ACID GAS PRODUCTION IN INHIBITED PREMIXED FLAMES.

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Introduction: Halogenated fire extinguishing agents such as CF_3Br decompose in flames to form hydrogen halides such as HF and HBr and other toxic and corrosive products.[1-8] Possible replacements for halon 1301 are required in significantly higher concentrations to extinguish fires; consequently, the post combustion gases in the inhibited flames may have higher concentrations of these undesirable species. Previous experiments and analyses have been preformed[9] to understand the phenomena important for HF production in inhibited propane-air diffusion flames. These tests have suggested that, for diffusion flames, both the rate of agent transport to the reaction zone and the chemical kinetic rates influence the formation of HF. In order to more clearly separate the importance of these processes and study HF formation in a more tractable configuration, the methods previously applied to diffusion flames are now extended in the present work to premixed flames.

Experiment: A Mache-Hebra nozzle burner (fabricated from a quartz tube with a final diameter 0.974 cm) is located concentrically in a 45 cm tall quartz chimney with a contraction to 3 cm diameter at the top. Calibrated mass flow controllers (Sierra Model 860*) under computer control meter the flows of fuel, air, and inhibitor and maintain an air co-flow of 25 l/min. A quartz probe, centered in the contraction of the chimney, extracts a measured fraction of the product gases, and directs the gases through polyethylene sample lines to two bubblers filled with water which trap the acid gases. The test duration is 4 minutes with a product gas sampling rate of 0.18 l/min. The bubbler water is weighed and then tested for F^- using an ion-selective electrode (Orion model 96-09). It should be noted that since COF_2 rapidly hydrolyzes in water, this technique for acid gas measurement includes F^- from both HF and COF_2.

The inhibitor is added to the premixed flow of fuel and air at a high concentration (one which reduces the burning rate by about a factor of two) and at a low concentration (about one tenth of the high concentration). The flames are operated at a unity fuel-air equivalence ratio ϕ (based on the oxygen demand of the fuel, but not on the inhibitor). For these tests, the heat loss rate to the burner is held constant by maintaining the flame at a constant height (1.24 cm) while changing the total mass flow rate and keeping the stoichiometry and inhibitor concentration as desired.

Results and Discussion: Figure 1 presents the measured number of moles of F^- per mole of fuel (points) as a function of the inhibitor concentration in the premixed stream for ϕ equal to 1.0 for CF_4, CF_3H, CF_2H_2, and C_2F_6 with methane and for C_2HF_5, C_3HF_7, and C_3F_8 with propane. Also shown is the amount of HF which would have been formed if all of the fluorine in the inhibitor were converted to HF. As shown, the conversion of the fluorine in the inhibitor to species which form F^- in the bubbler is nearly complete for these concentrations and stoichiometries for all of these agents except CF_4, for which there were kinetic limitations (although significant F^-, about 15% of the maximum, was detected). For near-stoichiometric premixed flames, HF formation is controlled by equilibrium thermodynamics at least up to inhibitor concentrations which give a factor of two reduction in burning rate for C_2F_6, C_3F_8, C_2HF_5, and C_3HF_7, and CF_3H. These results show that for these conditions, essentially all the fluorine in the inhibitors is converted to species which appear as F^- in the bubblers, and that the mechanism of inhibition of these agents is not one of an inert agent.

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* Certain commercial equipment, instruments, or materials are identified in this paper in order to adequately specify the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment are necessarily the best available for the intended use.

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Figure 1 Moles of F⁻ per mole of fuel for CF_4, CF_3H, CF_2H_2, and C_2F_6 addition to a methane-air flame and for C_2HF_5, C_3HF_7, and C_3F_8 with propane. Symbols are the experimental results, and the solid lines are the predicted quantities based on equilibrium thermodynamics.