# STUDIES IN GAS-LIQUID REACTIONS : ABSORPTION OF LEAN NITRIC OXIDE IN AQUEOUS SOLUTIONS OF HYDROGEN PEROXIDE, ALKALINE SODIUM HYPOCHLORITE AND SULFURIC ACID - NITRIC ACID MIXTURES

K.K.BAVEJA

Thesis submitted to the
Indian Institute of Technology, Delhi
for the award of

DOCTOR OF PHILOSOPHY

DEPARTMENT OF CHEMICAL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY, DELHI
NEW DELHI - 110029

NOVEMBER 1979

## CERTIFICATE

This is to certify that the thesis entitled "STUDIES IN GAS-LIQUID REACTIONS: Absorption of Lean Nitric Oxide in Aqueous Solutions of Hydrogen Peroxide, Alkaline Sodium Hypochlorite and Sulfuric Acid - Nitric Acid Mixtures" being submitted by Mr. K.K.Baveja to Indian Institute of Technology, Delhi, for the award of Degree of Doctor of Philosophy in Chemical Engineering, is a record of bonafide research work carried out by him. Mr. K.K.Baveja has worked under our guidance and supervision and has fulfilled the requirements for the submission of thesis, which to our knowledge has reached the requisite standard.

The results contained in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

(D.SUBBA RAO)
Assistant Professor
Dept. of Chemical Engineering
IIT Delhi

(M.K.SARKAR)
Professor
Dept. of Chemical Engineering
IIT Delhi

ACKNOWLEDGEMENTS

I am grateful to Prof. M.K.Sarkar and Dr. D. Subba Rao for the guidance, encouragement and help throughout the course of this work. I also extend my thanks to Prof. P.D.Grover, Head of the Department, for continuous help and encouragement that was required for completing this work on part time basis. Thanks are due to Dr. A.K.Gupta for his active help, whenever sought.

I am grateful to my other colleagues, research scholars and laboratory staff for their cooperation and useful suggestions from time to time. I particularly like to mention late Mr. Nand Kishore who was of immense help in the early stages of this work.

I express my sincere gratitude to my wife Usha for all the patience and show of impatience, which helped completion of this work.

And finally, I extend my warm appreciation to Mr. R.N.Shukla and Mr. R.P.Dixit for helping me in preparation of this thesis.

(K.K.Baveja)

## ABSTRACT

Absorption with chemical reaction is a useful method for the removal of lean nitric oxide from a variety of gaseous mixtures. A number of absorbents have been proposed and investigated for the removal of nitric oxide. These are basically of three types: (i) oxidising, (ii) complexing, and (iii) reducing. The present study is concerned with an investigation of the kinetics of absorption of lean nitric oxide in aqueous solutions of hydrogen peroxide, alkaline sodium hypochlorite and in mixtures of sulfuric acid and nitric acid.

Absorption experiments were conducted in a glass stirred cell (total volume nearly 1 litre) with a common stirrer for liquid and gas phases, and in a stirred contactor (total volume nearly 500 $cm^3$) with independent stirring of the two phases. The theory of gas absorption accompanied by very fast reaction was used to analyse the results.

The kinetics of the reaction between nitric oxide and hydrogen peroxide were investigated at three different temperatures (30°C, 22.5°C and 15°C). The reaction was found to be first order with respect to both the reactants. The second order rate constant at 30°C was found to be

$6.6 \times 10^5$ $cm^3/(g\ mol)(sec)$, with an energy of activation of 11,250 cal/g mol.

The reaction between nitric oxide and sodium hypochlorite was studied at 20°C at three different values of average pH namely 7.5, 9.5 and 13 (approximately). The reaction was found to be first order with respect to nitric oxide and zero order with respect to sodium hypochlorite. The value of the first order rate constant was found to be maximum at an average pH of 9.5 ($= 3.17 \times 10^7$ $sec^{-1}$). At the same pH, the values of the transition concentration of sodium hypochlorite (for transition from very fast reaction regime to instantaneous reaction regime) predicted by the theory of zero order reaction with respect to the liquid phase reactant were compared with the experimentally derived values and the agreement was found to be reasonably good.

The kinetics of absorption of nitric oxide in mixtures of sulfuric acid and nitric acid were investigated at 30°C, keeping the composition with respect to sulfuric acid nearly constant. The reaction was found to be first order with respect to both nitric oxide and nitric acid, the second order rate constant being $7.2 \times 10^9$ $cm^3/(g\ mol)(sec)$.

CONTENTS