# COMBUSTION OF LIQUEFIED PETROLEUM GAS
# IN A PACKED BED

by

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submitted

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# CERTIFICATE

This is to certify that thesis entitled 'COMBUSTION OF LIQUEFIED PETROLEUM GAS' being submitted by Mr. Ashwani Kumar to Indian Institute of Technology, Delhi, for the award of degree of DOCTOR OF PHILOSOPHY, is a record of bonafide research work carried out by him. Mr. Ashwani Kumar has worked under my guidance and supervision and has fulfiled the requirements for the submission of thesis, which to my knowledge has reached the requisite standard.

The results contained in this dissertation have not been submitted in part or in full to any other university or institute for the award of any degree or diploma.

(M.K. Sarkar)

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# ABSTRACT

The literature on the kinetics of catalytic combustion of $C_2$-$C_4$ hydrocarbons and their mixtures, specially at higher temperatures, is limited. Apart from the low temperature combustion for air-pollution control, catalytic combustion of hydrocarbons for high temperature applications in furnaces etc. remains to be fully exploited. In an earlier investigation combustion of propane in presence of nickel oxide-alumina catalyst was studied in a temperature range 300-800 °C. The reaction mechanism could be well explained between 300-450 °C by a zero order reaction, and above 650 °C by two parallel first order reactions. However, combustion in the middle temperature range of 450-600 °C could not be properly explained. The present work was undertaken to investigate the combustion of hydrocarbons in this temperature range.

The present study on liquefied petroleum gas combustion was conducted using an isothermal packed bed plugflow microreactor (stainless steel) under steady state conditions. The catalysts employed were (i) copper oxide impregnated over silica gel (425-650 °C) and (ii) alumina (450-700 °C). Analyses of reactants and products were done by gas chromatography. The effects of temperature, time factor and particle size on conversion were investigated for both the catalysts. On kinetic analysis the order of the hydrocarbon disappearance

reaction was found to be unity with respect to hydrocarbon concentration (on carbon basis) for both the catalysts.

Assuming there were no internal diffusion effects present in copper oxide impregnated catalyst, the results could be explained satisfactorily. The Arrhenius plots of hydrocarbon disappearance and carbon dioxide formation were found to fall almost on the same line at lower temperatures indicating that hydrocarbon disappearance yielded carbon dioxide as the only carbon containing combustion product in this region. Beyond the temperature of 550°C unsaturates were forming and a break in the Arrhenius plot of hydrocarbon disappearance appeared. The rate equation for unsaturate formation was evaluated by assuming that the hydrocarbon disappearance beyond 550°C was taking place via two parallel reactions giving carbon dioxide and unsaturates. The activation energies of both the parallel reactions were found to be in close agreement with the reported values in literature.

In case of alumina catalyst, presence of internal diffusion was indicated by a decrease in the slope of the Arrhenius plot with increase of temperature. The values of effectiveness factors calculated from the experimental data on carbon dioxide formation, assuming that at the lowest temperatures the reaction was diffusion free, were comparable to those calculated by using a theoretical method. The diffusion corrected Arrhenius plots were similar to copper oxide impregnated silica gel catalyst except at lowest temperatures where the Arrhenius plots of hydrocarbon disappearance and carbon dioxide formation did not match satisfactorily. Results beyond 550°C could be explained on the basis of two parallel reactions for hydrocarbon disappearance viz. formation of carbon dioxide and formation of unsaturates.

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