

# **THE THERMODYNAMIC PROPERTIES OF AMMONIA**

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649019809

The thermodynamic properties of ammonia by Frederick G. Keyes & Robert B. Brownlee

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**FREDERICK G. KEYES & ROBERT B. BROWNLEE**

**THE THERMODYNAMIC  
PROPERTIES  
OF AMMONIA**



THE  
THERMODYNAMIC PROPERTIES  
OF AMMONIA

COMPUTED FOR THE USE OF ENGINEERS FROM NEW EXPERI-  
MENTAL DATA DERIVED FROM INVESTIGATIONS MADE  
AT THE MASSACHUSETTS INSTITUTE OF  
TECHNOLOGY

BY  
FREDERICK G. KEYES AND ROBERT B. BROWNLEE

*FIRST EDITION*  
FIRST THOUSAND

NEW YORK  
JOHN WILEY & SONS, INC.  
LONDON: CHAPMAN & HALL, LIMITED  
1916

This One



N2H6-BL5-6CD2

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AND  
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Stanbope Press  
F. H. GILSON COMPANY  
BOSTON, U.S.A.

## PREFACE

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These tables of the properties of saturated and superheated ammonia are based for the most part on an experimental investigation carried out during the course of several years in the Research Laboratory of Physical Chemistry of the Massachusetts Institute of Technology. This investigation was suggested by Professor Edward F. Miller of the Institute's Mechanical Engineering Department, which generously supplied many of the facilities needed in prosecuting the experimental investigation.

The original intention was to determine the vapor-pressure curve and the specific heat-capacity of liquid ammonia with the view of utilizing the results obtained as a partial basis for the computation of a new table of the thermodynamic properties of ammonia which would prove useful in controlling the performance of refrigerating machines. After the completion of the preliminary work, in connection with which the already existing data had been critically examined, it appeared desirable to carry out a more comprehensive experimental investigation. Throughout the whole work we have been indebted to Professor Miller for his advice and support.

The experimental work was carried out by Henry A. Babcock, Harvey S. Benson and Robert B. Brownlee, senior and graduate students in the Mechanical Engineering Department, under the direction of Frederick G. Keyes, a member of the Research Laboratory staff. Mr. Babcock took up the portion of the work bearing on the heat-capacity of liquid ammonia. Messrs. Benson and Brownlee began the determination of the vapor-pressures, the liquid specific volumes, and the isotherms of the substance and continued this work during the following year. Mr. Brownlee collaborated with Mr. Keyes in working over all the data and in constructing the necessary diagrams for the tables.

The computation of the tables was carried out by George W. Clark, Instructor in the Mechanical Engineering Department of the Institute. Mr. Clark's task was especially difficult because of the form of the equation of state employed; and it was carried out by him with great skill and intelligence. This part of the work was aided financially by a generous grant from the Rumford Fund of the American Academy. The computed values have been thoroughly and independently checked by F. G. Keyes.

The experimental methods employed and the details of the data obtained will, it is hoped, soon be ready for publication. It was decided, however, to print the tables in advance of the publication of the experi-

mental research on account of the technical need of more accurate tables than have been hitherto accessible.

The treatment of the experimental results obtained and the critical study of other observers' data have resulted in some new methods of examining experimental data which are here presented in considerable detail, for it is hoped that they will be of service to others interested in similar studies. The form of the equation of state employed is very different from those which have hitherto been employed in computing tables. The usual equations employed give the volume explicitly, while the equation used in computing the present tables possesses five values of the volume. The multiple value of the volume is an obvious physical necessity from the point of view of the continuity of the phases; and a careful study of the application of the equation, not only to the vapor phase of ammonia but also to the existing data for several other substances, has shown its use to be justified. The use of the equation for practical purposes has moreover led to the development of special methods of application which greatly lighten the labor involved in computing.

The tables have been brought into the usual forms convenient for engineering practice. In addition to the tables an accurate "Mollier" diagram has been prepared which has proved to be of very material assistance for rapidly solving engineering problems.

FREDERICK G. KEYES.  
ROBERT B. BROWNLEE.

January, 1916.



## CONTENTS

### PART I. DISCUSSION OF THE DATA AND COMPUTATIONS

	PAGE
1. FUNDAMENTAL THERMODYNAMIC RELATIONS.....	3
2. FUNCTIONAL EXPRESSIONS FOR THE CHANGE OF VAPOR-PRESSURE WITH TEMPERATURE.....	8
3. THE VAPOR-PRESSURE DATA FOR AMMONIA.....	10
4. THE SPECIFIC VOLUME OF LIQUID AMMONIA.....	14
5. EQUATIONS OF STATE IN GENERAL.....	16
6. THE EQUATION OF STATE FOR AMMONIA VAPOR.....	20
7. THE HEAT OF VAPORIZATION OF LIQUID AMMONIA.....	23
8. THE SPECIFIC HEAT-CAPACITY OF AMMONIA VAPOR.....	26
9. THE ENTROPY OF AMMONIA VAPOR.....	27
10. THE SPECIFIC HEAT-CAPACITY OF LIQUID AMMONIA.....	29

### PART II. TABLES OF THE THERMODYNAMIC CONSTANTS OF AMMONIA

DESCRIPTION OF THE TABLES.....	34
TABLE I. SATURATED AMMONIA. TEMPERATURE TABLE.....	36
TABLE II. SATURATED AMMONIA. PRESSURE TABLE.....	44
TABLE III. SUPERHEATED AMMONIA.....	54



**PART I**  
**DISCUSSION OF THE DATA AND COMPUTATIONS**