Combustion of Ammonia Mixed with Dimethyl Ether

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Summary

In view of the problems caused by conventional means of energy, it is necessary to promote cleaner and more environmentally friendly ways to produce energy. Therefore, the study of ammonia combustion can be providential for the progressive substitution of more conventional combustion fuels such as oil or natural gas.

Introduction

Currently, the most used energy resources are hydrocarbon fuels. The use of these compounds is one of the main causes of climate change due to greenhouse gasses emissions.

An alternative to conventional fuels could be ammonia. Ammonia is a large storage of hydrogen. In addition, NH_3 storage technology is widely developed due to its extensive use in the fertilizer industry. Furthermore, it is possible to synthesize ammonia in a sustainable way, as using renewable energies such as wind energy or photovoltaics to replace conventional energy sources [1].

The use of ammonia as a fuel may have various problems: NH_3 has a low flammability limit, high ignition energy, low energy density and high NO emissions [2]. To solve some of these disadvantages, NH_3 mixed with dimethyl ether (DME) is proposed. DME has a low auto-ignition temperature and a higher cetane number. Thus, the use of DME as a promoter in ammonia combustion could present a nice efficiency. In addition, the use of DME can be sustainable. It is synthesized from different materials, such as biomass, garbage or agricultural waste.

Experimental

The experiments have been carried out using a quartz flow reactor. The reactor, with internal diameter 8.7 mm and 200 mm in length, is placed into an electric heated oven [3]. A Type-K fine-wire thermocouple was used to measure the isothermal conditions achieved (± 10 K).

A total gas flow rate of 1000 $mL\cdot min^{-1}$ (STP) is used. The control of reactant flow rates is performed by mass flow controllers. Every gas reactant was added individually. Excess oxygen ratio (λ) is defined as the fed oxygen divided by the O_2 necessary for complete conversion in the reactions:

$$NH_3 + 0.75\ O_2 \rightarrow 0.5\ N_2 + 1.5\ H_2O \qquad (r1)$$

$$CH_3OCH_3 + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O \qquad (r2)$$

Temperature, excess oxygen ratio (λ), NH_3 and DME have been varied in these experiments. Ammonia and DME had an initial concentration at 1000 ppm both. λ was changed for each experiment (0-2). Each experimental set was run in a range of temperatures between 873-1423 K. A gas chromatograph Agilent 490 Micro GC equipped with TCD and FID detectors is used to measure CO, CO_2, CH_4, C_2H_6, C_2H_4, C_2H_2, NH_3, N_2O, H_2, N_2, O_2 and HCN. In addition, the outlet gas stream is also analyzed by an Advance Optima AO2020 series continuous gas analyzer, which measures concentration of NO.

Additionally, a comparison between experimental and simulated results was made. Simulations results are done using a mechanism compiled from literature.

Results and discussion

Figure 1 shows the concentration profile of NH_3 (A), DME (B) and NO (C) as a function of temperature for different stoichiometries.

As shown in Figure 1, reaction takes place at lower temperature as the conditions become fuel-leaner. Both DME and NH_3 show this behavior, although both compounds are seen to react independently in different temperature intervals, with DME conversion occurring at comparatively lower temperatures. DME is fully converted before 10% of the NH_3 has combusted. Referring to the model, it fits perfectly for DME, while the ammonia conversion is overestimated by the model at the higher temperatures studied.

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During NH_3-DME combustion, little amount of NO was formed, and increases with temperature. Also, as the concentration of DME is higher, the concentration of NO obtained is lower. Although the kinetic model predicts higher NO emissions, the concentrations found experimentally are much lower. This fact may be due to the presence of reactions between NH_3-DME that the model does not take into account properly.

Conclusion

NH_3 conversion occurs at lower temperature with excess of O_2. In contrast, DME can oxidize even in the absence of O_2, although it shows a similar tendency to NH_3 with increasing O_2 concentration. NO formation occurs at the highest temperatures studied with an ammonia yield to NO not higher than 62 ppm. NO formation is lower if the DME/NH_3 ratio increases.

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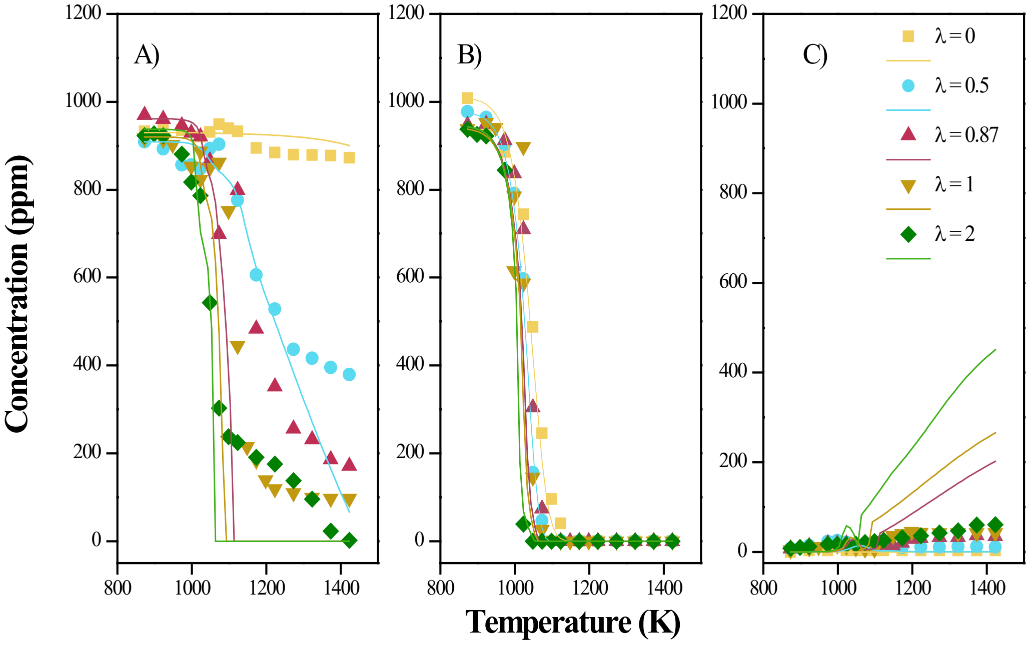

Figure 1. A) NH3 concentration at temperature combustion between 873-1423 K. B) DME concentration at temperature combustion between 873-1423 K. C) NO concentration at temperature between 873-1423 K.