of a cation and anion, is conventionally taken to be ionic substances with a melting point under 100°C. Various ionic liquids (ILs) have demonstrated energetic properties with select oxidizers.

Motivation:
Find a non-toxic, well-performing fuel to replace Hydrazine

Research Objective:
Understand ignition mechanism of various hypergolic ionic liquids using droplet ignition experiments and computational kinetics techniques

Objectives

Density Functional Theory (DFT) Modeling:
1. Predicting reaction intermediates
2. Excitation frequencies for infrared spectral analysis
3. Free energy calculations

N₂O Involvement in Ignition using DFT:
Goal: Find lowest quantum energy conformations of various potential intermediates involving N₂O and our IL of choice and its decomposition products.
Outcome: Propose the most probable kinetic path involving N₂O’s role in the ignition mechanism. Results will be validated by experimental efforts.

Experimental Components

A droplet ignition test chamber has been constructed at Stanford University with the capability to test propellant combinations in an inert nitrogen environment under a range of pressures from vacuum to 500 psi.

1. Droplet tests in fume hood at atmospheric conditions of two ILs with white fuming nitric acid (WFNA)
2. Droplet tests of the two ILs with 70% nitric acid in pure N₂ at varying pressures
3. Droplet tests with varying concentrations of N₂O in N₂ at varying pressures

Table 1. Ignition Delay Data for the ILs and WFNA at Atmospheric Conditions

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Oxidizer</th>
<th>Avg. ID [ms]</th>
<th>Avg. ID from Lit. [ms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMIm+DCA</td>
<td>WFNA</td>
<td>77</td>
<td>47</td>
</tr>
<tr>
<td>BMPy+DCA</td>
<td>WFNA</td>
<td>79</td>
<td>44</td>
</tr>
</tbody>
</table>

Next Steps

1. Droplet ignition testing with supplemental N₂O
2. DFT calculations on the interaction of N₂O with the ILs and decomposition products
3. Formulate probable ignition kinetic pathways to aid in the design of future ILs as a green propellant alternatives

References

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