

Handbook of Physical Properties of Liquids and Gases Pure Substances and Mixtures

Third Augmented and Revised Edition

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Translated from Russian by Yurii A. Gorshkov.

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FOREWORD

The present book has evolved from the well-known Handbook of Physical Properties of Liquids and Gases that has been published in four editions in USSR, USA, and Japan within a period between 1963 and 1975.

Since the last edition, both the scope of the experimental material and the methods of processing and compilation of data have undergone considerable changes. The experimentally studied regions of the reference parameters have been expanded to cover higher pressures as well as the regions of both high and very low temperatures, including the extreme states. Taking these changes into account, the book has been substantially revised. In some cases, in an effort to avoid excessive increase in the volume, a new approach to selection and presentation of the data was used.

The present edition contains about 60% of new data and has the following modifications:

- The list of the substances and the regions of the state parameters covered in the Handbook have been extended.
- For a number of substances the property tables have been totally replaced
- In addition to the tabular material, the book includes extensive information in the form of correlation equations.
- In order to update the reference data we have used the results obtained by such authoritative scientific groups as the Institute for High Temperatures of Russian Academy of Sciences, Moscow Aviation Institute, Moscow Power Institute, Central Aerohydrodynamic Institute (TsAGI), Khar'kov Physical and Technical Institute, Sankt-Petersburg Technological Institute.

This edition incorporates the State Bureau of Standard and Reference Data of USSR (GSSSD) tables and other materials issued by the State Standard and Reference Data Service of Russia.

The improved system of data presentation allowed us to include the following new features in this edition:

- the Handbook covers a number of new substances such as deuterium and other isocompounds of hydrogen, helium-3, lithium hydride, sulfur hexafluoride, iodine, alkaline-earth and rare-earth metals liquid and gas, deutero-containing compounds;
- the thermodynamic data for ionized states of a number of substances are given;
- the thermodynamic and transport property data for the critical region of a large number of substances were replaced or updated;
- the property tabulations for noble gases, water substance, deuterium oxide, nitrogen, oxygen, a few organic compounds, halogens, CO, CO₂, alkali metals and other substances were substantially enlarged;
- new experimental thermodynamic tables for potassium, rubidium, and cesium are given, which allowed us to extend the pressure range of the tabulations from 1 to 10 MPa. The thermodynamic property tabulations for lithium and sodium were based on the theoretical estimates made in accordance with the recent quantum mechanical techniques;
- the Handbook incorporates an expanded coverage of diffusion and thermodiffusion;
- where available, the accuracy estimates for the tabulated values are specified.

FOREWORD

The Handbook gives the data both in the form of the detailed tables and correlation equations demonstrating the temperature and pressure dependences of the properties. In some regions extrapolated values are given which, as a rule, are indicated in the text. In a few extreme regions the property values were estimated theoretically.

The scope of the material included in the Handbook and its presentation make it a valuable tool for engineers, designers, and technologists engaged in the field of power engineering, nuclear and space technology, chemical and mechanical engineering, and instrument manufacturing industries. The book can be also recommended for scientists, post-graduate students, and students dealing with applied sciences.

We would like to acknowledge the staff of the Chair of Physics of Moscow Aviation Institute for valuable help in preparing the manuscript of the Handbook.

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Foreword to the English Translation—Second Edition

I am indeed pleased to write a foreword to this extensive work. This book is a translation of the second, most recent edition of Professor Vargaftik's "Spravochnik po Teplofizicheskim Svoistvam Gazov i Zhidkostey," which first appeared in this format in 1963. The primary contribution of the translated version comes from the author's extensive presentation, primarily from the Russian literature, on a wide range of materials of technological importance, in the liquid, vapor, gaseous, dissociated and ionized states. The thermodynamic and transport properties presented, often over a wide range of temperatures and pressures, are basically reproductions from other data sources. In several instances, the tabular material is unique, and this reasonably up-to-date compendium would be most welcome by many in the English-speaking world to whom much of the data would otherwise remain unobtainable.

In the absence of any evaluative commentary in the presentation of the data, those who use this work will have to rely at this time on the author's judgment in the selection of the data and his internationally acknowledged reputation for his many valuable and original contributions to the field. I very much hope, however, that this work, together with others, may constitute the basis for future cooperative endeavors for the generation of an internationally agreed-upon set of thermophysical properties tables for gases and liquids such as that currently sponsored by special Task Groups within CODATA/ICSU, IUPAC and the International Association for the Properties of Steam.

In this translation the corrections found on the errata page of the original work have been incorporated as have additional corrections noted since it was published. As an added feature the translated edition presents a thorough index to both the substances and the properties covered in the volume. The reader will find these conveniences most helpful in using this extensive reference work.

Y. S. Touloukian, Director
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Foreword to the Second Edition

Since the publication of the first edition of this Handbook (in 1963) a large amount of material on thermophysical properties of different substances have been published. The following changes and additions have been incorporated in the present edition:

1. New, detailed data are given for two types of hydrogen, both in the liquid and in the gaseous states. The present tables contain data up to 6,000°K and 1,000 bar, that is, the data include the region of high temperatures where hydrogen exists in a dissociated state. New tables of transport properties of hydrogen have been provided for both the liquid and the gaseous states at different pressures up to a temperature of 2,000°K.
2. The thermophysical properties of nitrogen, oxygen, air and argon are given over a much wider range of parameters. Detailed new data at high temperatures are given for these substances, for both the liquid as well as for the gaseous states, ranging from extremely low to very high pressures (up to 1,000 bar).
3. The tables of thermophysical properties of carbon dioxide (CO_2) have been re-worked, expanded and rendered more accurate. This section contains new detailed data for liquid carbon dioxide at high temperatures (up to 4,000° K) in the critical region, where it exists in the dissociated state.
4. More detailed tables are given for alkali metals and mercury. Thermodynamic properties have been determined on the basis of new, more accurate data on the dissociation energy of diatomic molecules of alkali metals. The thermodynamic properties tables have been expanded to 3,000°K, taking into account both dissociation and ionization. Thermodynamic properties for ionized lithium at high temperatures are given in a separate set of tables. Viscosity and thermal conductivity of alkali metals in the gas phase are reported here for the first time.

FOREWORD TO THE SECOND EDITION

5. Information on thermophysical properties of monatomic substances has been significantly expanded. In particular, new tables for helium include data for both liquid and gas phases at extremely low and high temperatures (up to 3,000°K) at different pressures. Thermophysical properties of neon, krypton and xenon are given for a wide range of temperatures and pressures.

6. Thermophysical properties of water and steam are given here on the basis of new international tables adapted in 1963—1964. For dissociated steam, data are given up to 6,000°K and 1,000 bar taking into account true properties of dissociated steam.

7. New data are given on diffusion in binary gas mixtures, on viscosity and thermal conductivity of mixtures and solutions; data at different pressures are included.

8. The majority of tables for the remaining substances cite more accurate and newer data over a wider range of parameters.

9. The editors have not included in the present edition data on thermophysical properties of compounds of boron, nitrogen oxide, gallium, deuterium and individual hydrocarbons, due to the fact that almost no new information for these substances has been published since the appearance of the original edition of the Handbook.

10. All thermophysical properties are given in SI units, with the exception of the data for ionized lithium, argon and nitrogen.

The author is grateful to the entire faculty of the Department of Physics at Moscow Institute of Aviation for their help in the preparation of this Handbook. The author was helped in many aspects of the preparation of the present edition by Prof. P. M. Kesselman, Docents L. D. Volyak, Y. K. Vinogradov and N. D. Kosov and Assistant E. L. Studnikov, to whom he wishes to express his appreciation.

The author is very grateful to Academician A. S. Predvoditelev and Professor L. P. Filippov for valuable comments and to E. I. Gaydul for great help in the preparation of the manuscript.

N. B. Vargaftik

FOREWORD TO THE FIRST EDITION

The requirements of modern science and technology necessitate the knowledge of thermophysical properties of gases and liquids.

This area of science, in addition to experimental work, centers on research in diffusion, thermal conductivity and viscosity of gases, as well as on the derivation of equations of state for real gases. Over the recent years, a large amount of data on thermophysical properties of gases and liquids have been collected; these data are of great practical interest.

The present book attempts to provide a systematic presentation of data obtained over the last 5 - 10 years. Most reliable data for pure substances, gas mixtures and solutions are presented. The data are essentially based on experimental results. Most often, the data are given for whole-number temperatures and pressures, and in the cases of mixtures for concentrations convenient for practical calculations.

The Handbook gives data for thermophysical properties of a number of gases: hydrogen, lithium, nitrogen, argon and steam; data are given at high temperatures and take into account the dissociation of the given gas. Data on thermophysical properties of vapors of lithium, sodium and potassium up to 2,000°K take into account the dimerization of these substances in the gaseous state. The book gives I-S [entropy-enthalpy] charts for these substances in the range of high temperatures.

In the compilation of this Handbook, data reported in both monographic and periodical literature have been cited.

The author would like to express his appreciation to the entire faculty of the Department of Physics at the Moscow Institute of Aviation for their help in the preparation of this book.

Special thanks are due to Docent L. D. Volyak who arranged and correlated the data and compiled the tables on thermodynamic properties of potassium in the gas phase, to Assistant Yu. D. Vasilevskaya who worked on diffusion in binary mixtures, to V. V. Rybakov for thermodynamic properties of lithium at high temperatures in the gas phase. Candidate of Technical Sciences, L. S. Zaytseva prepared the graphical presentation of thermodynamic properties of air at high temperatures.

The author is deeply grateful to Academician A. S. Predvoditelev and Candidate of Physical-Mathematical Sciences L. P. Filippov for their very valuable comments, and to E. I. Gaydul for great help in the preparation of the manuscript.

N. B. Vargaftik

NOTATION

a	— thermal diffusivity	z	— compressibility factor (pV/RT)
C_p, c_p	— heat capacity at constant pressure	C_v, c_v	— heat capacity at constant volume
α	— volumetric expansion coefficient $\left(\frac{1}{V} \frac{\delta V}{\delta T}\right)_p$	β	— coefficient of thermal compressibility $\left(-\frac{1}{V} \frac{\delta V}{\delta p}\right)_T$
D	— diffusion coefficient	η	— viscosity
I, i	— enthalpy	λ	— thermal conductivity
K_T	— thermodiffusion ratio	$\Delta\lambda$	— coefficient of thermodiffusion separation of the gas mixture
S, s	— entropy	ν	— kinematic viscosity
p	— pressure	ρ	— density
Pr	— Prandtl number	σ	— surface tension, electrical conductivity
q	— heat of melting	u	— velocity of sound
R, r	— heat of vaporization	V, v	— specific volume
r_i, X_i	— volumetric component fractions in a gas mixture		
G, g	— Gibbs potential		

Subscript cr and superscript 0 refer, respectively, to critical and ideal states of the gas. A prime and a double prime refer, respectively, to liquid and vapor at saturation. In all tables a horizontal line indicates the separation of liquid and vapor states.

CONVERSION OF UNITS FROM SI TO OTHER SYSTEMS

Quantity	Symbol	Units, in SI	Units, in other systems	To convert from SI to other system, multiply by
Pressure	p	N/m ² (Pa)	dyne/cm ² bar atm (phys) atm (phys) kg/cm ² (atm. abs)	10 0.00001 $0.9869 \cdot 10^{-5}$ 0.9869 1.0197
Density	ρ	kg/m ³	mm Hg	750
Specific volume	v	m ³ /kg	g/cm ³ cm ³ /g	0.001 10^3
Heat capacity	c	kJ/kg · K	Kcal/kg · deg	0.2388
Enthalpy	i	kJ/kg	Kcal/kg	0.2388
Entropy	s	kJ/kg · K	Kcal/kg · deg	0.2388
Latent heat of vaporization	r	kJ/kg	Kcal/kg	0.2388
Thermal conductivity	λ	W/m · K	cal/cm · s · deg Kcal/m · hr · deg	$2.388 \cdot 10^{-3}$ 0.86
Viscosity	η	N · s/m ² (Pa · s)	g/cm · s (poise) kg · s/m ²	10 0.102
Kinematic viscosity	$\nu = \frac{\eta}{\rho}$	m ² /s	cm ² /s (stroke)	10^4
Surface tension	σ	N/m	dyne/cm (erg/cm ²)	10^3

USEFUL CONVERSION TABLES AND SYMBOLS*

Conversion Table

	To convert number of	To	Multiply by
Length	inch	cm	2.540
	ft	m	0.3048
Area	ft ²	m ²	0.0929
Volume	ft ³	m ³	0.02832
Mass	lbm	kg	0.45359
	Slugs	kg	14.594
Force	lbf	Newtons	4.4482
Density	lbm/ft ³	kg/m ³	16.02
Work	ft · lbf	m · kgf	0.1383
	hp · hr	m · kgf	273700
Heat	Btu	kcal	0.2520
	Chu	Btu	1.800
	Btu	Joules	1054.35
	Btu	ft · lbf	778.26
	kW · hr	Btu	3412.75
Specific heat	Btu/lbm · °F	cal/g · °C	1.000
	Btu/lbm · °F	W · s/kg · °C	4184.0
Pressure	lbf/in ² , psi	kgf/cm ²	0.070309
	psi	atm	0.068046
	psi	bars	0.068948
	psi	dynes/cm ²	68947.0
Surface tension	lbf/ft	dynes/cm	6.8519 · 10 ⁻⁵

Conversion Factors

The following tables of conversion factors are convenient. In order to convert the numerical value of a property expressed in one of the units in the left-hand column of the table to the numerical value of the same property expressed in one of the units in the tow row of the table, multiply the former value by the factor in the block common to both units.

In tables involving energy, *cal* denotes the thermochemical calorie; *IT cal* denotes the International Steam Table calorie. The thermochemical calorie (*cal*) equals 4.184 joule. The International Steam Table calorie (*IT cal*) equals 4.186 joule. The Btu is the International Steam Table Btu and it equals 1055.04 joule.

Conversion Factors for Mass

	lbm	slugs	g	kg	ton
1 lbm	1	0.03108	453.59	0.45359	0.0005
1 slug	32.174	1	1.4594 · 10 ⁴	14.594	0.016087
1 g	2.2046 · 10 ⁻³	6.8521 · 10 ⁻⁵	1	0.001	1.1023 · 10 ⁻⁶
1 kg	2.2046	6.8521 · 10 ⁻³	1000	1	1.1023 · 10 ⁻³
1 ton	2000	61.162	9.0718 · 10 ⁵	907.18	1

SOURCE: Modified and extended from "Selected Values of Properties of Hydrocarbons," National Bureau of Standards.

* The tables below were presented by Y.S. Touloukian for American edition of N.B. Vargaftik's "Handbook of physical properties of liquids and gases."

Conversion Factors for Density

	lbm/ft ³	slug/ft ³	lbm/in ³	lbm/gal	g/cc
1 lbm/ft ³	1	0.03108	$5.787 \cdot 10^{-4}$	0.13368	0.01602
1 slug/ft ³	32.174	1	0.1862	4.3010	0.51543
1 lbm/in ³	1728	53.706	1	231	27.680
1 lbm/gal	7.4805	0.2325	$4.329 \cdot 10^{-3}$	1	0.11983
1 g/cc	62.428	1.9403	0.03613	8.345	1

SOURCE: Modified and extended from "Selected Values of Properties of Hydrocarbons," National Bureau of Standards.

Conversion Factors for Specific Energy per Degree

	abs joule/g · K	cal/g · K	IT cal/g · K	Btu/lbm · °F	W · s/kg · K
1 abs joule/g · K	1	0.2390	0.2388	0.2388	1000
1 cal/g · K	4.184	1	0.9993	0.9993	4184
1 IT cal/g · K	4.186	1.0007	1	1	4186
1 Btu/lbm · °F	4.186	1.0007	1	1	4186
1 W · s/kg · K	0.001	$2.390 \cdot 10^{-4}$	$2.388 \cdot 10^{-4}$	$2.388 \cdot 10^{-4}$	1

Conversion Factors for Thermal Conductivity

	cal/s · cm · °C	Btu/hr · ft · °F	Btu/hr · ft ² · °F/in	W/cm · °C
1 cal/s · cm · °C	1	241.9	2903	4.183
1 Btu/hr · ft · °F	$4.13 \cdot 10^{-3}$	1	12	0.0173
1 Btu/hr · ft ² · °F/in	$3.45 \cdot 10^{-4}$	0.833	1	$1.44 \cdot 10^{-3}$
1 W/cm · °C	0.239	57.8	694	1

Heat Flux, q/A

Multiply number of To obtain↓ by↘	Btu ft ² · hr	W cm ²	kcal hr · m ²	cal s · cm ²
Btu/ft ² · hr	1	3170.75	0.36865	13277.26
W/cm ²	$3.154 \cdot 10^{-4}$	1	$1.163 \cdot 10^{-4}$	4.1868
kcal/hr · m ²	2.7126	8,600	1	$2.778 \cdot 10^{-5}$
cal/s · cm ²	$7.536 \cdot 10^{-5}$	0.2389	36000	1

Heat Transfer Coefficient, h

Multiply number of To obtain↓ by↘	Btu hr · ft ² · °F	W cm ² · °C	cal s · cm ² · °C	kcal hr · m ² · °C
Btu/hr · ft ² · °F	1	1761	7376	0.20489
W/cm ² · °C	$5.6785 \cdot 10^{-4}$	1	4.186	$1.163 \cdot 10^{-4}$
cal/s · cm ² · °C	$1.356 \cdot 10^{-4}$	0.2391	1	$2.778 \cdot 10^{-5}$
kcal/hr · m ² · °C	4.8826	8600	36000	1

USEFUL CONVERSION TABLES AND SYMBOLS

Thermal Conductivity, λ

Multiply number of To obtain↓ by↘	Btu hr · ft · °F	W cm · °C	cal s · cm · °C	kcal hr · m · °C	Btu · in hr · ft² · °F
Btu/hr · ft · °F	1	57.793	241.9	0.6722	0.08333
W/cm · °C	0.01730	1	4.186	0.01171	$1.442 \cdot 10^{-3}$
cal/s · cm · °C	$4.134 \cdot 10^{-3}$	0.2389	1	$2.778 \cdot 10^{-3}$	$3.445 \cdot 10^{-4}$
kcal/hr · m · °C	1.488	86.01	360	1	0.1240
Btu · in/hr · ft² · °F	12	693.5	2903	8.064	1

Viscosity, η

Multiply number of To obtain↓ by↘	lbm ft · hr	lbf · s ft²	Centipoise	kg m · hr	kgf · s m²
lbm/ft · hr	1	116000	2.42	0.672	23733
lbf · s/ft²	$8.62 \cdot 10^{-6}$	1	$2.086 \cdot 10^{-5}$	$5.79 \cdot 10^{-6}$	0.2048
Centipoise	0.413	47880	1	0.278	9807
kg/m · hr	1.49	172000	3.60	1	35305
kgf · s/m²	$4.21 \cdot 10^{-5}$	4.882	$1.020 \cdot 10^{-4}$	$2.84 \cdot 10^{-5}$	1

100 centipoise = 1 Poise = 1 g/s · cm = 1 dyne · s/cm².

Kinematic Viscosity, ν

Multiply number of To obtain↓ by↘	ft² hr	Strokes	m² hr	m² s
ft²/hr	1	3875	10.764	38.751
Strokes	0.25806	1	2.778	10000
m²/hr	0.092903	0.3599	1	3600
m²/s	$2.581 \cdot 10^{-5}$	0.0001	$2.778 \cdot 10^{-4}$	1

Conversion Factors for Dynamic Viscosity

	poise g/cm · s dyn · s/cm²	lbm/ft · hr pdl · hr/ft²	lbm/ft · s pdl · s/ft²
1 poise	1	242	0.0672
1 lbm/ft · hr	$4.13 \cdot 10^{-3}$	1	$2.78 \cdot 10^{-4}$
1 lbm/ft · s	14.87	3600	1

Conversion Factors for Kinematic Viscosity

	ft²/hr	strokes	m²/hr	m²/s
1 ft²/hr	1	0.25806	0.092903	$2.58 \cdot 10^{-5}$
1 stroke	3.885	1	0.36	0.0001
1 m²/hr	10.764	2.778	1	$2.778 \cdot 10^{-4}$
1 m²/s	38750	10^4	3600	1

Conversion Factors for Pressure					
	lbf/ft ²	lb/in ²	atm	in Hg	in H ₂ O
1 lbf/ft ²	1	0.006944	4.726 · 10 ⁻⁴	0.014139	0.19243
1 lbf/in ²	144	1	0.06805	2.036	27.71
1 atm	2116.2	14.696	1	29.921	51.715
1 in Hg				407.18	760
1 in H ₂ O	70.726	0.49116	0.033421	1	13.608
1 mm Hg	5.197	0.036092	0.002456	0.07348	25.40
1 mm Hg	2.7845	0.019337	1.315 · 10 ⁻³	0.03937	1.8665
1 mm H ₂ O	0.204816	14.2333 · 10 ⁻⁴	9.67841 · 10 ⁻⁵	2.8959 · 10 ⁻³	1
1 mm H ₂ O				3.93701 · 10 ⁻²	7.35559 · 10 ⁻²
					9.81 · 10 ⁻⁵

Conversion Factors for Energy					
	abs joule	cal	IT cal	Btu	int. kW · hr
1 abs joule	1	0.239005	0.238848	9.47827 · 10 ⁻⁴	2.77731 · 10 ⁻⁷
1 cal	4.18401	1	0.999344	3.96572 · 10 ⁻³	1.162028 · 10 ⁻⁶
1 IT cal	4.18676	1.000657	1	3.96832 · 10 ⁻³	1.162791 · 10 ⁻⁶
1 Btu	1055.045	252.161	251.996	1	2.93018 · 10 ⁻⁴
1 int. kW · hr	3.600612 · 10 ⁶	8.60565 · 10 ⁵	8.60000 · 10 ⁵	3412.76	1.341247
1 hp · hr	2.684525 · 10 ⁶	641.615	641.194	2544.46	0.745575
1 ft · lbf	1.355821	0.324048	0.323836	1.285083 · 10 ⁻³	3.76553 · 10 ⁻⁷
1 liter · atm	101.3278	24.2179	24.2020	0.0960412	2.81418 · 10 ⁻⁵
					3.77452 · 10 ⁻⁵
					74.7354
					1

Conversion Factors for Specific Energy					
	abs joule/g	cal/g	IT cal/g	Btu/lbm	ft · lbf/lbm
1 abs joule/g	1	0.2390	0.2388	0.4299	334.53
1 cal/g	4.184	1	0.9993	1.7988	1399.75
1 IT cal/g	4.186	1.0007	1	1.8	1400.69
1 Btu/lbm	2.326	0.5559	0.5556	1	778.16
1 ft · lbf/lbm	2.989 · 10 ⁻³	7.144 · 10 ⁻⁴	7.139 · 10 ⁻⁴	1.285 · 10 ⁻³	1
1 int. kW · hr/g	3.610 · 10 ⁶	8.60565 · 10 ⁵	8.60000 · 10 ⁵	1.548 · 10 ⁶	1.2046 · 10 ⁹
1 hp · hr/lbm	5919	1414.5	1413.6	2545	1.980 · 10 ⁶
1 ft ² /s ²	9.291 · 10 ⁻⁵	2.220 · 10 ⁻⁵	2.219 · 10 ⁻⁵	3.994 · 10 ⁻⁵	0.03108
					2.580 · 10 ⁻¹¹
					1.567 · 10 ⁻⁸
					1

PART 1

PURE SUBSTANCES

Chapter 1

HYDROGEN AND HYDROGEN COMPOUNDS

HYDROGEN (H_2)

Molecular weight 2.01594

Parahydrogen ($p - H_2$): $T_{melt} = 13.8 \text{ K}$; $T_{boil} = 20.28 \text{ K}$ at 760 mm Hg; $T_{cr} = 32.98 \text{ K}$; $p_{cr} = 12.93 \text{ bar}$; $\rho_{cr} = 31.4 \text{ kg/m}^3$.

Normal hydrogen ($n - H_2$: 25% $p - H_2 + 75\% o - H_2$): $T_{melt} = 13.95 \text{ K}$; $T_{boil} = 20.38 \text{ K}$ at 760 mm Hg; $T_{cr} = 33.23 \text{ K}$; $p_{cr} = 13.16 \text{ bar}$; $\rho_{cr} = 31.6 \text{ kg/m}^3$.

Thermophysical Properties of Hydrogen

Molecules of hydrogen exist in two modifications, differing from each other by the orientation of the nuclear spin of the atoms. At low temperatures (0 to 20 K) hydrogen is practically in the form of pure paramodification ($p - H_2$). At somewhat higher temperatures, parahydrogen undergoes partial isomerisation into orthohydrogen ($o - H_2$) and remains in equilibrium with the latter. The ratio of the concentration of the two forms of hydrogen is basically temperature-dependent and is almost independent of pressure [1]. Figure 1 shows the equilibrium concentration of parahydrogen as a function of temperature. In the absence of catalysts, the equilibrium composition corresponding to a given temperature is established quite slowly, giving rise to possibility of prolonged coexistence of components in a mixture different from equilibrium [2]. The most widely used compositions are those reaching equilibrium at 300 K (Fig. 1) and boiling temperature of liquid hydrogen at a pressure of 1 atmosphere (20.3 K). The first is referred to as (normal) hydrogen ($n - H_2$: 25% $p - H_2 + 75\% o - H_2$), and the second represents practically pure parahydrogen. Experiments show [3] that the thermal properties $V = f(p, T)$ of the mentioned compositions, while differing at low temperatures, become practically identical at temperatures above Boyle temperature of 110 K. However, calorific properties (heat capacity, enthalpy, entropy) above 110 K for both compositions differ at each temperature by a constant value. At temperatures above 500 K both the thermal and the calorific properties of the both hydrogen compositions become practically identical.

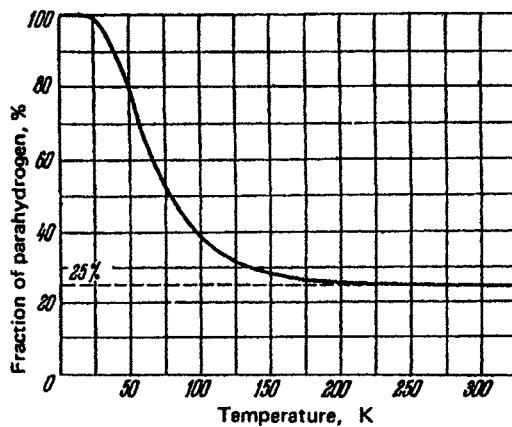


Fig. 1: Equilibrium concentration of parahydrogen as a function of temperatures.

Serdyuk and Kazavchinskii [3, 4] derived equations of state for parahydrogen and normal hydrogen describing with sufficient accuracy the entire complex of thermodynamic properties of those compositions over a range of temperatures from the triple point to the appearance of the noticeable dissociation, and in the range of reduced densities $\omega = V_{cr}/V$ from 0 to 2.8. These equations [3, 4] were used to compile detailed data of thermodynamic properties of parahydrogen [5-6] which are used in the present book.

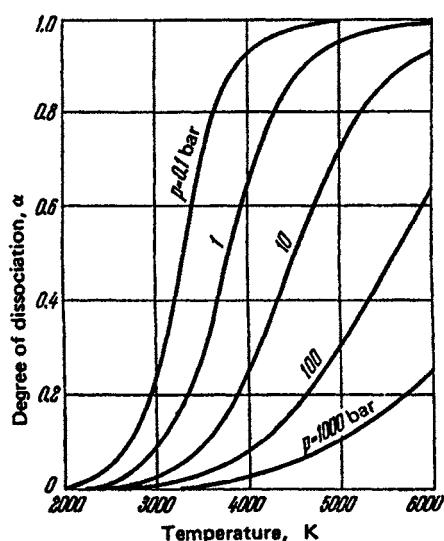


Fig. 2: Degree of dissociation of hydrogen as a function of temperature at different pressures.

conductivity as a function of temperature at different pressures.

A table is also given for viscosity of ionised hydrogen at temperatures ranging from 6000 to 30000 K and pressures from 0.001 to 10 bar. These data were compiled by Belov [14] on the basis of the theoretical calculations.

Melting temperature of normal hydrogen and parahydrogen
as a function of pressure [7, 396, 399, 400]

T , K	p , bar		T , K	p , bar	
	normal hydrogen	para-hydrogen		normal hydrogen	para-hydrogen
13.803*		0.0704*	25	457.2	463.1
13.947*	0.072*		26	509.4	515.4
14	1.66	5.96	28	618.3	624.7
15	32.9	37.4	30	733.4	740.0
16	66.5	71.1	35	1047	1055
17	102.3	107.1	40	1398	1405
18	140.1	145.1	45	1785	1794
19	180.0	185.1	50	2206	2215
20	221.8	227.1	55	2663	2672
21	265.4	270.8	60	3154	3164
22	310.8	316.4	65	3679	3689
23	357.9	363.8	70	4238	4249
24	406.8	412.6	80	5460	5472

* Triple point

The tables below give thermodynamic properties of hydrogen at saturation, as well as values of V , I , and S from 14 to 1500 K and pressures from 1 to 1000 bar. Below 500 K the data for parahydrogen and normal hydrogen are given separately.

For the first time, we are publishing here the data on the thermodynamic properties of dissociated hydrogen from 1500 to 6000 K at a pressures ranging from 0.1 to 1000 bar as calculated by Kesselman and Gorykin [8, 9]. The curves in Figs. 2 and 3 describe the degree of dissociation of and heat capacity of dissociated hydrogen as a function of temperature at different pressures.

The book includes the values of viscosity and thermal conductivity for dissociated hydrogen as calculated by Vargaftik and Vasilevskaya [13] in the range of temperatures from 1400 to 6000 K and pressures from 10^{-5} to 200 bar without taking ionization into account. Figures 4 and 5 give the viscosity and the thermal conductivity as a function of temperature at different pressures.

Thermodynamic properties of normal hydrogen at saturation:
 V (cm³/mole), I and R (J/mole), S and C_p (J/(mole-K)) [1, 7]

T , K	p , bar	V'	V''	I'	I''	R	S'	S''	C'_p	C''_p
14	0.07451	25.17	15380	425	1348	923	16.49	82.18	13.41	20.90
15	0.1274	26.44	9564.5	438	1366	928	17.45	79.07	14.10	21.23
16	0.2054	26.74	6269.0	453	1384	931	18.35	76.31	14.80	21.56
17	0.3150	27.05	4294.6	468	1400	932	19.33	73.95	15.52	21.91
18	0.4629	27.40	3052.7	485	1416	931	20.27	71.81	16.48	22.30
19	0.6561	27.78	2237.7	502	1429	927	21.18	69.84	17.68	22.77
20	0.9021	28.20	1682.6	522	1443	921	22.17	68.10	19.06	23.35
21	1.209	28.65	1292.1	541	1453	912	23.08	66.39	20.56	24.07
22	1.584	29.15	1009.5	563	1461	898	24.06	64.84	22.13	24.99
23	2.036	29.70	800.1	587	1469	882	25.03	63.32	23.81	26.15
24	2.574	30.32	641.5	613	1474	861	26.03	61.88	25.62	27.63
25	3.206	31.02	519.2	640	1476	836	27.09	60.50	27.67	29.53
26	3.942	31.81	423.2	670	1476	806	28.18	59.14	30.08	32.02
27	4.789	32.72	346.9	701	1471	770	29.27	57.75	33.07	35.35
28	5.755	33.80	285.2	735	1462	727	30.43	56.36	37.01	40.01
29	6.848	35.10	234.5	774	1450	676	31.66	54.92	42.63	46.93
30	8.077	36.75	191.9	819	1431	612	32.99	53.37	51.52	58.21
30.5	8.747	37.79	173.0	842	1417	575	33.70	52.52	58.35	67.03
31	9.455	38.98	155.1	868	1400	532	34.46	51.59	68.23	79.94
31.5	10.20	40.49	138.1	898	1379	431	35.33	50.58	83.88	100.66
32	11.00	42.47	121.3	933	1352	419	36.32	49.40	112.5	139.29
33	12.73	51.15	83.01	1045	1245	200	39.48	45.54	560.3	817.7
33.23	13.16	63.86	63.86	1131	1131	0	41.99	41.99	∞	∞

Thermodynamic properties of parahydrogen at saturation:
 V (cm³/mole), I and R (J/mole), S and C_p (J/(mole-K)) [1, 7]

T , K	p , bar	V'	V''	I'	I''	R	S'	S''	C'_p	C''_p
14	0.07880	26.26	14529	-623	285	908	10.05	74.80	13.25	20.90
15	0.1342	26.54	9072.9	-609	303	912	11.01	71.75	13.97	21.25
16	0.2154	26.84	5968.9	-594	321	915	11.93	69.04	14.59	21.60
17	0.3291	27.17	4102.5	-580	337	917	12.84	66.65	15.33	21.97
18	0.4820	27.53	2924.5	-563	352	915	13.77	64.53	16.35	22.38
19	0.6812	27.92	2148.8	-545	367	912	14.69	62.60	17.61	22.87
20	0.9342	28.35	1618.9	-526	379	905	15.71	60.91	19.04	23.47
21	1.249	28.82	1245.2	-506	389	895	16.62	59.21	20.56	24.24
22	1.633	29.34	974.1	-484	398	882	17.56	57.62	22.15	25.20
23	2.095	29.91	772.7	-460	404	864	18.56	56.14	23.81	26.43
24	2.645	30.55	619.8	-435	409	844	19.57	54.70	25.63	28.01
25	3.290	31.27	501.7	-408	410	818	20.61	53.90	27.69	30.05
26	4.039	32.10	409.0	-378	409	787	21.70	51.94	30.18	32.73
27	4.901	33.05	335.0	-346	404	750	22.79	50.54	33.27	36.37
28	5.883	34.18	275.1	-310	395	705	23.97	49.14	37.45	41.52

continued

T, K	p, bar	V'	V''	I'	I''	R	S'	S''	C' _p	C'' _p
29	6.993	35.57	225.7	-272	380	653	25.15	47.63	43.61	49.32
30	8.240	37.34	184.2	-228	359	587	26.55	46.08	53.64	62.39
30.5	8.920	38.45	165.5	-203	344	547	27.24	45.16		
31	9.638	39.81	147.8	-176	325	501	28.05	44.19	73.79	89.25
31.5	10.399	41.53	130.7	-144	301	445	28.97	43.12		
32	11.205	43.90	113.6	-107	269	376	30.07	41.82	136.04	174.52
32.5	12.068	47.77	94.88	-56	220	276	31.50	39.99		
32.98	12.933	64	64	61	61	0	34.90	34.90	∞	∞

Thermodynamic properties of normal hydrogen at different temperatures and pressures:
 V (cm³/mole), I (J/mole), S and C_p (J/(mole·K)) [5, 7]

p, bar	V	I	S	C_p	V	I	S	C_p
<i>T=14 K</i>								
1	26.14	426	16.47	13.40	26.71	455	18.33	14.76
2					26.68	456	18.30	14.72
4					26.61	461	18.24	14.64
6					26.55	466	18.18	14.56
8					26.48	470	18.12	14.49
10					26.42	474	18.07	14.41
12					26.38	479	18.01	14.34
14					26.30	483	17.96	14.27
16					26.24	488	17.90	14.21
18					26.19	492	17.85	14.14
20					26.13	496	17.80	14.08
30					25.87	518	17.55	13.79
40					25.62	540	17.32	13.54
50					25.40	563	17.10	13.32
60					25.19	585	16.90	13.11
<i>T=16 K</i>								
1	27.38	486	20.25	16.45	28.19	552	22.16	19.05
2	27.34	488	20.21	16.39	28.14	524	22.11	18.96
4	27.26	493	20.14	16.27	28.04	528	22.03	18.79
6	27.18	497	20.07	16.16	27.94	532	21.94	18.62
8	27.11	501	20.00	16.05	27.85	536	21.86	18.46
10	27.03	505	19.93	15.94	27.76	540	21.78	18.32
12	26.96	509	19.89	15.84	27.67	544	21.70	18.18
14	26.89	514	19.80	15.75	27.59	548	21.62	18.04
16	26.82	518	19.74	15.65	27.50	552	21.55	17.91
18	26.76	522	19.68	15.57	27.42	556	21.48	17.79
20	26.69	526	19.62	15.48	27.34	560	21.41	17.67
30	26.38	548	19.33	15.09	26.98	580	21.07	17.16
40	26.10	569	19.08	14.75	26.65	601	20.76	16.73
<i>T=18 K</i>								
1	27.38	486	20.25	16.45	28.19	552	22.16	19.05
2	27.34	488	20.21	16.39	28.14	524	22.11	18.96
4	27.26	493	20.14	16.27	28.04	528	22.03	18.79
6	27.18	497	20.07	16.16	27.94	532	21.94	18.62
8	27.11	501	20.00	16.05	27.85	536	21.86	18.46
10	27.03	505	19.93	15.94	27.76	540	21.78	18.32
12	26.96	509	19.89	15.84	27.67	544	21.70	18.18
14	26.89	514	19.80	15.75	27.59	548	21.62	18.04
16	26.82	518	19.74	15.65	27.50	552	21.55	17.91
18	26.76	522	19.68	15.57	27.42	556	21.48	17.79
20	26.69	526	19.62	15.48	27.34	560	21.41	17.67
30	26.38	548	19.33	15.09	26.98	580	21.07	17.16
40	26.10	569	19.08	14.75	26.65	601	20.76	16.73
<i>T=20 K</i>								
1	27.38	486	20.25	16.45	28.19	552	22.16	19.05
2	27.34	488	20.21	16.39	28.14	524	22.11	18.96
4	27.26	493	20.14	16.27	28.04	528	22.03	18.79
6	27.18	497	20.07	16.16	27.94	532	21.94	18.62
8	27.11	501	20.00	16.05	27.85	536	21.86	18.46
10	27.03	505	19.93	15.94	27.76	540	21.78	18.32
12	26.96	509	19.89	15.84	27.67	544	21.70	18.18
14	26.89	514	19.80	15.75	27.59	548	21.62	18.04
16	26.82	518	19.74	15.65	27.50	552	21.55	17.91
18	26.76	522	19.68	15.57	27.42	556	21.48	17.79
20	26.69	526	19.62	15.48	27.34	560	21.41	17.67
30	26.38	548	19.33	15.09	26.98	580	21.07	17.16
40	26.10	569	19.08	14.75	26.65	601	20.76	16.73

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
50	25.84	591	18.81	14.46	26.35	622	20.48	16.36
60	25.61	612	18.58	14.19	26.08	643	20.22	16.04
80	25.18	655	18.18	13.74	25.60	685	19.74	15.51
100	24.80	698	17.78	13.35	25.18	727	19.32	15.08
150					24.33	833	18.43	14.26
200					23.64	938	17.70	13.67
<i>T=22 K</i>					<i>T=24 K</i>			
1	1690.5	1484	69.31	23.03	1875.8	1530	71.29	22.59
2	29.12	563	24.04	22.07	869.7	1497	64.60	25.30
4	28.99	567	23.94	21.79	30.19	614	25.95	25.28
6	28.89	571	23.83	21.54	30.02	617	25.81	24.83
8	28.75	574	23.73	21.30	29.86	620	25.67	24.43
10	28.63	577	23.63	21.07	29.70	623	25.50	24.07
12	28.52	581	23.54	20.88	29.56	626	25.45	23.74
14	28.41	585	23.45	20.69	29.42	629	25.33	23.43
16	28.31	588	23.36	20.48	29.28	632	25.22	23.15
18	28.21	592	23.27	20.31	29.15	636	25.12	22.89
20	28.11	596	23.19	20.15	29.03	639	25.02	22.65
30	27.69	615	22.79	19.44	28.47	657	24.55	21.64
40	27.28	635	22.44	18.87	28.00	675	24.14	20.89
50	26.93	655	22.12	18.40	27.59	694	23.77	20.26
60	26.62	675	21.82	18.01	27.22	713	23.44	19.75
80	26.07	716	21.29	17.36	26.59	753	22.84	18.96
100	25.60	758	20.83	16.88	26.08	798	22.33	18.36
150	24.66	862	19.85	15.95	25.02	896	21.27	17.30
200	23.32	966	19.08	15.32	24.22	998	20.42	16.60
250	23.31	1069	18.39	14.84	23.57	1001	19.71	16.08
300					23.02	1202	19.09	15.67
<i>T=26 K</i>					<i>T=28 K</i>			
1	2058.4	1575	73.09	22.29	2234.8	1619	74.74	22.05
2	970.5	1546	66.61	24.32	1067.4	1593	68.40	23.66
4	31.80	670	28.17	30.05	476.2	1533	61.21	28.84
6	31.54	671	27.99	29.15	33.74	735	30.40	36.73
8	31.30	673	27.82	28.88	33.32	735	30.14	34.75
10	31.07	675	27.65	27.71	32.94	734	29.90	33.22
12	30.88	677	27.50	27.15	32.61	735	29.68	31.97
14	30.69	680	27.36	26.61	32.31	736	29.48	30.94
16	30.48	682	27.22	26.14	32.03	738	29.30	30.07
18	30.31	685	27.09	25.72	31.76	739	29.13	29.31
20	30.14	687	26.96	25.34	31.52	740	28.98	28.65
30	29.43	703	26.39	23.64	30.57	752	28.30	26.27
40	28.84	719	25.91	22.79	29.82	766	27.68	24.74

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
50	28.34	737	25.49	21.96	29.20	782	27.18	23.64
60	27.90	755	25.11	21.31	28.67	798	26.75	22.80
80	27.17	792	24.44	20.32	27.81	834	26.00	21.59
100	26.59	832	23.88	19.59	27.12	871	25.38	20.69
150	25.41	982	22.73	18.36	25.83	969	24.10	19.25
200	24.54	1033	21.82	17.55	24.88	1068	23.16	18.33
250	23.85	1134	21.06	16.99	24.13	1168	22.35	17.68
300	23.26	1235	20.40	16.52	23.52	1268	21.68	17.19
<i>T</i> =30 K					<i>T</i> =32 K			
1	2411.2	1664	76.27	21.88	2588.1	1707	77.68	21.71
2	1161.8	1642	70.03	23.17	1254.1	1689	71.51	22.79
4	532.3	1590	63.14	26.89	585.1	1642	64.83	25.63
6	315.8	1527	58.29	33.95	358.2	1590	60.35	30.12
8	195.9	1439	53.58	56.18	239.9	1526	56.51	38.68
10	35.91	813	32.55	45.30	160.2	1434	52.40	64.59
12	35.23	809	32.18	41.29	40.82	917	35.67	80.97
14	34.67	806	31.88	38.49	38.93	899	34.86	59.68
16	34.19	805	31.58	36.38	37.72	889	34.31	50.61
18	33.78	804	31.33	34.75	36.83	882	33.89	45.33
20	33.41	804	31.10	33.42	36.12	878	33.50	41.80
30	31.99	809	30.18	29.26	33.80	871	32.19	33.28
40	30.98	819	29.47	26.96	32.39	875	31.29	29.62
50	30.20	832	28.89	25.44	31.38	884	30.59	27.49
60	29.56	847	28.39	24.33	30.56	897	30.01	26.00
80	28.53	880	27.54	22.80	29.33	926	29.06	24.08
100	27.73	915	26.87	21.75	28.40	959	28.29	22.83
150	26.28	1009	25.50	20.06	26.78	1050	26.82	20.92
200	25.24	1109	24.43	19.05	25.63	1145	25.71	19.77
250	24.44	1204	23.61	18.33	24.78	1242	24.81	18.98
300	23.78	1304	22.88	17.79	24.03	1340	24.05	18.40
400					22.98	1534	22.77	17.62
<i>T</i> =34 K					<i>T</i> =36 K			
1	2759.6	1751	79.01	21.59	2932.2	1794	80.22	21.48
2	1345.0	1733	72.90	22.49	1434.8	1777	74.16	22.25
4	635.7	1693	66.38	24.75	684.7	1741	67.75	24.09
6	396.8	1648	62.12	27.93	433.1	1702	63.66	26.51
8	274.8	1597	58.67	32.87	305.8	1659	60.44	29.84
10	198.3	1535	55.47	41.79	227.8	1610	57.61	34.78
12	142.0	1451	52.01	63.66	173.7	1552	54.91	42.87
14	88.06	1293	46.68	210.04	132.5	1481	52.07	58.18
16	47.95	1044	39.00	142.32	98.08	1384	48.75	92.25
18	43.19	993	37.42	80.25	69.91	1257	44.75	138.79
20	40.96	978	36.55	62.25	54.62	1155	41.59	118.41

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
30	36.27	943	34.39	39.18	39.89	1029	36.85	48.29
40	34.14	938	33.21	32.96	36.38	1007	35.19	37.21
50	32.75	942	32.35	29.82	34.42	1004	34.11	32.56
60	31.72	951	31.66	27.85	33.07	1008	33.29	29.90
80	30.22	976	30.58	25.43	31.22	1028	32.06	26.85
100	29.13	1006	29.73	23.94	29.94	1055	31.11	25.08
150	27.28	1093	28.14	21.77	27.84	1137	29.39	22.63
200	26.03	1186	26.95	20.51	26.46	1227	28.13	21.27
250	25.10	1281	26.00	19.66	25.45	1321	27.13	20.35
300	24.35	1378	25.20	19.03	24.66	1416	26.29	19.69
400	23.20	1570	23.88	18.21	23.44	1607	24.92	18.82
<i>T=38 K</i>					<i>T=40 K</i>			
1	3104.0	1837	81.39	21.40	3275.0	1880	82.47	21.32
2	1523.7	1821	75.36	22.06	1611.8	1866	76.48	21.90
4	732.5	1789	69.05	23.59	779.5	1836	70.24	23.19
6	467.8	1754	65.07	25.50	501.4	1805	66.35	24.75
8	334.5	1717	62.01	27.95	361.8	1772	63.40	26.64
10	253.6	1676	59.40	31.20	277.4	1737	60.93	29.00
12	198.7	1630	57.02	35.74	220.7	1698	58.74	32.00
14	158.3	1579	54.72	42.38	179.6	1657	56.70	35.92
16	127.0	1519	52.39	52.51	148.3	1611	54.74	41.08
18	101.6	1448	49.94	67.60	123.5	1561	52.81	47.82
20	81.47	1370	47.39	84.48	103.5	1506	50.88	56.06
30	45.69	1138	39.79	60.16	54.56	1266	43.05	65.38
40	39.35	1087	37.34	42.40	43.33	1178	39.64	47.62
50	36.47	1072	35.96	35.69	39.00	1148	37.86	39.01
60	34.66	1071	34.97	32.14	36.54	1138	36.67	34.50
80	32.34	1083	33.55	28.33	33.61	1142	35.04	29.85
100	30.83	1107	32.51	26.24	31.80	1161	33.87	27.40
150	28.43	1183	30.64	23.49	29.06	1232	31.86	24.33
200	26.92	1271	29.31	22.02	27.40	1316	30.44	22.75
250	25.83	1363	28.25	21.05	26.21	1406	29.34	21.73
300	24.97	1456	27.38	20.35	25.30	1498	28.43	21.00
400	23.69	1645	25.97	19.43	23.94	1685	26.96	20.04
500					22.94	1872	25.77	19.52
<i>T=50 K</i>					<i>T=60 K</i>			
1	4123.8	2092	87.20	21.13	4966.0	2303	91.06	21.14
2	2045.2	2082	81.31	21.44	2471.7	2296	85.21	21.34
4	1005.8	2062	75.27	22.11	1224.8	2281	79.27	21.74
6	659.4	2041	71.62	22.82	809.2	2264	75.72	22.19
8	486.2	2020	68.94	23.60	601.5	2250	73.14	22.61
10	382.2	1999	66.79	24.45	477.0	2235	71.11	23.08
12	313.0	1977	64.97	25.37	394.1	2214	69.41	23.54

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
14	263.5	1954	63.38	26.39	334.7	2203	67.94	24.03
16	226.4	1932	61.95	27.45	290.6	2189	66.65	24.53
18	197.8	1909	60.64	28.62	256.2	2174	65.48	25.06
20	174.8	1885	59.43	29.87	228.7	2158	64.42	25.59
30	106.6	1765	54.31	36.78	141.0	2082	60.12	28.43
40	75.43	1655	50.33	41.39	107.2	2010	56.02	31.14
50	59.77	1575	47.31	41.57	84.58	1946	54.17	33.11
60	51.19	1523	45.24	39.68	70.55	1893	52.01	34.06
80	42.53	1473	42.39	35.33	55.02	1823	48.78	33.82
100	38.18	1461	40.54	32.12	47.02	1788	46.51	32.58
150	32.87	1493	37.68	27.78	37.78	1781	42.93	29.45
200	30.17	1559	35.86	25.71	33.54	1826	40.71	27.36
250	28.41	1637	34.51	24.48	31.00	1891	39.12	26.01
300	27.13	1722	33.42	23.64	29.25	1969	37.87	25.10
400	25.33	1899	31.72	22.53	26.90	2132	35.96	23.93
500	24.08	2079	30.39	21.84	25.33	2305	34.51	23.17
600	23.14	2261	29.30	21.47	24.18	2482	33.33	22.63
700					23.29	2660	32.34	22.29
	<i>T</i> =70 K				<i>T</i> =80 K			
1	5804.8	2515	94.32	21.31	6641.6	2730	97.19	21.64
2	2894.9	2509	88.50	21.45	3316.0	2726	91.38	21.75
4	1440.0	2497	82.61	21.79	1653.3	2716	85.53	21.95
6	955.3	2486	79.11	22.01	1099.2	2707	82.06	22.16
8	713.0	2474	76.60	22.30	822.2	2698	79.56	22.36
10	567.7	2462	74.62	22.60	656.2	2689	77.63	22.57
12	470.9	2451	72.98	22.89	545.5	2679	76.02	22.78
14	401.8	2439	71.57	23.20	466.5	2671	74.65	22.99
16	350.1	2428	70.34	23.50	407.3	2662	73.45	23.20
18	309.9	2417	69.23	23.81	361.4	2653	72.38	23.41
20	277.8	2405	68.24	24.13	324.5	2644	71.42	23.62
30	182.1	2350	64.26	25.72	214.8	2602	67.62	24.67
40	135.0	2299	61.29	27.27	160.5	2563	64.81	25.69
50	107.3	2251	58.89	28.64	128.3	2527	62.57	26.62
60	89.51	2209	56.90	29.69	107.3	2494	60.70	27.43
80	68.52	2145	53.75	30.71	81.82	2440	57.70	28.54
100	57.06	2104	51.39	30.71	67.36	2403	55.38	29.02
150	43.53	2075	47.48	29.40	49.74	2367	51.36	28.74
200	37.46	2103	44.98	27.95	41.76	2383	48.72	27.95
250	33.96	2155	43.19	26.77	37.20	2425	46.80	27.13
300	31.62	2222	41.50	25.87	34.21	2483	45.30	26.38
400	28.61	2375	39.71	24.66	30.45	2625	43.04	25.23
500	26.67	2540	38.14	23.89	28.11	2783	41.36	24.45
600	25.29	2712	36.87	23.31	26.47	2948	40.02	23.88
800	23.40	3060	34.92	22.50	24.26	3288	37.96	22.99
1000					22.84	3635	36.42	22.32

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
<i>T</i> =90 K					<i>T</i> =100 K			
1	7477.2	2949	99.76	22.09	8311.8	3172	102.11	22.63
2	3735.8	2945	93.96	22.17	4154.7	3169	96.32	22.69
4	1867.2	2938	88.13	22.33	2076.3	3163	90.50	22.82
6	1230.3	2930	84.69	22.49	1383.5	3156	87.08	22.94
8	930.2	2923	82.22	22.64	1037.3	3150	84.63	23.06
10	743.3	2916	80.30	22.80	829.5	3145	82.72	23.19
12	618.8	2908	78.71	22.96	691.1	3139	81.15	23.31
14	529.8	2901	77.36	23.12	592.3	3133	79.81	23.43
16	463.2	2894	76.18	23.27	518.2	3127	78.65	23.55
18	411.4	2887	75.14	23.43	460.6	3122	77.61	23.67
20	370.0	2880	74.19	23.58	414.6	3116	76.68	23.79
30	246.2	2847	70.49	24.34	276.7	3090	73.06	24.37
40	184.7	2816	67.79	25.07	208.2	3065	70.42	24.93
50	148.2	2788	65.64	25.74	167.4	3043	68.33	25.44
60	124.1	2762	63.85	26.35	140.3	3023	66.60	25.92
80	94.64	2719	60.98	27.32	107.0	2988	63.82	26.73
100	77.55	2687	58.73	27.92	87.51	2962	61.63	27.31
150	56.13	2652	54.71	28.19	62.57	2931	57.66	27.88
200	46.28	2662	52.00	27.82	50.90	2939	54.93	27.78
250	40.65	2698	50.00	27.32	44.21	2971	52.88	27.50
300	36.98	2750	48.42	26.79	39.86	3019	51.26	27.17
400	32.42	2880	46.04	25.83	34.48	3141	48.80	26.46
500	29.64	3030	44.28	25.09	31.23	3284	46.95	25.81
600	27.71	3190	42.87	24.53	29.01	3438	45.49	25.30
800	25.16	3522	40.70	23.68	26.11	3762	43.24	24.53
1000	23.53	3861	39.07	22.93	24.26	4094	41.53	23.84
<i>T</i> =120 K					<i>T</i> =140 K			
1	9979.4	3637	106.35	23.80	11645	4124	110.11	24.92
2	4990.8	3635	100.57	23.84	5325.5	4122	104.33	24.96
4	2496.6	3631	94.77	23.93	2915.5	4120	98.54	25.02
6	1665.3	3627	91.36	24.01	1945.6	4117	95.15	25.08
8	1249.7	3623	88.93	24.09	1460.7	4114	92.73	25.14
10	1000.3	3619	87.04	24.18	1169.7	4112	90.85	25.20
12	834.2	3615	85.49	24.26	975.8	4109	89.30	25.25
14	715.5	3612	84.17	24.34	837.3	4107	88.00	25.31
16	626.5	3608	83.02	24.42	733.5	4105	86.86	25.37
18	557.3	3604	82.01	24.50	652.7	4102	85.86	25.42
20	502.0	3600	81.10	24.58	588.1	4100	84.96	25.48
30	336.3	3583	77.55	24.96	394.5	4089	81.46	25.75
40	253.6	3568	75.00	25.32	297.9	4080	78.96	26.01
50	204.3	3554	72.99	25.66	240.0	4072	76.99	26.25
60	171.5	3551	71.33	25.97	201.6	4065	75.37	26.47
80	130.9	3520	68.67	26.54	153.8	4054	72.79	26.88
100	106.8	3505	66.58	27.01	125.3	4046	70.76	27.24

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
150	75.36	3488	62.73	27.76	87.86	4044	67.03	27.92
200	60.27	3498	60.02	28.02	69.55	4060	64.36	28.29
250	51.50	3527	57.95	28.03	58.83	4091	62.31	28.45
300	45.80	3571	56.30	27.96	51.81	4135	60.65	28.51
400	38.78	3684	53.75	27.72	43.19	4246	58.08	28.51
500	34.57	3818	51.81	27.40	38.04	4376	56.12	28.41
600	31.74	3968	50.27	27.07	34.53	4517	54.54	28.27
800	28.11	4273	47.89	26.52	30.18	4818	52.10	27.94
1000	25.81	4594	46.09	26.09	27.45	5132	50.24	27.67
	<i>T</i> =160 K				<i>T</i> =180 K			
1	13311	4632	113.49	25.87	14975	5158	116.60	26.66
2	6659.2	4631	107.72	25.89	7492.4	5157	110.83	26.68
4	3333.5	4630	101.94	25.94	3751.0	5156	105.05	26.72
6	2325.0	4628	98.55	25.98	2503.9	5155	101.66	26.75
8	1670.8	4627	96.14	26.03	1880.3	5155	99.25	26.78
10	1338.3	4625	94.26	26.07	1506.2	5154	97.38	26.82
12	1116.6	4624	92.73	26.11	1256.8	5153	95.85	26.85
14	958.3	4622	91.43	26.16	1078.7	5153	94.55	26.89
16	839.6	4621	90.30	26.20	945.1	5152	93.43	26.92
18	747.2	4619	89.30	26.24	841.2	5151	92.44	26.95
20	673.4	4618	88.40	26.28	758.2	5151	91.55	26.98
30	452.0	4612	84.94	26.49	508.9	5148	88.11	27.14
40	341.4	4607	82.47	26.68	384.4	5147	85.65	27.29
50	275.1	4603	80.53	26.86	309.8	5146	83.73	27.43
60	231.1	4600	78.93	27.03	260.1	5146	82.16	27.56
80	176.2	4596	76.40	27.34	198.2	5147	79.65	27.80
100	143.4	4595	74.41	27.61	161.1	5151	77.70	28.02
150	100.1	4605	70.76	28.17	112.0	5171	74.10	28.47
200	78.72	4629	68.15	28.55	87.74	5202	71.53	28.81
250	66.11	4664	66.12	28.77	73.31	5242	69.54	29.04
300	57.82	4709	64.48	28.88	68.79	5290	67.91	29.18
400	47.61	4821	61.91	28.98	52.01	5404	65.36	29.33
500	41.53	4951	59.95	29.02	45.03	5535	63.40	29.41
600	37.46	5090	59.36	29.01	40.36	5675	61.82	29.46
800	32.30	5387	55.89	28.88	34.44	5971	59.33	29.47
1000	29.12	5697	54.00	28.71	30.80	6278	57.43	29.39
	<i>T</i> =200 K				<i>T</i> =220 K			
1	16640	5697	119.43	27.29	18303	6248	122.06	27.79
2	8825.2	5697	113.66	27.31	9147.7	6248	116.29	27.80
4	4168.0	5697	107.89	27.33	4584.8	6249	110.52	27.82
6	2782.3	5696	104.50	27.36	3060.5	6249	107.14	27.85
8	2089.5	5696	102.10	27.39	2298.4	6249	104.74	27.87
10	1673.8	5696	100.23	27.42	1841.1	6250	102.87	27.89
12	1396.7	5696	98.71	27.44	1536.3	6250	101.35	27.91
14	1198.8	5696	97.41	27.47	1318.6	6250	100.06	27.93

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
16	1050.3	5696	96.39	27.50	1155.3	6251	98.94	27.96
18	934.9	5696	95.30	27.52	1023.3	6251	97.95	27.98
20	842.5	5696	94.41	27.55	926.7	6252	97.06	28.00
30	565.5	5697	90.99	27.67	621.9	6254	93.65	28.10
40	427.1	5697	88.55	27.79	469.6	6258	91.22	28.20
50	344.2	5699	86.64	27.90	378.3	6261	89.32	28.29
60	288.9	5701	85.08	28.01	317.4	6265	87.77	28.38
80	219.9	5707	82.60	28.21	241.5	6275	85.30	28.54
100	178.6	5715	80.66	28.38	196.0	6286	83.38	28.68
150	123.8	5743	77.11	28.75	135.5	6321	79.86	28.99
200	96.64	5780	74.57	29.04	105.4	6363	77.35	29.24
250	80.43	5825	72.60	29.26	87.48	6412	75.40	29.43
300	69.70	5876	70.98	29.40	75.57	6466	73.80	29.58
400	56.42	5993	68.45	29.57	60.79	6587	71.28	29.75
500	48.51	6125	66.51	29.66	51.98	6721	69.34	29.84
600	43.24	6267	64.93	29.73	46.11	6864	67.77	29.91
800	36.58	6563	62.44	29.82	38.73	7162	65.30	30.09
1000	32.50	6870	60.54	29.81	34.21	7469	63.40	30.08
<i>T=240 K</i>					<i>T=260 K</i>			
1	19967	6807	124.48	28.18	21681	7375	126.76	28.53
2	9990.0	6808	118.71	28.19	10822	7375	120.99	28.53
4	5001.3	6808	112.94	28.20	5417.8	7376	115.22	28.55
6	3338.5	6809	109.57	28.22	3616.3	7377	111.84	28.57
8	2507.1	6810	107.17	28.24	2715.6	7378	109.45	28.58
10	2008.2	6811	105.80	28.26	2175.2	7379	107.59	28.60
12	1675.7	6811	103.78	28.28	1814.9	7381	106.06	28.61
14	1438.1	6812	102.49	28.30	1557.6	7382	104.78	28.63
16	1260.0	6813	101.37	28.31	1364.6	7383	103.66	28.64
18	1121.4	6814	100.39	28.33	1214.5	7384	102.67	28.66
20	1010.6	6815	99.50	28.35	1094.4	7385	101.79	28.67
30	678.1	6819	96.10	28.48	734.2	7391	98.39	28.74
40	511.9	6824	93.67	28.51	554.1	7398	95.97	28.81
50	412.3	6829	91.78	28.59	446.1	7404	94.09	28.87
60	345.8	6835	90.24	28.66	374.1	7411	92.55	28.94
80	262.9	6848	87.79	28.90	284.2	7426	90.11	29.05
100	213.2	6862	85.87	28.92	230.3	7443	88.21	29.16
150	147.1	6902	82.38	29.18	158.5	7488	84.73	29.38
200	114.1	6949	79.89	29.39	122.8	7539	82.26	29.56
250	94.47	7001	77.95	29.56	101.4	7594	80.83	29.71
300	81.40	7058	76.36	29.70	87.18	7653	78.75	29.84
400	65.14	7182	73.86	29.87	69.46	7781	76.27	30.01
500	55.48	7318	71.98	29.97	58.87	7919	74.34	30.10
600	48.98	7462	70.37	30.08	51.83	8064	72.78	30.17
800	40.86	7763	67.91	30.15	42.99	8368	70.33	30.27
1000	35.90	8072	66.01	30.28	37.60	8678	68.44	30.37

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
<i>T</i> =280 K								
1	23294	7946	128.37	28.70	24958	8522	130.86	28.85
2	11654	7946	123.41	28.71	12466	8523	125.09	28.86
4	5834.0	7948	117.34	28.72	6250.2	8524	119.33	28.87
6	3894.0	7949	113.96	28.73	4171.6	8526	115.95	28.88
8	2924.0	7950	111.57	28.75	3132.3	8528	118.55	28.89
10	2342.0	7952	109.71	28.76	2506.8	8529	111.70	28.90
12	1954.0	7953	108.19	28.77	2093.1	8531	110.18	28.92
14	1676.9	7955	106.90	28.78	1796.1	8533	108.89	28.93
16	1469.0	7956	105.78	28.80	1573.4	8534	107.77	28.94
18	1307.4	7958	104.80	28.81	1400.2	8536	106.79	28.95
20	1178.1	7959	103.92	28.82	1261.7	8538	105.91	28.96
30	790.1	7966	100.52	28.88	846.0	8546	102.52	29.01
40	596.2	7974	98.11	28.94	638.2	8555	100.11	29.07
50	479.8	7982	96.23	29.00	513.5	8564	98.53	29.11
60	402.3	7990	94.69	29.05	430.4	8573	96.70	29.15
80	305.4	8007	92.26	29.15	326.5	8592	94.37	29.24
100	247.3	8025	90.37	29.24	264.3	8612	92.39	29.32
150	170.0	8075	86.91	29.43	181.4	8665	88.94	29.51
200	131.4	8129	84.45	29.59	140.0	8742	86.49	29.68
250	108.3	8187	82.58	29.69	115.2	8783	84.58	29.75
300	92.94	8249	80.96	29.82	98.67	8877	83.02	29.85
400	73.77	8380	78.48	30.00	78.06	8981	80.55	30.00
500	62.30	8520	76.57	30.09	65.72	9153	78.65	30.09
600	54.67	8667	75.01	30.16	57.51	9271	77.09	30.15
800	45.10	8972	72.57	30.25	47.22	9578	74.66	30.24
1000	39.29	9284	70.69	30.35	40.98	9892	72.78	30.33
<i>T</i> =350 K								
1	29116	9971	135.34	29.09	33273	11428	139.33	29.19
2	14565	9972	129.57	29.09	16645	11429	133.47	29.19
4	7290.4	9974	123.81	29.10	8390.3	11432	127.70	29.20
6	4866.4	9976	120.43	29.11	6558.8	11434	124.33	29.20
8	3652.8	9978	118.04	29.12	4172.1	11436	121.94	29.21
10	2925.3	9980	116.18	29.13	3341.6	11439	120.08	29.21
12	2440.3	9982	114.66	29.13	2787.3	11441	118.56	29.22
14	2093.9	9985	113.38	29.14	2301.1	11444	117.28	29.22
16	1834.1	9987	112.27	29.15	2094.5	11446	116.17	29.23
18	1632.0	9989	111.28	29.16	1863.5	11449	115.19	29.23
20	1470.3	9991	110.40	29.16	1678.8	11454	114.31	29.24
30	935.4	10002	107.02	29.20	1124.5	11463	110.93	29.27
40	742.9	10012	104.62	29.24	847.3	11476	108.58	29.29

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
50	597.4	10023	102.75	29.27	681.0	11488	108.66	29.32
60	500.0	10035	101.22	29.30	570.2	11501	105.14	29.34
80	379.2	10057	98.80	29.37	431.7	11526	102.73	29.39
100	306.5	10080	96.93	29.43	348.5	11552	100.86	29.44
150	209.6	10141	93.51	29.55	237.7	11618	97.45	29.53
200	161.2	10204	91.07	29.66	182.3	11686	95.03	29.61
250	132.2	10281	89.18	29.75	149.1	11756	93.15	29.68
300	112.9	10338	87.63	29.82	127.0	11826	91.61	29.74
400	88.72	10479	85.19	29.95	99.30	11974	89.18	29.84
500	74.23	10626	83.29	30.03	82.68	12124	87.30	29.92
600	64.57	10777	81.65	30.09	71.60	12278	85.76	29.97
800	52.47	11088	79.33	30.17	60.49	12513	83.89	30.04
1000	45.17	11405	74.46	30.22	51.10	12832	81.92	30.08
<i>T=450 K</i>					<i>T=500 K</i>			
1	37431	12883	142.66	29.24	41588	14350	145.75	29.27
2	18724	12889	136.90	29.24	20803	14352	139.97	29.27
4	9369.9	12892	131.13	29.25	10410	14355	134.21	29.27
6	6252.1	12894	127.76	29.25	6945.2	14358	130.85	29.27
8	4693.1	12897	125.37	29.26	5213.0	14360	128.45	29.28
10	3757.7	12900	123.51	29.26	4173.7	14363	126.60	29.28
12	3134.2	12902	121.99	29.27	3480.9	14366	125.08	29.28
14	2688.7	12905	120.71	29.27	2986.0	14369	123.80	29.29
16	2354.7	12908	119.60	29.27	2614.8	14372	122.69	29.29
18	2094.9	12911	118.62	29.28	2326.1	14375	121.71	29.29
20	1887.0	12913	117.74	29.28	2095.1	14378	120.83	29.30
30	1263.4	12927	114.36	29.30	1402.3	14392	117.45	29.31
40	951.6	12940	111.97	29.32	1055.8	14406	115.06	29.33
50	764.6	12954	110.10	29.34	848.0	14421	113.20	29.34
60	640.0	12967	108.58	29.36	709.4	14435	111.68	29.36
80	484.0	12995	106.18	29.40	536.2	14464	109.28	29.39
100	390.4	13022	104.31	29.43	432.2	14494	107.42	29.41
150	265.7	13093	100.92	29.51	293.6	14587	104.03	29.48
200	203.4	13164	98.50	29.57	224.3	14642	101.62	29.53
250	166.0	13237	96.63	29.63	182.7	14717	99.75	29.57
300	141.0	13312	95.10	29.65	155.0	14794	98.22	29.61
400	109.8	13468	92.68	29.76	120.3	14948	95.81	29.68
500	91.10	13617	90.80	29.82	99.48	15105	93.94	29.73
600	78.59	13773	89.27	29.87	85.57	15264	92.42	29.77
800	62.93	14090	86.87	29.93	68.13	15584	90.02	29.83
1000	53.48	14412	85.01	29.96	57.63	15907	88.16	29.85

Thermodynamic properties of parahydrogen at different temperatures and pressures:
 V (cm³/mole), I (J/mole), S and C_p (J/(mole·K)) [5, 7]

p , bar	V	I	S	C_p	V	I	S	C_p
$T=14$ K								
1	26.23	-621	10.02	13.23	26.82	-593	11.90	14.57
2	26.20	-618	9.99	13.21	26.78	-591	11.87	14.52
4	26.14	-614	9.96	13.17	26.71	-586	11.81	14.44
6					26.64	-582	11.75	14.36
8					26.58	-578	11.69	14.28
10					26.51	-573	11.63	14.20
12					26.45	-569	11.57	14.13
14					26.39	-564	11.52	14.06
16					26.33	-560	11.46	13.99
18					26.27	-556	11.41	13.92
20					26.21	-551	11.35	13.86
30					25.94	-529	11.10	13.57
40					25.68	-507	10.86	13.31
50					25.45	-465	10.64	13.08
60					25.23	-463	10.43	12.87
$T=18$ K								
1	27.51	-562	13.75	16.32	28.35	-526	15.71	19.03
2	27.47	-560	13.71	16.25	28.29	-524	15.66	18.94
4	27.38	-556	13.64	16.13	28.19	-520	15.57	18.75
6	27.30	-552	13.56	16.01	28.09	-516	15.49	18.58
8	27.22	-548	13.49	15.90	27.99	-512	15.40	18.42
10	27.14	-543	13.42	15.79	27.89	-508	15.32	18.27
12	27.07	-539	13.36	15.69	27.80	-504	15.24	18.12
14	27.00	-535	13.29	15.59	27.71	-500	15.16	17.98
16	26.92	-531	13.23	15.50	27.62	-496	15.08	17.85
18	26.85	-526	13.16	15.40	27.54	-492	15.01	17.72
20	26.79	-522	13.10	15.32	27.46	-488	14.94	17.61
30	26.46	-501	12.60	14.92	27.08	-468	14.58	17.08
40	26.17	-480	12.53	14.58	26.74	-447	14.28	16.64
50	25.91	-458	12.28	14.28	26.43	-426	13.99	16.27
60	25.66	-437	12.04	14.01	26.15	-405	13.72	15.95
80	25.22	-393	11.61	13.55	25.66	-363	13.24	15.42
100	24.84	-350	11.23	13.17	25.23	-321	12.81	14.99
150					24.35	-215	11.91	14.17
200					23.66	-110	11.17	13.58
$T=22$ K								
1	1609.7	422	62.41	23.03	1875.5	468	64.40	22.59
2	29.31	-484	17.54	22.09	869.8	434	57.73	25.31
4	29.17	-480	17.43	21.79	30.42	-433	19.47	25.29
6	29.04	-477	17.32	21.52	30.24	-431	19.33	24.82
8	28.91	-473	17.22	21.27	30.06	-428	19.20	24.39
10	28.79	-470	17.12	21.04	29.90	-425	19.08	24.01

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
12	28.67	-466	17.02	20.82	29.74	-422	18.95	23.66
14	28.56	-462	16.93	20.62	29.59	-419	18.84	23.35
16	28.45	-459	16.83	20.43	29.45	-415	18.72	23.05
18	28.35	-455	16.75	20.25	29.32	-412	18.62	22.78
20	28.25	-451	16.66	20.08	29.19	-409	18.51	22.53
30	27.78	-432	16.26	19.36	28.61	-391	18.03	21.50
40	27.38	-413	15.89	18.78	28.12	-373	17.61	20.72
50	27.02	-393	15.57	18.31	27.69	-354	17.24	20.11
60	26.70	-372	15.27	17.91	27.31	-335	16.90	19.60
80	26.13	-331	14.73	17.27	26.66	-295	16.30	18.81
100	25.66	-290	14.25	16.77	26.12	-255	15.78	18.21
150	24.69	-186	13.27	15.87	25.05	-153	14.71	17.17
200	23.94	-82	12.47	15.25	24.24	-50	13.85	16.47
250	23.32	21	11.79	14.77	23.59	52	13.13	15.96
300					23.03	153	12.50	15.55
<i>T=26 K</i>					<i>T=28 K</i>			
1	2056.6	513	66.22	22.29	2235.0	558	67.88	22.05
2	970.6	483	59.74	24.33	1067.6	532	61.54	23.66
4	414.7	410	52.07	32.45	476.4	472	54.34	28.86
6	31.82	-377	21.51	29.21	34.15	-311	23.95	37.32
8	31.56	-375	21.33	28.38	33.68	-312	23.67	35.07
10	31.32	-373	21.16	27.67	33.27	-312	23.42	33.36
12	31.09	-371	21.00	27.04	32.91	-312	23.19	32.00
14	30.89	-369	20.85	26.49	32.59	-311	22.98	30.89
16	30.69	-366	20.71	26.01	32.29	-310	22.79	29.95
18	30.51	-364	20.57	25.57	32.02	-308	22.61	29.16
20	30.33	-361	20.44	25.17	31.77	-307	22.44	28.47
30	29.58	-346	19.86	23.63	30.75	-296	21.72	26.00
40	28.97	-330	19.37	22.54	29.96	-282	21.13	24.44
50	28.45	-312	18.94	21.72	29.32	-266	20.63	23.33
60	28.00	-294	18.55	21.07	28.78	-250	20.19	22.49
80	27.25	-256	17.88	20.09	27.90	-214	19.43	21.26
100	26.63	-217	17.31	19.37	27.19	-177	18.80	20.39
150	25.45	-118	16.15	18.15	25.87	-79	17.54	18.97
200	24.57	-16	15.23	17.36	24.91	20	16.57	18.06
250	23.86	85	14.47	16.78	24.15	120	15.76	17.43
300	23.27	185	13.81	16.34	23.53	220	15.06	16.94
<i>T=30 K</i>					<i>T=32 K</i>			
1	2411.4	602	69.42	21.87	2586.2	645	70.83	21.71
2	1161.9	579	63.17	23.17	1254.3	625	64.66	22.79
4	532.5	528	56.28	26.90	585.2	580	57.98	25.64
6	316.0	465	51.44	33.96	358.4	528	53.50	30.13
8	196.4	374	46.74	55.66	240.2	464	49.66	38.60
10	36.46	-234	26.11	46.67	160.9	373	45.59	63.42
12	35.69	-239	25.71	41.93	42.07	-125	29.40	92.89

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
14	35.07	-242	25.37	38.77	39.69	-147	28.45	62.67
16	34.54	-244	25.08	36.47	38.30	-159	27.83	51.79
18	34.09	-245	24.82	34.71	37.30	-167	27.36	45.83
20	33.70	-245	24.58	33.30	36.52	-172	26.98	41.96
30	32.19	-241	23.63	28.96	34.05	-180	25.62	32.99
40	31.14	-231	22.91	26.61	32.57	-176	24.71	29.25
50	30.33	-218	22.32	25.08	31.51	-166	24.00	27.07
60	29.67	-203	21.81	23.97	30.68	-154	23.41	25.61
80	28.62	-170	20.96	22.44	29.42	-125	22.45	23.69
100	27.80	-135	20.27	21.40	28.48	-92	21.68	22.44
150	26.32	-41	18.90	19.75	26.81	-1	20.20	20.55
200	25.27	57	17.86	18.74	25.66	94	19.09	19.42
250	24.46	155	17.00	18.03	24.78	191	18.19	18.65
300	23.80	254	16.27	17.50	24.08	289	17.42	18.07
400					22.97	483	16.14	17.30
<i>T=34 K</i>					<i>T=36 K</i>			
1	2759.8	689	72.13	21.50	2932.4	732	73.36	21.48
2	1345.2	670	66.02	22.49	1435.0	715	67.30	22.25
4	635.8	630	59.50	24.75	684.8	680	60.89	24.09
6	397.0	586	55.25	27.94	433.3	640	56.80	26.51
8	275.0	535	51.79	32.85	306.0	598	53.58	29.84
10	198.6	473	48.60	41.63	228.0	549	50.76	34.73
12	142.7	390	45.18	62.40	174.0	492	48.06	42.65
14	91.25	245	40.22	171.37	133.1	421	45.26	57.23
16	50.25	7	32.83	160.93	99.25	328	42.03	87.80
18	44.22	-46	30.98	83.42	71.81	209	38.24	128.34
20	41.66	-70	30.04	63.49	56.14	110	35.14	115.08
30	36.58	-108	27.78	38.91	40.30	-21	30.24	47.97
40	34.35	-114	26.57	32.57	36.62	-44	28.55	36.79
50	32.91	-110	25.70	29.40	34.60	-48	27.46	32.13
60	31.85	-101	25.01	27.43	33.22	-44	26.63	29.47
80	30.32	-76	23.92	25.02	31.33	-24	25.40	26.44
100	29.21	-45	23.06	23.54	30.02	3	24.44	24.68
150	27.33	41	21.46	21.39	27.89	85	22.71	22.25
200	26.07	134	20.28	20.15	26.50	176	21.45	20.90
250	25.12	230	19.33	19.30	25.48	269	20.45	20.00
300	24.37	326	18.52	18.69	24.67	364	19.61	19.34
400	23.21	518	17.19	17.86	23.45	555	18.23	18.47
<i>T=38 K</i>					<i>T=40 K</i>			
1	3104.1	775	74.54	21.39	3275.2	818	75.63	21.34
2	1523.8	759	68.52	22.05	1611.8	803	69.63	21.91
4	732.7	727	62.20	23.59	779.6	774	63.39	23.21
6	468.0	692	58.22	25.50	501.5	743	59.50	24.76
8	334.7	655	55.16	27.94	361.9	710	56.55	26.65

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
10	253.8	614	52.55	31.18	277.6	674	54.08	29.00
12	198.9	569	50.18	35.66	220.8	636	51.87	31.98
14	158.7	517	47.89	42.14	179.8	595	49.86	35.84
16	127.5	458	45.58	51.85	148.5	550	47.92	40.87
18	102.3	390	43.18	65.93	123.9	500	46.00	47.36
20	82.41	313	40.69	81.37	104.0	446	44.09	55.19
30	46.20	86	33.16	59.36	55.08	211	36.36	54.08
40	39.62	37	30.68	41.89	43.64	123	32.98	46.97
50	36.66	20	29.29	35.24	39.21	93	31.17	38.52
60	34.81	17	28.30	31.71	36.90	83	29.98	34.07
80	32.45	30	26.87	27.92	33.72	87	28.34	29.46
100	30.91	53	25.83	25.85	31.88	106	27.17	27.03
150	28.48	130	23.96	23.12	29.12	178	25.16	23.90
200	26.95	218	22.63	21.66	27.44	262	23.74	22.42
250	25.85	310	21.57	20.70	26.24	352	22.64	21.41
300	24.99	403	20.69	20.00	25.32	444	21.72	20.66
400	23.70	592	19.26	19.09	23.96	631	20.25	19.72
500					20.95	813	19.08	19.20
	<i>T</i> =50 K				<i>T</i> =60 K			
1	4123.9	1030	80.37	21.25	4966.1	1244	84.27	21.59
2	2045.2	1020	74.47	21.56	2471.8	1236	78.42	21.79
4	1005.9	1000	68.44	22.22	1224.8	1221	74.48	22.20
6	659.5	979	64.79	22.94	809.3	1206	68.93	22.62
8	486.3	958	62.12	23.72	601.6	1191	66.35	23.06
10	382.3	937	59.96	24.57	477.1	1176	64.32	23.51
12	313.1	915	58.14	25.48	394.1	1170	62.62	23.99
14	263.6	893	56.55	26.48	335.0	1145	61.16	24.47
16	226.5	870	55.12	27.55	290.7	1130	59.86	24.98
18	197.7	847	53.81	28.71	256.3	1115	58.70	25.59
20	174.7	824	52.60	29.95	228.8	1099	57.64	26.04
30	106.8	704	47.49	36.74	147.1	1024	53.33	28.85
40	75.60	596	43.54	41.25	107.3	952	50.05	31.53
50	59.91	516	40.60	41.39	84.66	888	47.40	33.48
60	51.32	464	38.46	39.48	70.63	835	45.24	34.40
80	42.63	415	35.62	35.14	55.09	766	42.02	34.14
100	38.26	403	33.78	31.94	47.07	731	39.75	32.88
150	32.92	436	30.92	27.63	37.82	725	36.18	29.75
200	30.20	503	29.10	25.56	33.58	770	33.97	27.66
250	28.44	582	27.75	24.34	31.03	836	32.38	26.32
300	27.15	666	26.66	23.53	29.27	912	31.13	25.42
400	25.35	843	24.96	22.43	26.91	1077	29.22	24.25
500	24.09	1024	23.63	21.70	25.34	1250	27.76	23.50
600	23.15	1205	22.55	21.36	24.19	1427	26.59	22.96

continued

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
150	56.15	1643	48.57	31.41	62.59	1962	51.92	32.30
200	46.30	1653	45.86	31.03	50.92	1970	49.19	32.20
250	40.67	1690	43.86	30.52	44.23	2002	47.15	31.92
300	36.99	1742	42.29	29.99	39.87	2050	45.53	31.58
400	32.43	1873	39.91	29.03	34.49	2172	43.06	30.88
500	29.65	2023	38.14	28.29	31.24	2316	41.22	30.23
600	27.72	2183	36.73	27.74	29.02	2470	39.76	29.72
800	25.17	2514	34.56	26.90	26.12	2793	37.51	28.96
1000	23.53	2854	32.93	26.15	24.26	3126	35.81	28.27
<i>T</i> =120 K					<i>T</i> =140 K			
1	9979.4	2775	101.59	30.19	11645	3402	106.37	32.11
2	4990.8	2773	95.81	30.23	5825.5	3400	100.59	32.15
4	2496.6	2769	90.01	30.32	2915.5	3398	94.80	32.21
6	1665.3	2765	86.60	30.40	1945.6	3395	91.41	
8	1249.7	2761	84.17	30.48	1460.7	3392	88.99	32.33
10	1000.3	2757	82.28	30.57	1169.7	3390	87.11	32.39
12	834.2	2753	80.73	30.65	975.8	3387	85.56	32.44
14	715.5	2750	79.41	30.73	837.3	3385	84.26	
16	626.5	2746	78.26	30.81	733.5	3383	83.12	32.56
18	557.3	2742	77.25	30.89	652.7	3380	82.12	
20	502.0	2738	76.34	30.97	588.1	3378	81.22	32.67
30	336.3	2721	72.79	31.35	394.5	3367	77.72	32.94
40	253.6	2706	70.24	31.71	297.9	3358	75.22	33.20
50	204.9	2692	68.23	32.05	240.0	3350	73.25	33.44
60	171.5	2689	66.57	32.36	201.6	3343	71.63	33.66
80	130.9	2658	63.91	32.93	153.8	3332	69.05	34.07
100	106.8	2643	61.82	33.40	125.3	3324	67.02	34.43
150	75.36	2626	57.97	34.15	87.86	3322	63.29	35.11
200	60.27	2636	55.26	34.41	69.55	3338	60.62	35.48
250	51.50	2665	53.19	34.42	58.83	3369	58.57	35.64
300	45.80	2709	51.54	34.35	51.81	3413	56.91	35.70
400	38.78	2822	48.99	34.11	43.19	3524	54.34	35.69
500	34.57	2956	47.05	33.79	38.04	3654	52.38	35.60
600	31.74	3101	45.51	33.46	34.58	3795	50.80	35.46
800	28.11	3411	43.13	32.91	30.18	4096	48.36	35.13
1000	25.81	3732	41.33	32.48	27.45	4410	46.50	34.86
<i>T</i> =160 K					<i>T</i> =180 K			
1	13311	4045	110.74	32.89	14975	4712	114.64	32.82
2	6659.2	4044	104.97	32.91	7492.4	4711	108.87	32.84
4	3333.5	4043	99.19	32.96	3751.0	4710	103.09	32.88
6	2225.0	4041	95.80		2503.9	4709	99.70	
8	1670.8	4040	93.39	33.05	1880.3	4709	97.29	32.94
10	1338.3	4038	91.51	33.09	1506.2	4708	95.42	32.98
12	1116.6	4037	89.98	33.19	1256.8	4707	93.89	33.01
14	958.3	4035	88.68		1078.7	4707	92.59	

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
16	839.6	4034	87.55	33.22	945.1	4706	91.47	33.08
18	747.2	4032	86.55		841.2	4705	90.48	
20	673.4	4031	85.65	33.30	758.1	4705	89.59	33.14
30	452.0	4025	82.19	33.51	508.9	4702	86.15	33.30
40	341.4	4020	79.72	33.70	384.4	4701	83.69	33.45
50	275.1	4016	77.78	33.88	309.8	4700	81.77	33.59
60	231.1	4013	76.18	34.05	260.1	4700	80.20	33.72
80	176.2	4009	73.65	34.36	198.2	4701	77.69	33.96
100	143.4	4008	71.66	34.63	161.1	4705	75.74	34.18
150	100.1	4018	68.01	35.19	112.0	4725	72.14	34.63
200	78.72	4042	65.40	35.57	87.74	4756	69.57	34.97
250	66.11	4077	63.37	35.79	73.31	4796	67.58	35.20
300	57.82	4122	61.73	35.90	63.79	4844	65.95	35.34
400	47.61	4234	59.16	36.00	52.01	4958	63.40	35.49
500	41.63	4364	57.20	36.04	45.03	5089	61.44	35.57
600	37.46	4503	55.61	36.03	40.35	5229	59.86	35.62
800	32.30	4800	53.14	35.90	34.44	5525	57.37	35.63
1000	29.12	5110	51.25	35.73	30.80	5832	55.47	35.55
<i>T</i> =200 K					<i>T</i> =220 K			
1	16640	5367	118.10	32.41	18303	6004	121.15	31.76
2	8325.2	5367	112.33	32.43	9157.7	6004	115.38	31.77
4	4168.0	5367	106.56	32.45	4584.8	6005	109.61	31.79
6	2782.3	5366	103.17		3060.5	6005	106.23	
8	2089.5	5366	100.77	32.51	2298.4	6005	103.83	31.84
10	1673.8	5366	98.90	32.54	1841.1	6006	101.96	31.86
12	1396.7	5366	97.38	32.56	1536.3	6006	100.44	31.88
14	1198.8	5366	96.08		1318.6	6006	99.15	
16	1050.3	5366	94.96	32.62	1153.3	6007	98.03	31.93
18	934.9	5366	93.97		1028.3	6007	97.04	
20	842.5	5366	93.08	32.67	926.7	6008	96.15	31.97
30	565.5	5366	89.66	32.79	621.9	6010	92.74	32.07
40	427.1	5367	87.22	32.91	469.6	6014	90.31	32.17
50	344.2	5369	85.31	33.02	378.3	6017	88.41	32.26
60	288.9	5371	83.75	33.13	317.4	6021	86.86	32.35
80	219.9	5377	81.27	33.33	241.5	6031	84.39	32.51
100	178.6	5385	79.33	33.50	196.0	6042	82.47	32.65
150	123.8	5413	75.78	33.87	135.5	6077	78.95	32.96
200	96.64	5450	73.24	34.16	105.4	6119	76.44	33.21
250	80.43	5495	71.27	34.38	87.48	6168	74.49	33.40
300	69.70	5546	69.65	34.52	75.57	6222	72.89	33.55
400	56.42	5663	67.12	34.69	60.79	6343	70.37	33.72
500	48.51	5795	65.18	34.78	51.98	6477	68.43	33.81
600	43.24	5937	63.60	34.85	46.11	6620	66.86	33.88
800	36.58	6233	61.11	34.94	38.73	6918	64.39	34.00
1000	32.50	6540	59.21	34.93	34.21	7225	62.49	34.05

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
<i>T=240 K</i>					<i>T=260 K</i>			
1	19967	6631	123.88	31.16	21631	7248	126.41	30.67
2	9990.0	6632	118.11	31.17	10822	7248	120.64	30.67
4	5001.3	6632	112.34	31.18	5417.8	7249	114.87	30.69
6	3338.5	6633	108.97		3616.3	7250	111.49	
8	2507.1	6634	106.57	31.22	2715.6	7251	109.10	30.72
10	2008.2	6635	104.70	31.24	2175.2	7252	107.24	30.74
12	1675.7	6635	103.18	31.26	1814.9	7254	105.71	30.75
14	1438.1	6636	101.89		1557.6	7255	104.43	
16	1260.0	6637	100.77	31.29	1364.6	7256	103.31	30.78
18	1121.4	6638	99.79		1214.5	7257	102.32	
20	1010.6	6639	98.90	31.33	1094.4	7258	101.44	30.81
30	678.1	6643	95.50	31.41	734.2	7264	98.04	30.88
40	511.9	6648	93.07	31.49	554.1	7271	95.62	30.95
50	412.2	6653	91.18	31.57	446.1	7277	93.74	31.01
60	345.8	6659	89.64	31.64	374.1	7284	92.20	31.08
80	262.9	6672	87.19	31.78	284.2	7299	89.76	31.19
100	213.2	6686	85.27	31.90	230.3	7316	87.86	31.30
150	147.1	6726	81.78	32.16	158.5	7361	84.38	31.52
200	114.1	6773	79.29	32.37	122.8	7412	81.91	31.70
250	94.47	6825	77.35	32.54	101.4	7467	79.98	31.85
300	81.40	6882	75.76	32.68	87.18	7526	78.40	31.98
400	65.14	7006	73.26	32.85	69.46	7654	75.92	32.15
500	55.43	7142	71.33	32.95	58.87	7792	73.99	32.24
600	48.98	7286	69.77	33.01	51.83	7937	72.43	32.31
800	40.86	7587	67.31	33.13	42.99	8241	69.98	32.41
1000	35.90	7896	65.41	33.21	37.60	8551	68.09	32.51
<i>T=280 K</i>					<i>T=300 K</i>			
1	23294	7851	128.65	30.27	24958	8466	130.70	29.94
2	11654	7851	122.89	30.28	12466	8467	124.93	29.94
4	5834.0	7853	117.12	30.29	6250.2	8468	119.17	29.95
6	3894.0	7854	113.74		4171.6	8470	115.79	
8	2924.0	7855	111.35	30.32	3132.3	8472	113.39	29.97
10	2342.0	7857	109.49	30.33	2506.8	8473	111.54	29.98
12	1954.0	7858	107.97	30.34	2093.1	8475	110.02	30.00
14	1676.9	7860	106.68		1796.1	8477	108.73	
16	1469.0	7861	105.56	30.37	1573.4	8478	107.61	30.02
18	1307.4	7863	104.58		1400.2	8480	106.63	
20	1178.1	7864	103.70	30.39	1261.7	8482	105.75	30.04
30	790.1	7871	100.30	30.45	846.0	8490	102.36	30.09
40	596.2	7879	97.89	30.51	638.2	8499	99.95	30.15
50	479.8	7887	96.01	30.57	513.5	8508	98.37	30.19
60	402.3	7895	94.47	30.62	430.4	8517	96.54	30.23
80	305.4	7912	92.04	30.72	326.5	8536	94.21	30.32
100	247.3	7930	90.15	30.81	264.3	8556	92.23	30.40

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
150	170.0	7980	86.69	31.00	181.4	8609	88.78	30.59
200	131.4	8034	84.23	31.16	140.0	8686	86.33	30.71
250	108.3	8092	82.31	31.29	115.2	8727	84.42	30.83
300	92.94	8154	80.74	31.41	98.67	8791	82.86	30.93
400	73.77	8285	78.26	31.57	78.06	8925	80.39	31.08
500	62.30	8425	76.35	31.66	65.72	9097	78.49	31.17
600	54.67	8572	74.79	31.79	57.51	9215	76.93	31.23
800	45.10	8877	72.35	31.82	47.22	9522	74.50	31.32
1000	39.29	9189	70.47	31.92	40.98	9836	72.62	31.41
<i>T</i> =350 K					<i>T</i> =400 K			
1	29116	9950	135.28	29.50	33273	11420	139.20	29.34
2	14565	9951	129.51	29.50	16645	11421	133.44	29.34
4	7290.4	9953	123.75	29.51	8330.3	11424	127.67	29.35
6	4866.4	9955	120.37		5558.8	11426	124.30	
8	3652.8	9957	117.98	29.53	4173.1	11428	121.91	29.36
10	2925.3	9959	116.12	29.54	3341.6	11431	120.05	29.36
12	2440.3	9961	114.60	29.54	2787.3	11433	118.53	29.37
14	2093.9	9964	113.32		2391.4	11436	117.25	
16	1834.1	9966	112.21	29.56	2094.5	11438	116.14	29.38
18	1632.0	9968	111.22		1863.5	11441	115.16	
20	1470.3	9970	110.24	29.57	1678.8	11443	114.28	29.39
30	985.4	9981	106.96	29.61	1124.5	11455	110.90	29.42
40	742.9	9991	104.56	29.65	847.3	11468	108.50	29.44
50	597.4	10002	102.69	29.68	681.0	11480	106.63	29.47
60	500.0	10014	101.16	29.71	570.2	11493	105.11	29.49
80	379.2	10036	98.74	29.78	431.7	11518	102.70	29.54
100	306.5	10059	96.87	29.84	348.5	11544	100.83	29.59
150	209.6	10120	93.45	29.96	237.7	11610	97.42	29.68
200	161.2	10183	91.01	30.07	182.3	11678	95.00	29.76
250	132.2	10259	89.12	30.16	149.1	11748	93.12	29.83
300	112.9	10317	87.57	30.23	127.0	11819	91.58	29.89
400	88.72	10458	85.13	30.36	99.30	11966	89.15	29.99
500	74.23	10605	83.23	30.44	82.68	12116	87.27	30.07
600	64.57	10756	81.69	30.50	71.60	12270	85.73	30.12
800	52.47	11067	79.27	30.57	57.71	12584	83.32	30.19
1000	45.17	11384	77.40	30.63	49.33	12904	81.46	30.23
<i>T</i> =450 K					<i>T</i> =500 K			
1	37431	12884	142.58	29.29	41588	14349	145.74	29.29
2	18724	12885	136.82	29.29	20803	14351	139.97	29.29
4	9369.9	12888	131.05	29.30	10410	14354	134.21	29.29
6	6252.1	12890	127.68		6945.2	14357	130.84	
8	4693.1	12893	125.29	29.31	5213.0	14359	128.44	29.30
10	3757.7	12896	123.43	29.31	4173.7	14362	126.59	29.30
12	3134.2	12898	121.91	29.32	3480.9	14365	125.07	29.30
14	2688.7	12901	120.63		2986.0	14368	123.79	

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
16	2354.7	12904	119.52	29.32	2614.8	14371	122.68	29.31
18	2094.9	12907	118.54		2326.1	14374	121.70	
20	1887.0	12909	117.66	29.33	2095.1	14377	120.82	29.32
30	1263.4	12923	114.28	29.35	1402.3	14391	117.44	29.33
40	951.6	12936	111.89	29.37	1055.8	14405	115.05	29.35
50	764.6	12950	110.02	29.39	848.0	14420	113.19	29.36
60	640.0	12963	108.50	29.41	709.4	14434	111.67	29.38
80	484.0	12991	106.10	29.45	536.2	14463	109.27	29.41
100	390.4	13018	104.23	29.48	432.2	14493	107.41	29.43
150	265.7	13089	100.84	29.56	293.6	14586	104.02	29.50
200	203.4	13160	98.42	29.62	224.3	14641	101.61	29.55
250	166.0	13233	96.55	29.68	182.7	14716	99.74	29.59
300	141.0	13308	95.02	29.73	155.0	14793	98.21	29.63
400	109.8	13459	92.60	29.81	120.3	14947	95.80	29.70
500	91.10	13613	90.72	29.87	99.48	15104	93.93	29.75
600	78.59	13769	89.19	29.92	85.57	15263	92.41	29.79
800	62.93	14086	86.79	29.98	68.13	15583	90.01	29.85
1000	53.48	14408	84.93	30.01	57.63	15906	88.15	29.87

Thermodynamic properties of hydrogen at high temperatures:

V (cm³/mole), *I* (J/mole), *S* and *C_p* (J/(mole·K)) [5, 7]

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
<i>T=500 K</i>					<i>T=600 K</i>			
1	45746	15815	148.54	29.30	49903	17280	151.09	29.34
2	22881	15816	142.78	29.30	24960	17281	145.32	29.34
4	11449	15819	137.01	29.30	12788	17284	139.56	29.34
6	7638.2	15822	133.64	29.31	8331.2	17287	136.19	29.34
8	5732.9	15825	131.25	29.31	6252.6	17291	133.80	29.34
10	4589.6	15828	129.39	29.31	5005.5	17294	131.94	29.34
12	3827.5	15831	127.87	29.31	4174.0	17297	130.42	29.35
14	3283.1	15834	126.59	29.31	3580.2	17300	129.14	29.35
16	2874.8	15837	125.48	29.32	3134.7	17303	128.03	29.35
18	2557.2	15840	124.50	29.32	2788.3	17306	127.05	29.35
20	2303.2	15843	123.63	29.32	2511.2	17309	126.17	29.35
30	1541.0	15858	120.25	29.34	1679.7	17325	122.80	29.36
40	1159.9	15873	117.86	29.35	1264.0	17340	120.41	29.37
50	931.3	15888	116.00	29.36	1014.5	17356	118.55	29.38
60	778.8	15904	114.48	29.37	848.2	17371	117.03	29.39
80	588.3	15934	112.08	29.40	640.2	17403	114.64	29.41
100	474.0	15964	110.22	29.42	515.6	17434	112.78	29.43

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
150	321.5	16041	106.84	29.47	349.3	17513	109.40	29.47
200	245.2	16118	104.44	29.51	266.1	17592	107.00	29.51
250	199.5	16195	102.57	29.55	216.2	17671	105.14	29.54
300	169.0	16274	101.05	29.58	182.9	17751	103.62	29.57
400	130.8	16431	98.64	29.64	141.2	17911	101.22	29.61
500	107.8	16590	96.78	29.68	116.2	18092	99.35	29.65
600	92.53	16751	95.25	29.71	99.47	18334	97.84	29.68
800	73.33	17014	92.86	29.76	78.52	18559	95.64	29.72
1000	61.77	17561	90.22	29.79	65.90	18885	93.60	29.74
<i>T</i> =650 K					<i>T</i> =700 K			
1	54060	18747	153.43	29.39	58218	20218	155.61	29.45
2	27039	18749	147.67	29.39	29117	20219	149.85	29.45
4	13528	18752	141.91	29.39	14567	20223	144.08	29.45
6	9024.2	18755	138.54	29.39	9717.1	20226	140.71	29.45
8	6772.4	18758	136.14	29.39	7292.1	20229	138.32	29.45
10	5421.3	18761	134.29	29.39	5837.0	20233	136.46	29.45
12	4520.6	18765	134.95	29.39	4867.0	20236	134.95	29.46
14	3877.2	18768	131.49	29.39	4174.2	20239	133.67	29.46
16	3394.6	18771	130.38	29.40	3654.5	20242	132.56	29.46
18	3019.3	18774	129.40	29.40	3250.3	20246	131.58	29.46
20	2719.1	18776	128.52	29.40	2927.0	20249	130.70	29.46
30	1818.4	18794	125.15	29.41	1957.0	20265	127.33	29.46
40	1368.0	18810	122.76	29.41	1472.0	20282	124.94	29.47
50	1097.8	18826	120.90	29.43	1180.9	20298	123.08	29.48
60	917.6	18842	119.39	29.44	986.9	20315	121.56	29.49
80	692.4	18874	116.99	29.45	744.4	20348	119.17	29.50
100	557.3	18906	115.13	29.46	598.9	20381	117.31	29.51
150	377.1	18987	111.76	29.50	404.8	20463	113.94	29.54
200	286.9	19068	109.36	29.53	307.8	20545	111.54	29.56
250	232.9	19148	107.50	29.55	249.5	20627	109.69	29.59
300	196.8	19229	105.98	29.58	210.7	20709	108.17	29.61
400	151.6	19392	103.58	29.62	162.0	20873	105.77	29.64
500	124.5	19554	101.73	29.65	132.8	21037	103.92	29.67
600	106.4	19718	100.21	29.67	113.3	21201	102.40	29.69
800	83.71	20044	97.82	29.70	88.89	21530	100.02	29.71
1000	70.03	20371	95.97	29.72	74.16	21858	98.17	29.73
<i>T</i> =750 K					<i>T</i> =800 K			
1	62375	21691	157.64	29.53	66532	23169	159.55	29.63
2	31196	21693	151.88	29.53	33275	23171	153.79	29.63
4	15606	21696	146.12	29.53	18646	23174	148.02	29.63
6	10410	21700	142.74	29.53	11103	23178	144.65	29.63
8	7811.7	21703	140.95	29.53	8331.4	23181	142.26	29.64
10	6252.8	21707	138.50	29.53	6668.5	23185	140.41	29.64
12	5213.5	21710	136.98	29.54	5559.9	23188	138.89	29.64
14	4471.1	21713	135.70	29.54	4768.1	23191	137.61	29.64

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
16	3914.4	21717	134.59	29.54	4174.2	23195	136.50	29.64
18	3481.3	21720	133.61	29.54	3712.3	23198	135.52	29.64
20	3134.9	21723	132.73	29.54	3342.8	23202	134.64	29.64
30	2095.6	21740	129.36	29.55	2234.2	23219	131.27	29.65
40	1575.9	21757	126.97	29.55	1679.9	23236	128.98	29.65
50	1264.1	21774	125.11	29.56	1347.3	23252	127.02	29.65
60	1056.2	21790	123.60	29.56	1125.5	23269	125.51	29.66
80	796.4	21824	121.21	29.57	848.4	23303	123.12	29.67
100	640.5	21857	119.35	29.58	682.1	23337	121.26	29.68
150	432.6	21940	115.98	29.60	460.3	23422	117.89	29.70
200	328.6	22024	113.58	29.63	349.4	23506	115.50	29.71
250	266.2	22107	111.73	29.65	282.8	23590	113.64	29.73
300	224.5	22190	110.21	29.66	238.4	23674	112.12	29.74
400	172.4	22355	107.82	29.69	182.8	23841	109.74	29.77
500	141.2	22521	105.96	29.71	149.5	24017	107.88	29.79
600	120.3	22686	104.45	29.73	127.2	24173	106.37	29.80
800	94.06	23016	102.07	29.76	99.23	24504	103.99	29.82
1000	78.29	23344	100.22	29.77	82.41	24833	102.14	29.83
<i>T=850 K</i>					<i>T=900 K</i>			
1	76689	24655	161.35	29.75	74846	26145	162.95	29.89
2	35353	24657	155.59	29.75	37432	26146	157.29	29.89
4	17685	24660	149.82	29.75	16724	26150	151.52	29.89
6	11796	24664	146.45	29.76	12489	26153	148.15	29.89
8	8851.0	24667	144.06	29.76	9370.7	26157	145.76	29.89
10	7084.2	24670	142.21	29.76	7499.9	26160	143.91	29.89
12	6906.4	24674	140.69	29.76	6252.8	26163	142.39	29.89
14	5065.0	24677	139.41	29.76	5361.9	26167	141.11	29.89
16	4434.0	24681	138.30	29.76	4693.8	26171	140.00	29.89
18	3943.2	24684	137.32	29.76	4174.2	26174	139.02	29.89
20	3550.6	24688	136.44	29.76	3758.4	26178	138.14	29.89
30	2372.7	24705	133.07	29.76	2411.3	26195	134.77	29.90
40	1783.8	24722	130.68	29.77	1887.7	26210	132.38	29.90
50	1430.4	24739	128.83	29.77	1613.5	26230	130.53	29.90
60	1194.8	24756	127.31	29.78	1264.1	26247	129.01	29.90
80	900.3	24791	124.92	29.78	952.3	26282	126.62	29.91
100	723.6	24825	123.06	29.79	765.2	26316	124.77	29.92
150	488.1	24910	119.69	29.81	515.7	26402	121.40	29.93
200	370.1	24995	117.30	29.82	390.3	26409	119.01	29.94
250	299.4	25080	115.45	29.83	316.0	26574	117.15	29.95
300	252.2	25165	113.93	29.85	266.1	26659	115.64	29.97
400	193.2	25333	111.45	29.87	203.6	26828	113.25	29.99
500	157.1	25500	109.69	29.89	166.0	26996	111.40	30.00
600	134.1	25667	108.18	29.90	141.0	27163	109.89	30.01
800	104.4	25998	105.80	29.92	109.7	27496	107.51	30.03
1000	86.53	26328	103.86	29.93	90.66	27826	105.66	30.03

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
<i>T=950 K</i>					<i>T=1000 K</i>			
1	79004	27643	164.67	30.04	83161	29149	166.22	30.21
2	39510	27645	158.91	30.04	41589	29151	160.45	30.21
4	19754	27649	153.15	30.05	26803	29154	154.69	30.21
6	13181	27652	149.77	30.05	13874	29158	151.32	30.21
8	9890.3	27656	147.38	30.05	10410	29162	148.93	30.21
10	7915.6	27659	145.53	30.05	8331.3	29165	147.17	30.21
12	6599.2	27663	144.01	30.05	6945.6	29169	145.56	30.21
14	5658.9	27666	142.73	30.05	5955.8	29173	144.27	30.21
16	4953.6	27668	141.62	30.05	5213.4	29176	143.16	30.21
18	4405.1	27673	140.64	30.05	4636.0	29179	142.19	30.21
20	3966.3	27677	139.76	30.05	4174.1	29183	141.31	30.21
30	2649.8	27694	136.40	30.05	2788.4	29200	137.94	30.22
40	1991.6	27712	134.00	30.05	2095.5	29218	135.55	30.22
50	1596.6	27729	132.15	30.06	1679.8	29235	133.69	30.22
60	1333.3	27747	130.63	30.06	1402.6	29253	132.18	30.22
80	1004.2	27781	128.24	30.06	1056.1	29288	129.79	30.23
100	806.7	27816	126.39	30.07	848.3	29323	127.93	30.23
150	543.2	27903	123.02	30.08	571.1	29410	124.57	30.24
200	411.7	27989	120.63	30.09	432.4	29497	122.18	30.25
250	332.6	28095	118.78	30.10	349.2	29584	120.32	30.26
300	279.9	28161	117.26	30.11	293.7	29670	118.81	30.27
400	214.0	28331	114.88	30.13	224.3	29841	116.43	30.28
500	174.3	28500	113.00	30.14	182.6	30010	114.58	30.29
600	147.4	28608	111.52	30.15	154.7	30179	113.07	30.30
800	114.7	29001	109.13	30.16	119.9	30512	110.69	30.31
1000	94.78	29331	107.29	30.17	98.90	30843	108.84	30.31
<i>T=1100 K</i>					<i>T=1200 K</i>			
1	91475	32189	169.12	30.58	99789	35265	171.79	30.99
2	45746	32190	163.36	30.58	49903	35267	166.03	30.99
4	22881	32194	157.59	30.58	24960	35270	160.27	30.99
6	15260	32198	154.22	30.59	16646	35274	156.90	30.99
8	11449	32201	151.83	30.59	12488	35278	154.50	30.99
10	9162.7	32205	149.98	30.59	9994.0	35281	152.65	30.99
12	7638.4	32208	148.46	30.59	8331.4	35285	151.13	30.99
14	6549.6	32212	147.28	30.59	7143.4	35288	149.85	30.99
16	5733.0	32215	146.07	30.59	6252.5	35292	148.74	30.99
18	5097.9	32219	145.09	30.59	5559.7	35296	147.76	30.99
20	4589.7	32222	144.21	30.59	5005.4	35299	146.89	30.99
30	3065.4	32240	141.04	30.59	3342.5	35317	143.62	31.00
40	2303.3	32258	138.45	30.59	2511.0	35335	141.13	31.00
50	1846.0	32276	136.60	30.59	2012.2	35353	139.27	31.00
60	1541.1	32293	135.08	30.59	1679.6	35371	137.76	31.00
80	1160.0	32329	132.69	30.60	1263.8	35406	135.37	31.00
100	931.3	32364	130.84	30.60	1014.4	35442	133.51	31.00

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	
150	626.4	32452	127.47	30.60	681.8	35530	130.15	31.01	
200	473.9	32540	125.08	30.61	515.4	35619	127.76	31.01	
250	382.4	32627	123.23	30.62	415.6	35706	125.91	31.01	
300	321.4	32714	121.72	30.62	349.0	35794	124.40	31.02	
400	245.0	32886	119.34	30.63	265.8	35967	122.01	31.03	
500	199.2	33057	117.49	30.64	215.8	36138	120.16	31.03	
600	168.6	33226	115.98	30.65	182.4	36308	118.65	31.04	
800	130.2	33560	113.60	30.66	140.6	36643	116.28	31.05	
1000	107.0	33891	111.76	30.66	115.4	36974	114.43	31.05	
<i>T=1300 K</i>					<i>T=1400 K</i>				
1	108100	38386	174.29	31.43	116420	41551	176.64	31.87	
2	54060	38388	168.53	31.43	58217	41553	170.88	31.87	
4	27038	38392	162.76	31.43	29117	41556	165.11	31.87	
6	16031	38395	159.39	31.43	19417	41560	161.74	31.87	
8	13527	38399	157.00	31.43	14567	41564	159.35	31.87	
10	10825	38403	155.15	31.43	11667	41567	157.50	31.87	
12	9023.9	38406	153.63	31.43	9716.7	41571	155.98	31.87	
14	7737.1	38410	152.35	31.43	8330.9	41574	154.70	31.87	
16	6772.1	38413	151.24	31.43	7291.6	41578	153.59	31.87	
18	6021.5	38417	150.26	31.43	6483.3	41582	152.61	31.87	
20	5421.0	38421	149.38	31.43	5836.6	41585	151.73	31.87	
30	3619.5	38439	146.01	31.43	3896.6	41603	148.36	31.87	
40	2718.8	38457	143.62	31.43	2926.6	41621	145.97	31.87	
50	2178.4	38474	141.77	31.43	2344.5	41639	144.12	31.87	
60	1818.1	38492	140.25	31.44	1956.5	41657	142.60	31.87	
80	1367.7	38528	137.96	31.44	1471.5	41693	140.21	31.87	
100	1097.4	38564	136.01	31.44	1180.5	41729	138.36	31.88	
150	737.1	38653	132.64	31.44	792.4	41818	134.99	31.88	
200	556.9	38741	130.26	31.44	598.4	41907	132.61	31.88	
250	448.8	38830	128.41	31.45	481.9	41995	130.76	31.88	
300	376.7	38917	126.90	31.45	404.3	42083	129.25	31.88	
400	286.5	39091	124.51	31.45	307.2	42257	126.86	31.89	
500	232.3	39263	122.66	31.46	248.9	42430	125.01	31.89	
600	196.2	39433	121.16	31.46	209.9	42600	123.51	31.89	
800	150.9	39769	118.78	31.47	161.2	42936	121.13	31.90	
1000	123.6	40100	116.93	31.47	131.9	43267	119.39	31.90	
<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
	<i>T = 1500 K</i>								
1	124730	44759	178.85	32.30	50	2510.7	44848	146.33	32.31
2	62374	44761	173.09	32.30	60	2095.0	44866	144.82	32.31
4	31185	44765	167.33	32.30	80	1575.3	44902	142.43	32.31
6	20802	44768	163.96	32.30	100	1263.5	44937	140.58	32.31
8	15606	44772	161.57	32.30	150	847.8	45027	137.21	32.31

continued

<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>	<i>p</i> , bar	<i>V</i>	<i>I</i>	<i>S</i>	<i>C_p</i>
<i>T</i> = 1500 K									
10	12488	44776	159.71	32.30	200	639.9	45116	134.82	32.31
12	10409	44779	158.20	32.30	250	515.1	45204	132.97	32.31
14	8924.7	44782	156.91	32.30	300	431.9	45282	131.46	32.31
16	7811.2	44786	155.80	32.30	400	327.9	45467	129.08	32.31
18	6945.1	44791	154.82	32.30	500	265.4	45639	127.23	32.31
20	6252.2	44794	153.95	32.30	600	223.7	45810	125.72	32.32
30	4173.6	44812	150.58	32.31	800	171.5	46147	123.34	32.32
40	3134.3	44830	148.19	32.31	1000	140.1	46477	121.50	32.32

Sound velocity *u* (m/s) in hydrogen [7]*

<i>p</i> , bar	15	20	22	24	26	28	30	32						
<i>T</i> , K														
1	1245.3	1135.8	375.7	395.5	413.1	431.1	447.8	463.4						
5	1260.3	1156.4	1090.3	1016.8	932.0	393.8	417.7	439.0						
10	1278.4	1180.7	1118.6	1051.1	976.0	886.1	765.2	397.5						
12	1285.7	1190.0	1129.3	1063.9	992.0	907.5	798.9	627.9						
14	1292.4	1199.1	1139.8	1078.2	1007.1	927.3	827.8	687.3						
16	1299.2	1208.0	1149.9	1088.1	1021.6	945.8	853.7	731.4						
18	1306.0	1216.7	1159.8	1099.8	1035.4	963.2	877.2	767.9						
20	1312.6	1225.3	1169.5	1110.8	1048.7	979.7	898.9	799.2						
25	1328.8	1245.9	1192.6	1137.2	1079.7	1017.8	946.6	863.6						
30	1344.5	1265.6	1214.5	1162.0	1108.3	1051.1	987.7	915.8						
40		1302.7	1255.2	1207.3	1159.5	1110.1	1057.1	998.8						
50			1337.1	1292.6	1248.2	1204.9	1161.1	1115.0	1065.3					
60				1369.2	1327.1	1285.8	1246.0	1208.4	1163.3	1121.7				
80					1428.1	1390.0	1353.0	1318.5	1284.9	1250.9	1213.3			
100						1481.1	1446.0	1412.5	1381.8	1352.5	1323.2	1292.8		
150							1594.6	1565.3	1538.2	1514.2	1492.0	1470.2	1447.5	
200								1687.0	1662.7	1640.8	1622.2	1605.2	1588.5	1570.7
250									1742.2	1725.8	1712.4	1700.5	1688.4	1674.9
300										1794.6	1787.4	1781.2	1774.2	1765.1
400													1911.2	

* The difference between speed of sound in hydrogen and parahydrogen in the liquid state is less than 1% [392]. This difference is even smaller in the gas phase.

continued

$T, K \rightarrow$	34	36	38	40	50	60	80	100
$p, \text{ bar}$								
1	478.6	493.3	507.5	521.3	584.5	640.2	733.4	808.8
5	458.4	476.4	493.3	509.3	579.8	639.1	735.4	811.9
10	428.9	453.9	475.6	495.2	575.5	638.9	738.6	816.2
12	415.4	444.7	468.9	490.1	574.3	639.3	740.0	818.0
14	407.7	436.4	462.8	485.6	573.5	639.9	741.6	819.9
16	533.7	433.6	458.6	482.3	573.2	640.7	743.4	821.8
18	614.3	454.4	458.9	480.9	573.3	641.9	745.2	823.9
20	669.0	511.7	468.8	483.0	574.0	643.3	747.2	826.0
25	764.4	648.7	549.2	515.1	578.7	648.4	752.7	831.5
30	733.0	740.5	648.1	583.3	588.9	655.1	758.9	837.5
40	734.8	865.6	794.4	728.0	628.6	675.7	773.8	850.6
50	1011.9	955.1	896.6	839.3	689.3	705.8	791.4	865.2
60	1075.3	1026.3	975.9	925.9	758.3	743.6	811.8	881.1
80	1177.8	1138.6	1098.2	1057.6	891.3	832.8	859.6	916.5
100	1260.9	1227.5	1193.1	1158.4	1004.6	925.1	914.7	955.8
150	1423.6	1398.4	1372.3	1345.6	1219.2	1129.2	1063.5	1066.1
200	1551.6	1530.9	1509.2	1486.7	1377.6	1292.1	1204.7	1181.2
250	1659.5	1642.2	1623.5	1603.9	1505.8	1426.3	1331.2	1291.2
300	1753.4	1739.4	1723.3	1705.8	1615.5	1540.9	1444.6	1393.3
400	1909.2	1902.8	1892.8	1880.0	1801.6	1732.7	1640.2	1576.5
500				2026.7	1962.4	1895.0	1804.8	1737.4
600					2110.8	2043.4	1948.4	1880.0
700						2188.3	2080.5	2008.0
800							2210.1	2125.9
900							2344.8	2239.9
1000							2490.0	2356.5
$T, K \rightarrow$	120	140	160	180	200	250	300	350
$p, \text{ bar}$								
1	873.4	932.1	987.3	1039.8	1090.2	1209.0	1319.3	1422.5
2	874.3	933.0	988.2	1040.7	1091.2	1209.8	1320.2	1423.3
5	877.0	935.8	991.0	1043.5	1094.0	1212.5	1322.7	1425.8
10	881.6	940.5	995.8	1048.3	1098.7	1217.0	1327.0	1429.8
20	891.6	950.6	1005.7	1058.0	1108.2	1226.0	1335.5	1437.8
30	902.7	961.3	1018.1	1068.1	1118.0	1235.1	1344.0	1445.9
40	914.8	972.6	1026.9	1078.4	1127.9	1244.3	1352.6	1454.0
50	927.8	984.6	1038.1	1089.1	1138.1	1253.6	1361.3	1462.1
60	941.5	997.1	1049.7	1100.0	1148.5	1263.0	1370.0	1470.1

continued

T, K		120	140	160	180	200	250	300	350
$p, \text{ bar}$									
80	971.2	1023.4	1073.9	1122.5	1169.8	1282.0	1387.4	1488.4	
100	1003.1	1051.3	1099.1	1145.8	1191.6	1301.3	1404.9	1502.6	
150	1090.5	1125.6	1165.2	1208.3	1247.9	1350.4	1449.2	1543.4	
200	1184.3	1204.6	1234.4	1268.8	1305.5	1400.0	1493.6	1584.0	
250	1278.2	1285.5	1305.4	1332.5	1363.9	1449.6	1537.9	1624.5	
300	1368.3	1365.3	1376.6	1396.8	1422.7	1499.3	1581.9	1664.6	
400	1533.3	1515.2	1513.8	1523.1	1539.5	1598.2	1669.1	1743.6	
500	1681.6	1651.3	1640.3	1641.7	1651.3	1695.2	1754.4	1821.1	
600	1817.0	1776.8	1757.0	1751.7	1755.9	1788.6	1838.7	1897.2	
700	1941.0	1894.1	1868.6	1854.7	1853.8	1877.2	1919.7	1971.4	
800	2054.9	2003.8	1970.4	1952.6	1946.6	1961.1	1997.3	2043.3	
900	2160.6	2106.1	2068.9	2048.2	2035.4	2041.0	2071.4	2112.6	
1000	2261.6	2202.0	2162.0	2136.8	2121.0	2117.7	2142.3	2179.2	
T, K		400	450	500	600	800	1000	1200	1500
$p, \text{ bar}$									
1	1519.6	1611.2	1697.9	1859.1	2142.1	2386.0	2601.2	2886.6	
2	1520.4	1611.9	1698.6	1859.7	2142.7	2386.4	2601.6	2887.0	
5	1522.7	1614.1	1700.7	1861.6	2144.3	2387.9	2602.9	2888.1	
10	1528.5	1617.7	1704.1	1864.7	2147.0	2390.2	2605.0	2890.0	
20	1534.1	1624.9	1711.0	1871.0	2152.4	2395.0	2609.2	2893.6	
30	1541.8	1632.2	1717.9	1877.3	2157.8	2399.7	2613.4	2897.3	
40	1549.4	1639.4	1724.8	1883.6	2163.2	2404.4	2617.7	2901.0	
50	1557.0	1648.6	1731.7	1889.8	2168.5	2409.1	2621.9	2904.6	
60	1564.6	1653.8	1738.5	1896.2	2173.9	2413.8	2628.1	2908.3	
80	1579.8	1668.2	1752.2	1908.6	2184.5	2423.2	2634.4	2915.5	
100	1595.1	1682.6	1765.8	1921.0	2195.1	2432.5	2642.8	2922.8	
150	1633.0	1718.3	1799.6	1951.7	2221.4	2455.6	2663.5	2940.8	
200	1670.8	1753.7	1833.1	1982.1	2247.3	2478.4	2684.0	2958.7	
250	1708.3	1788.8	1866.1	2011.9	2272.8	2500.9	2704.2	2976.4	
300	1745.4	1823.4	1898.8	2041.4	2297.9	2523.1	2724.2	2993.9	
400	1818.3	1891.5	1962.8	2099.1	2347.6	2566.4	2763.3	3028.2	
500	1889.6	1958.0	2025.3	2155.4	2394.7	2608.4	2801.1	3061.6	
600	1959.6	2023.1	2086.4	2210.3	2441.1	2649.2	2837.9	3094.0	
700	2028.0	2088.8	2148.2	2264.0	2486.5	2689.0	2873.7	3125.5	
800	2094.7	2149.1	2204.7	2316.5	2530.9	2727.9	2908.6	3158.2	
900	2159.6	2209.8	2261.9	2367.9	2574.3	2766.0	2942.7	3186.1	
1000	2222.3	2268.9	2317.7	2418.2	2617.0	2803.5	2976.2	3215.4	

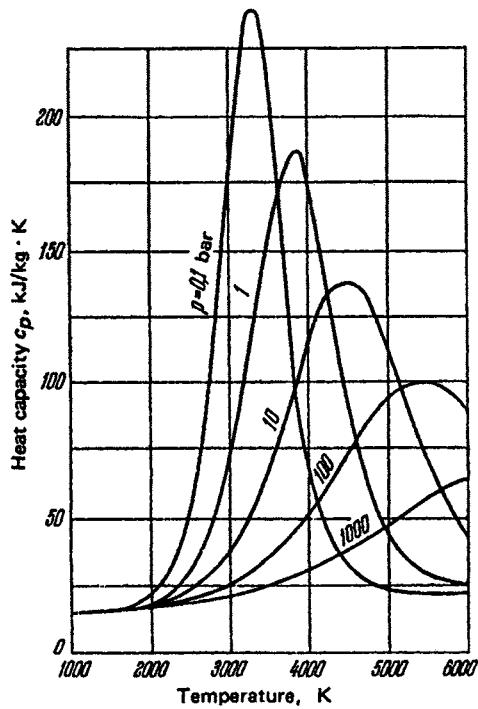


Fig: 3. Heat capacity of dissociated hydrogen as a function of temperature with pressure as a parameter.

Thermodynamic properties of dissociated hydrogen at different temperatures and pressures:
 v (m^3/kg), i (kJ/kg), s and c_p ($\text{kJ}/(\text{kg}\cdot\text{K})$) [8, 9]

T, K	v	i	s	c_p	v	i	s	c_p
$p = 0.1 \text{ bar}$					$p = 1 \text{ bar}$			
1500	618.7	22210	98.216	16.08	61.87	22207	88.718	16.03
1600	659.9	23834	99.259	16.42	66.00	23822	89.759	16.28
1700	701.3	25499	100.259	16.91	70.12	25464	90.751	16.58
1800	742.8	27226	101.226	17.69	74.26	27140	91.701	16.96
1900	784.6	29053	102.177	18.95	78.40	28860	92.618	17.49
2000	826.9	31041	103.136	20.97	82.56	30646	93.510	18.25
2200	915.4	35911	105.214	28.77	90.99	34534	95.267	20.96
2400	1015	43101	107.873	44.90	99.78	39201	97.101	26.27
2600	1137	54734	111.786	73.97	109.3	45320	99.207	35.74
2800	1303	73810	117.892	119.7	120.2	53883	101.865	50.99

continued

<i>T</i> , K	<i>v</i>	<i>i</i>	<i>s</i>	<i>c_p</i>	<i>v</i>	<i>i</i>	<i>s</i>	<i>c_p</i>
<i>p</i> = 0.1 bar								
3000	1537	103537	127.192	178.8	133.5	66198	105.436	73.42
3200	1856	144786	139.964	229.0	150.4	83573	110.327	103.3
3400	2237	191826	154.445	230.8	172.2	107836	116.890	137.9
3600	2612	233335	167.151	178.2	199.8	138688	125.195	169.1
3800	2928	262452	175.972	114.9	232.6	174349	134.723	183.7
4000	3183	280651	181.369	70.96	267.9	210397	144.300	172.5
4200	3398	292158	184.650	46.73	302.0	241669	152.630	141.1
4400	3590	300125	186.793	34.35	332.6	266551	159.048	105.1
4600	3771	306297	188.341	28.07	359.1	284474	163.646	75.61
4800	3944	311550	189.566	24.81	382.3	297412	166.875	55.21
5000	4114	316321	190.607	23.07	403.1	307055	169.189	42.24
5200	4282	320828	191.534	22.10	422.5	314639	170.921	34.26
5400	4449	325187	192.385	21.54	440.9	320962	172.285	29.37
5600	4616	329460	193.180	21.21	458.6	326510	173.415	26.35
5800	4781	333682	193.934	21.02	476.0	331577	174.390	24.46
6000	4947	337875	194.654	20.91	493.1	336342	175.259	23.27
<i>p</i> = 5 bar								
1500					6.194	22213	79.222	16.01
1600					6.607	23825	80.262	16.23
1700					7.019	25460	81.252	16.47
1800					7.432	27120	82.197	16.73
1900					7.845	28807	83.105	17.03
2000	16.51	30547	86.843	17.56	8.258	30528	83.979	17.39
2200	18.18	34185	88.528	18.96	9.089	34106	85.647	18.48
2400	19.87	38207	90.174	21.50	9.931	37975	87.253	20.38
2600	21.64	42911	91.870	25.89	10.79	42344	88.859	23.56
2800	23.52	48739	93.734	32.88	11.70	47522	90.549	28.57
3000	25.63	56285	95.920	43.19	12.69	53931	92.430	35.95
3200	28.06	66273	98.610	57.37	13.79	62086	94.628	46.09
3400	30.97	79501	102.001	75.55	15.06	72572	97.283	59.26
3600	34.53	96716	106.278	97.02	16.57	85982	100.535	75.28
3800	38.88	118385	111.558	119.6	18.38	102822	104.504	93.35
4000	44.09	144337	117.805	138.9	20.54	123339	109.251	111.6
4200	50.07	173397	124.743	149.7	23.07	147298	114.726	127.1
4400	56.55	203360	131.850	147.6	25.94	173777	120.725	136.2
4600	63.10	231620	138.509	133.2	29.05	201177	126.890	136.1
4800	69.37	256179	144.249	111.7	32.23	227591	132.794	126.6
5000	75.12	276261	148.887	89.38	35.34	251400	138.075	110.7
5200	80.32	292150	152.495	70.23	38.26	271734	142.539	92.57
5400	85.02	304654	155.267	55.56	40.95	288506	146.169	75.55
5600	89.35	314650	157.413	45.02	43.42	302147	149.065	61.40
5800	93.39	322876	159.112	37.69	45.70	313283	151.369	50.47
6000	97.23	329880	160.496	32.67	47.83	325526	153.222	42.39

continued

T, K	v	i	s	c _p	v	i	s	c _p
<i>p = 20 bar</i>								
2000	4.133	30520	81.116	17.28	2.758	30521	79.442	17.21
2200	4.547	34056	82.774	18.15	3.034	34039	81.096	18.00
2400	4.965	37817	84.352	19.58	3.313	37752	82.662	19.22
2600	5.392	41948	85.894	21.91	3.594	41778	84.182	21.18
2800	5.834	46667	87.471	25.53	3.885	46294	85.705	24.18
3000	6.303	52271	89.146	30.81	4.191	51541	87.293	28.54
3200	6.813	59125	91.011	38.08	4.519	57817	89.017	34.51
3400	7.385	67648	93.164	47.53	4.881	65466	90.954	42.29
3600	8.040	78285	95.705	59.20	5.288	74859	93.190	51.94
3800	8.805	91460	98.731	72.82	5.756	86357	95.803	63.32
4000	9.704	107497	102.316	87.67	6.298	100273	98.863	76.01
4200	10.76	126519	106.491	102.3	6.929	116796	102.413	89.21
4400	11.97	148310	111.211	114.9	7.656	135905	106.452	101.6
4600	13.33	172208	116.340	123.1	8.481	157278	110.917	111.5
4800	14.80	197106	121.644	124.8	9.391	180237	115.670	117.2
5000	16.34	221648	126.836	119.6	10.36	203798	120.512	117.4
5200	17.87	244561	131.649	108.8	11.36	226842	125.215	112.1
5400	19.34	264975	135.898	95.03	12.36	248371	129.576	102.6
5600	20.73	282542	139.512	80.74	13.33	267711	133.458	90.61
5800	22.03	297357	142.514	67.73	14.24	284586	136.806	78.21
6000	23.23	309776	144.980	56.84	15.10	299059	139.634	66.75
<i>p = 40 bar</i>								
1500					1.245	22248	72.586	16.01
1600					1.328	23860	73.626	16.22
1700					1.410	25493	74.615	16.44
1800					1.493	27148	75.560	16.67
1900					1.575	28827	76.465	16.91
2000	2.070	30525	78.256	17.18	1.658	30531	77.335	17.16
2200	2.277	34032	79.906	17.91	1.823	34030	78.984	17.85
2400	2.485	37716	81.466	19.07	1.989	37695	80.539	18.87
2600	2.696	41680	82.970	20.74	2.158	41616	82.033	20.45
2800	2.913	46075	84.465	23.37	2.330	45928	83.508	22.83
3000	3.139	51109	86.002	27.18	2.510	50817	85.011	26.25
3200	3.380	57040	87.643	32.39	2.699	56513	86.597	30.93
3400	3.642	64168	89.457	39.16	2.904	63284	88.327	37.02
3600	3.935	72814	91.513	47.58	3.131	71420	90.264	44.59
3800	4.266	83303	93.883	57.55	3.386	81215	92.471	53.58
4000	4.647	96921	96.631	68.81	3.676	92936	95.008	63.81
4200	5.086	110875	99.801	80.79	4.009	106790	97.917	74.82
4400	5.592	128224	103.409	92.56	4.391	122873	101.222	85.94
4600	6.168	147800	107.424	102.8	4.824	141103	104.910	96.12
4800	6.807	169160	111.759	110.1	5.308	161176	108.923	104.1
5000	7.499	191576	116.271	113.2	5.839	182537	113.154	108.8
5200	8.228	214122	120.777	111.4	6.403	204421	117.454	109.3

continued

<i>T</i> , K	<i>v</i>	<i>i</i>	<i>s</i>	<i>c_p</i>	<i>v</i>	<i>i</i>	<i>s</i>	<i>c_p</i>
5400	8.970	235852	125.088	105.2	6.986	225977	121.663	105.6
5600	9.703	255987	129.051	95.76	7.571	246418	125.622	98.35
5800	10.41	274050	132.572	84.76	8.145	265167	129.222	88.90
6000	11.08	289887	135.621	73.69	8.696	281922	132.405	78.63
<i>p</i> = 60 bar					<i>p</i> = 70 bar			
2000	1.383	30537	76.583	17.15	1.186	30544	75.947	17.14
2200	1.520	34031	78.231	17.81	1.304	34033	77.594	17.77
2400	1.659	37682	79.782	18.76	1.423	37673	79.143	18.68
2600	1.799	41571	81.269	20.23	1.542	41538	80.625	20.06
2800	1.942	45822	82.730	22.42	1.665	45741	82.075	22.11
3000	2.090	50603	84.209	25.57	1.792	50439	83.534	25.04
3200	2.247	56126	85.755	29.86	1.924	55827	85.049	29.03
3400	2.414	62634	87.423	35.44	2.066	62130	86.671	34.21
3600	2.599	70393	89.273	42.38	2.221	69596	88.454	40.65
3800	2.805	79673	91.361	50.64	2.394	78475	90.451	48.34
4000	3.038	90726	93.743	60.06	2.587	89006	92.713	57.14
4200	3.304	103754	96.460	70.32	2.807	101385	95.281	66.77
4400	3.607	118871	99.539	80.83	3.057	115735	98.183	76.76
4600	3.952	136049	102.976	90.77	3.341	132061	101.422	86.39
4800	4.337	155071	106.734	99.09	3.659	150208	104.971	94.79
5000	4.762	175503	110.729	104.7	4.009	169829	108.766	100.9
5200	5.217	196700	114.842	106.7	4.389	190388	112.708	104.0
5400	5.693	217932	118.927	104.9	4.788	211213	116.671	103.6
5600	6.177	238416	122.842	99.46	5.197	231596	120.521	99.70
5800	6.656	257543	126.467	91.49	5.607	250909	124.141	93.06
6000	7.122	274921	129.730	82.16	6.009	268703	127.446	84.70
<i>p</i> = 80 bar					<i>p</i> = 90 bar			
2000	1.039	30552	75.397	17.13	0.9244	30559	74.911	17.12
2200	1.142	34037	77.043	17.75	1.015	34042	76.556	17.78
2400	1.246	37668	78.589	18.61	1.108	37665	78.102	18.56
2600	1.351	41513	80.067	19.92	1.201	41493	79.575	19.81
2800	1.457	45678	81.508	21.85	1.296	45627	81.010	21.64
3000	1.568	50309	82.953	24.61	1.394	50203	82.442	24.26
3200	1.683	55588	84.443	28.36	1.495	55391	83.912	27.80
3400	1.806	61726	86.028	33.22	1.604	61393	85.466	32.40
3600	1.939	68955	87.757	39.27	1.721	68425	87.152	38.11
3800	2.087	77510	89.681	46.48	1.850	76712	89.016	44.94
4000	2.252	87618	91.848	54.76	1.993	86469	91.104	52.78
4200	2.439	99470	94.296	63.87	2.155	97880	93.453	61.44
4400	2.651	113191	97.055	73.39	2.358	111075	96.093	70.55
4600	2.891	128811	100.131	82.72	2.545	126096	99.034	79.60
4800	3.159	146216	103.507	91.10	2.777	142864	102.263	87.89
5000	3.457	165127	107.131	97.62	3.034	161148	105.739	94.62
5200	3.779	185084	110.921	101.4	3.313	180552	109.392	98.99
5400	4.121	205493	114.765	102.1	3.610	200546	113.125	100.4

continued

T, K	v	i	s	c _p	v	i	s	c _p
5600	4.474	225693	118.542	99.41	3.920	220518	116.826	98.78
5800	4.831	245067	122.137	93.93	4.235	239871	120.385	94.33
6000	5.184	263134	125.461	86.50	4.549	258108	123.711	87.77
<i>p = 100 bar</i>					<i>p = 150 bar</i>			
1500	0.6267	22292	69.730	16.01	0.4205	22336	68.060	16.01
1600	0.6679	23903	70.769	16.22	0.4479	23947	69.099	16.22
1700	0.7091	25536	71.759	16.43	0.4754	25580	70.089	16.43
1800	0.7503	27190	72.703	16.65	0.5028	27233	71.033	16.65
1900	0.7915	28867	73.608	16.88	0.5303	28909	71.938	16.87
2000	0.8328	30567	74.477	17.10				
2200	0.9153	34047	76.122	17.70				
2400	0.9982	37664	77.665	18.51				
2600	1.082	41479	79.136	19.71				
2800	1.167	45585	80.565	21.46				
3000	1.254	50114	81.986	23.96	0.8376	49827	80.244	22.94
3200	1.346	55226	83.440	27.33	0.8972	54681	81.642	25.73
3400	1.442	61112	84.968	31.70	0.9599	60174	83.086	29.34
3600	1.546	67978	86.617	37.14	1.027	66476	84.612	33.83
3800	1.661	76038	88.431	43.63	1.099	73763	86.258	39.19
4000	1.788	85496	90.452	51.11	1.178	82206	88.059	45.38
4200	1.930	96533	92.719	59.38	1.266	91961	90.047	52.28
4400	2.091	109278	95.258	68.13	1.364	103153	92.248	59.71
4600	2.272	123785	98.083	76.90	1.473	115857	94.677	67.35
4800	2.475	139998	101.186	85.07	1.595	130081	97.339	74.83
5000	2.700	157724	104.533	91.91	1.730	145743	100.221	81.63
5200	2.945	176622	108.064	96.67	1.879	162652	103.293	87.22
5400	3.208	196213	111.693	98.77	2.039	180514	106.504	91.08
5600	3.483	215934	115.317	97.96	2.210	198940	109.786	92.80
5800	3.764	235211	118.833	94.39	2.388	217481	113.062	92.23
6000	4.045	253542	122.150	88.63	2.571	235686	116.254	89.49
<i>p = 200 bar</i>					<i>p = 300 bar</i>			
1500	0.3174	22380	66.876	16.01	0.2142	22467	65.208	16.00
1600	0.3379	23991	67.915	16.22	0.2279	24078	66.248	16.22
1700	0.3585	25623	68.905	16.43	0.2416	25710	67.237	16.43
1800	0.3791	27277	69.849	16.64	0.2553	27363	68.181	16.64
1900	0.3997	28952	70.753	16.86	0.2691	29038	69.085	16.85
2000	0.4203	30649	71.622	17.08	0.2828	30734	69.953	17.06
2200	0.4615	34116	73.263	17.60	0.3102	34194	71.594	17.55
2400	0.5028	37698	74.800	19.26	0.3377	37761	73.127	18.15
2600	0.5445	41377	76.254	19.19	0.3654	41467	74.575	18.95
2800	0.5866	45399	77.652	20.50	0.3933	45364	75.959	20.07
3000	0.6295	49673	79.019	22.33	0.4217	49525	77.303	21.61
3200	0.6738	54372	80.384	24.78	0.4508	54042	78.630	23.65
3400	0.7199	59632	81.778	27.94	0.4809	59024	79.968	26.27
3600	0.7688	65598	83.234	31.85	0.5126	64590	81.342	29.50

continued

<i>T</i> , K	<i>v</i>	<i>i</i>	<i>s</i>	<i>c_p</i>	<i>v</i>	<i>i</i>	<i>s</i>	<i>c_p</i>
3800	0.8213	72422	84.782	36.53	0.5461	70867	82.779	33.37
4000	0.8783	80257	86.456	41.94	0.5822	77978	84.304	37.84
4200	0.9408	89241	88.281	47.99	0.6213	86040	85.940	42.87
4400	1.009	99489	90.282	54.56	0.6639	95156	87.709	48.35
4600	1.087	111083	92.475	61.41	0.7108	105401	89.625	54.15
4800	1.171	124052	94.869	68.25	0.7625	116822	91.696	60.07
5000	1.266	138360	97.459	74.73	0.8194	129421	93.933	65.88
5200	1.369	153893	100.228	80.43	0.8816	143147	96.322	71.30
5400	1.482	170449	103.143	84.90	0.9494	157894	98.849	76.02
5600	1.603	187746	106.158	87.78	1.022	173490	101.488	79.76
5800	1.730	205436	109.214	88.80	1.100	189112	104.204	82.24
6000	1.862	223139	112.248	87.91	1.182	206290	106.955	83.30
<i>p</i> = 400 bar					<i>p</i> = 600 bar			
1500	0.1627	22553	64.027	16.00	0.1110	22725	62.364	16.00
1600	0.1729	24164	65.066	16.22	0.1179	24336	63.404	16.21
1700	0.1832	25797	66.055	16.42	0.1247	25968	64.393	16.42
1800	0.1935	27450	67.000	16.63	0.1315	27621	65.337	16.63
1900	0.1637	29124	67.903	16.84	0.1384	29294	66.240	16.84
2000	0.2140	30819	68.771	17.05	0.1452	30989	67.108	17.04
2200	0.2346	34276	70.411	17.52	0.1589	34441	68.746	17.49
2400	0.2552	37834	71.942	18.08	0.1726	37988	70.275	18.00
2600	0.2759	41520	73.386	18.82	0.1864	41650	71.714	18.65
2800	0.2967	45378	74.762	19.82	0.2002	45463	73.082	19.52
3000	0.3179	49472	76.093	21.18	0.2142	49477	74.396	20.67
3200	0.3396	53879	77.399	22.98	0.2285	53755	75.678	22.18
3400	0.3619	58696	78.703	25.27	0.2431	58375	76.945	24.09
3600	0.3852	64024	80.030	28.10	0.2583	63421	78.217	26.44
3800	0.4097	69973	81.402	31.48	0.2742	68983	79.514	29.24
4000	0.4358	76652	82.841	35.39	0.2909	75148	80.855	32.48
4200	0.4639	84163	84.368	39.79	0.3087	82003	82.255	36.13
4400	0.4945	92597	86.001	44.61	0.3278	89624	83.732	40.13
4600	0.5277	102026	87.755	49.73	0.3484	98073	85.297	44.41
4800	0.5640	112498	89.640	55.01	0.3707	107398	86.960	48.87
5000	0.6039	124029	91.660	60.29	0.3950	117623	88.727	53.39
5200	0.6474	136598	93.814	65.35	0.4213	128749	90.600	57.85
5400	0.6947	150138	96.094	69.96	0.4498	140747	92.577	62.08
5600	0.7457	164536	98.483	73.89	0.4806	153557	94.650	65.94
5800	0.8004	179635	100.958	76.93	0.5136	167086	96.807	69.26
6000	0.8583	195234	103.489	78.88	0.5488	181213	99.031	71.90
<i>p</i> = 800 bar					<i>p</i> = 1000 bar			
1500	0.08521	22894	61.188	16.00	0.06969	23061	60.277	16.00
1600	0.09033	24506	62.227	16.21	0.07378	24673	61.316	16.21
1700	0.09545	26138	63.215	16.42	0.07787	26305	62.305	16.42
1800	0.1006	27790	64.159	16.63	0.08196	27958	63.248	16.63
1900	0.1057	29464	65.062	16.83	0.08605	29631	64.152	16.93

continued

T, K	v	i	s	c _p	v	i	s	c _p
2000	0.1108	31157	65.930	17.03	0.09014	31325	65.018	17.02
2200	0.1210	34607	67.568	17.46	0.09833	34773	66.656	17.45
2400	0.1313	38148	69.095	17.95	0.1065	38309	68.182	17.92
2600	0.1416	41796	70.531	18.55	0.1147	41947	69.616	18.48
2800	0.1520	45581	71.894	19.34	0.1230	45714	70.975	19.21
3000	0.1624	49547	73.199	20.37	0.1313	49647	72.274	20.16
3200	0.1730	53848	74.466	21.70	0.1398	53796	73.531	21.38
3400	0.1839	58251	75.711	23.39	0.1484	58219	74.762	22.91
3600	0.1951	63129	76.952	25.45	0.1573	62982	75.982	24.78
3800	0.2068	68459	78.206	27.91	0.1665	68154	77.207	26.99
4000	0.2190	74319	79.489	30.75	0.1761	73805	78.452	29.56
4200	0.2319	80782	80.817	33.94	0.1862	80001	79.732	32.45
4400	0.2458	87916	82.203	37.45	0.1969	86802	81.057	35.61
4600	0.2604	95777	83.659	41.20	0.2083	94261	82.439	39.01
4800	0.2763	104409	85.192	45.14	0.2205	102417	83.886	42.58
5000	0.2934	113839	86.810	49.17	0.2336	111297	85.404	46.24
5200	0.3119	124074	88.516	53.18	0.2477	120913	86.997	49.92
5400	0.3319	135102	90.310	57.06	0.2629	131259	88.665	53.52
5600	0.3534	146884	92.187	60.71	0.2792	142311	90.407	56.96
5800	0.3765	159366	94.141	64.00	0.2967	154027	92.219	60.15
6000	0.4011	172454	96.162	66.83	0.3153	166347	94.094	62.99

Thermodynamic properties of dissociated hydrogen at different temperatures and pressures: x_2 is mole fraction H₂, M is molecular weight of the mixture, u is sound velocity (m/s), and k adiabatic exponent [8, 9]

T, K	x_2	M	u	k	x_2	M	u	k
$p = 0.1 \text{ bar}$					$p = 1 \text{ bar}$			
1500	0.9999	2.016	2885	1.345			2887	1.347
1600	0.9998	2.016	2970	1.337			2974	1.340
1700	0.9996	2.016	3049	1.326	0.9998	2.016	3057	1.332
1800	0.9988	2.015	3120	1.311	0.9996	2.016	3135	1.323
1900	0.9974	2.013	3182	1.291	0.9992	2.015	3208	1.313
2000	0.9948	2.011	3235	1.266	0.9984	2.014	3276	1.300
2200	0.9824	1.998	3328	1.210	0.9944	2.010	3394	1.266
2400	0.9508	1.966	3439	1.166	0.9841	2.000	3497	1.226
2600	0.8855	1.901	3602	1.141	0.9623	1.978	3606	1.190
2800	0.7723	1.786	3840	1.131	0.9212	1.937	3744	1.166
3000	0.6095	1.622	4170	1.131	0.8539	1.869	3923	1.153
3200	0.4219	1.433	4595	1.137	0.7553	1.769	4155	1.148
3400	0.2538	1.264	5071	1.150	0.6285	1.642	4449	1.150
3600	0.1370	1.146	5527	1.170	0.4860	1.498	4805	1.155
3800	0.0706	1.079	5937	1.204	0.3475	1.358	5206	1.165

continued

<i>T, K</i>	<i>x₂</i>	<i>M</i>	<i>u</i>	<i>k</i>	<i>x₂</i>	<i>M</i>	<i>u</i>	<i>k</i>
4000	0.0364	1.045	6327	1.257	0.2317	1.242	5620	1.179
4200	0.0195	1.028	6728	1.332	0.1471	1.156	6018	1.199
4400	0.0108	1.019	7133	1.417	0.0913	1.100	6389	1.227
4600	0.0063	1.014	7509	1.495	0.0567	1.065	6743	1.266
4800	0.0038	1.012	7833	1.555	0.0357	1.044	7092	1.316
5000	0.0024	1.010	8104	1.596	0.0230	1.031	7442	1.374
5200	0.0016	1.010	8336	1.622	0.0152	1.023	7783	1.434
5400	0.0011	1.009	8539	1.639	0.0103	1.018	8103	1.489
5600	0.0008	1.009	8723	1.649	0.0072	1.015	8392	1.536
5800	0.0005	1.009	8894	1.654	0.0051	1.013	8649	1.572
6000	0.0004	1.008	9055	1.657	0.0037	1.012	8876	1.595
<i>p = 5 bar</i>					<i>p = 10 bar</i>			
1500							2890	1.349
1600							2978	1.342
1700							3062	1.336
1800							3143	1.329
1900					0.9998	2.016	3222	1.322
2000	0.9992	2.015	3290	1.311	0.9994	2.015	3295	1.315
2200	0.9976	2.014	3423	1.289	0.9982	2.014	3432	1.296
2400	0.9928	2.009	3540	1.261	0.9950	2.011	3554	1.272
2600	0.9829	1.999	3648	1.230	0.9879	2.004	3666	1.245
2800	0.9631	1.979	3761	1.202	0.9743	1.990	3777	1.219
3000	0.9316	1.947	3892	1.182	0.9501	1.966	3897	1.197
3200	0.8818	1.897	4050	1.169	0.9148	1.930	4037	1.182
3400	0.8113	1.826	4245	1.163	0.8624	1.877	4204	1.173
3600	0.7201	1.734	4480	1.162	0.7605	1.775	4402	1.169
3800	0.6125	1.625	4761	1.165	0.7059	1.720	4637	1.170
4000	0.4968	1.509	5084	1.172	0.6068	1.620	4910	1.174
4200	0.3838	1.395	5439	1.181	0.5017	1.514	5219	1.180
4400	0.2836	1.294	5811	1.194	0.3991	1.410	5556	1.190
4600	0.2025	1.212	6181	1.210	0.3064	1.317	5969	1.202
4800	0.1414	1.151	6535	1.231	0.2286	1.238	6263	1.217
5000	0.0981	1.107	6874	1.258	0.1672	1.177	6608	1.236
5200	0.0681	1.077	7199	1.291	0.1211	1.130	6939	1.258
5400	0.0478	1.056	7518	1.329	0.0877	1.097	7258	1.286
5600	0.0340	1.042	7832	1.373	0.0638	1.072	7567	1.319
5800	0.0245	1.033	8139	1.418	0.0468	1.055	7870	1.355
6000	0.0180	1.026	8431	1.465	0.0348	1.043	8166	1.397
<i>p = 20 bar</i>					<i>p = 30 bar</i>			
2000	0.9996	2.016	3300	1.318	0.9998	2.016	3304	1.320
2200	0.9988	2.015	3441	1.302	0.9990	2.015	3446	1.305
2400	0.9964	2.012	3568	1.282	0.9970	2.013	3576	1.287
2600	0.9914	2.007	3684	1.258	0.9930	2.009	3694	1.266

continued

<i>T</i> , K	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>
2800	0.9818	1.998	3795	1.234	0.9851	2.001	3807	1.243
3000	0.9652	1.981	3910	1.213	0.9716	1.987	3920	1.222
3200	0.9389	1.954	4037	1.196	0.9499	1.965	4042	1.205
3400	0.9006	1.916	4183	1.185	0.9179	1.933	4179	1.192
3600	0.8481	1.863	4354	1.179	0.8741	1.889	4336	1.185
3800	0.7813	1.796	4552	1.177	0.8170	1.832	4517	1.181
4000	0.7011	1.715	4782	1.178	0.7478	1.762	4725	1.181
4200	0.6111	1.624	5043	1.182	0.6681	1.681	4962	1.184
4400	0.5165	1.529	5335	1.189	0.5813	1.594	5227	1.189
4600	0.4234	1.435	5652	1.198	0.4992	1.504	5518	1.197
4800	0.3373	1.348	5984	1.209	0.4061	1.417	5831	1.207
5000	0.2623	1.272	6322	1.223	0.3272	1.338	6154	1.218
5200	0.2005	1.210	6655	1.239	0.2586	1.269	6482	1.232
5400	0.1516	1.161	6979	1.259	0.2014	1.211	6805	1.249
5600	0.1141	1.123	7292	1.282	0.1556	1.165	7120	1.268
5800	0.0861	1.095	7594	1.309	0.1198	1.129	7424	1.290
6000	0.0654	1.074	7887	1.339	0.0924	1.101	7719	1.311
<i>p</i> = 40 bar					<i>p</i> = 50 bar			
1500							2905	1.355
1600							2992	1.348
1700							3076	1.342
1800							3157	1.336
1900							3239	1.329
2000	0.9998	2.016	3308	1.321	0.9998	2.016	3311	1.323
2200	0.9992	2.015	3451	1.307	0.9992	2.016	3455	1.309
2400	0.9974	2.013	3582	1.290	0.9978	2.014	3586	1.293
2600	0.9940	2.010	3702	1.270	0.9946	2.011	3708	1.274
2800	0.9871	2.003	3815	1.249	0.9885	2.004	3822	1.254
3000	0.9753	1.991	3928	1.229	0.9778	1.994	3934	1.234
3200	0.9564	1.972	4047	1.211	0.9610	1.977	4052	1.217
3400	0.9286	1.944	4179	1.198	0.9359	1.951	4180	1.203
3600	0.8900	1.905	4328	1.190	0.9010	1.916	4324	1.194
3800	0.8396	1.854	4498	1.185	0.8551	1.870	4486	1.189
4000	0.7773	1.792	4692	1.184	0.7982	1.813	4671	1.187
4200	0.7046	1.718	4913	1.186	0.7309	1.745	4881	1.188
4400	0.6242	1.637	5161	1.191	0.6555	1.669	5115	1.192
4600	0.5396	1.552	5434	1.197	0.5749	1.587	5375	1.197
4800	0.4553	1.467	5729	1.206	0.4930	1.505	5656	1.205
5000	0.3756	1.387	6040	1.216	0.4138	1.425	5955	1.215
5200	0.3103	1.321	6359	1.228	0.3407	1.351	6266	1.226
5400	0.2419	1.252	6679	1.243	0.2759	1.286	6580	1.239
5600	0.1905	1.200	6993	1.260	0.2207	1.230	6893	1.255
5800	0.1492	1.158	7299	1.279	0.1753	1.185	7199	1.272
6000	0.1167	1.126	7595	1.298	0.1386	1.148	7496	1.291

continued

<i>T, K</i>	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>
<i>p</i> = 60 bar								
2000	0.9998	2.016	3315	1.324	0.9998	2.016	3318	1.326
2200	0.9992	2.015	3458	1.311	0.9994	2.015	3462	1.312
2400	0.9980	2.014	3591	1.295	0.9980	2.014	3595	1.297
2600	0.9950	2.011	3713	1.277	0.9954	2.011	3717	1.280
2800	0.9895	2.005	3828	1.257	0.9902	2.006	3833	1.261
3000	0.9798	1.996	3941	1.238	0.9812	1.997	3946	1.242
3200	0.9643	1.980	4057	1.221	0.9670	1.983	4061	1.224
3400	0.9412	1.957	4182	1.207	0.9455	1.961	4185	1.211
3600	0.9091	1.924	4322	1.198	0.9155	1.931	4320	1.200
3800	0.8669	1.882	4479	1.192	0.8760	1.891	4474	1.195
4000	0.8139	1.828	4657	1.189	0.8263	1.841	4646	1.192
4200	0.7510	1.765	4857	1.190	0.7671	1.781	4839	1.192
4400	0.6797	1.693	5080	1.193	0.6991	1.713	5056	1.194
4600	0.6027	1.616	5330	1.198	0.6252	1.638	5295	1.199
4800	0.5232	1.535	5600	1.205	0.5481	1.560	5556	1.205
5000	0.4450	1.457	5889	1.214	0.4711	1.483	5836	1.214
5200	0.3714	1.382	6192	1.225	0.3977	1.409	6131	1.224
5400	0.3050	1.315	6500	1.237	0.3302	1.341	6434	1.235
5600	0.2472	1.257	6810	1.251	0.2706	1.281	6740	1.249
5800	0.1985	1.208	7115	1.267	0.2196	1.229	7044	1.264
6000	0.1587	1.168	7413	1.285	0.1771	1.177	7341	1.279
<i>p</i> = 80 bar								
2000	0.9998	2.016	3321	1.327	0.9998	2.016	3324	1.328
2200	0.9994	2.015	3465	1.314	0.9994	2.015	3468	1.315
2400	0.9982	2.014	3598	1.299	0.9984	2.014	3602	1.301
2600	0.9956	2.012	3722	1.282	0.9960	2.012	3726	1.284
2800	0.9908	2.007	3838	1.263	0.9914	2.007	3843	1.266
3000	0.9824	1.998	3951	1.245	0.9833	1.999	3955	1.247
3200	0.9683	1.985	4066	1.228	0.9706	1.986	4070	1.231
3400	0.9489	1.964	4187	1.214	0.9518	1.967	4190	1.216
3600	0.9209	1.936	4321	1.203	0.9251	1.941	4322	1.206
3800	0.8836	1.899	4471	1.197	0.8898	1.905	4468	1.199
4000	0.8365	1.851	4638	1.194	0.8450	1.860	4632	1.196
4200	0.7802	1.794	4825	1.193	0.7913	1.806	4814	1.195
4400	0.7154	1.765	5035	1.195	0.7291	1.743	5018	1.196
4600	0.6441	1.657	5267	1.199	0.6602	1.673	5243	1.200
4800	0.5692	1.582	5520	1.205	0.5873	1.600	5490	1.206
5000	0.4937	1.506	5793	1.213	0.5132	1.525	5755	1.213
5200	0.4206	1.432	6080	1.223	0.4407	1.452	6036	1.222
5400	0.3526	1.363	6378	1.234	0.3726	1.384	6329	1.233
5600	0.2917	1.302	6680	1.247	0.3107	1.321	6628	1.245
5800	0.2388	1.249	6982	1.261	0.2563	1.266	6927	1.259
6000	0.1941	1.204	7278	1.276	0.2098	1.219	7223	1.274

continued

<i>T</i> , K	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>
<i>p</i> = 100 bar								
1500			2923	1.363			2941	1.372
1600			3009	1.356			3027	1.364
1700			3093	1.349			3110	1.356
1800			3174	1.343			3190	1.349
1900			3268	1.336			3283	1.342
2000	0.9998	2.016	3327	1.330				
2200	0.9994	2.015	3472	1.317	0.9996	2.016		
2400	0.9984	2.014	3605	1.302	0.9987	2.014		
2600	0.9962	2.012	3730	1.286	0.9969	2.013		
2800	0.9918	2.008	3847	1.268	0.9934	2.010		
3000	0.9843	2.000	3960	1.250	0.9871	2.003	3978	1.260
3200	0.9722	1.988	4074	1.233	0.9773	1.993	4091	1.244
3400	0.9541	1.970	4193	1.219	0.9623	1.978	4208	1.229
3600	0.9288	1.944	4323	1.208	0.9414	1.957	4332	1.218
3800	0.8950	1.910	4467	1.201	0.9135	1.929	4466	1.210
4000	0.8524	1.867	4627	1.197	0.8776	1.893	4615	1.205
4200	0.8007	1.815	4805	1.196	0.8339	1.849	4779	1.202
4400	0.7408	1.755	5004	1.197	0.7824	1.797	4960	1.202
4600	0.6743	1.688	5224	1.200	0.7241	1.738	5159	1.205
4800	0.6032	1.616	5464	1.206	0.6607	1.674	5378	1.208
5000	0.5305	1.543	5724	1.213	0.5940	1.607	5614	1.214
5200	0.4587	1.470	5999	1.222	0.5263	1.539	5867	1.221
5400	0.3905	1.402	6287	1.232	0.4597	1.471	6134	1.230
5600	0.3280	1.339	6582	1.244	0.3965	1.408	6411	1.240
5800	0.2725	1.283	6878	1.257	0.3381	1.349	6695	1.251
6000	0.2245	1.234	7173	1.271	0.3023	1.313	6981	1.262
<i>p</i> = 200 bar								
1500			2959	1.380			2995	1.396
1600			3044	1.371			3079	1.386
1700			3127	1.363			3160	1.377
1800			3206	1.356			3238	1.369
1900			3299	1.349			3330	1.361
2000	0.9998	2.016	3358	1.342			3388	1.353
2200	0.9996	2.016	3502	1.328	0.9996	2.016	3530	1.339
2400	0.9988	2.015	3636	1.315	0.9990	2.015	3664	1.325
2600	0.9972	2.013	3762	1.300	0.9978	2.014	3791	1.311
2800	0.9942	2.010	3881	1.284	0.9952	2.011	3910	1.295
3000	0.9889	2.005	3995	1.267	0.9908	2.007	4024	1.280
3200	0.9802	1.996	4107	1.252	0.9837	2.000	4135	1.264
3400	0.9673	1.983	4221	1.237	0.9732	1.989	4247	1.250
3600	0.9489	1.961	4342	1.226	0.9581	1.971	4363	1.238
3800	0.9246	1.940	4471	1.217	0.9378	1.953	4486	1.228
4000	0.8930	1.908	4612	1.211	0.9117	1.927	4619	1.221
4200	0.8543	1.869	4767	1.208	0.8790	1.894	4762	1.217

continued

<i>T</i> , K	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>
4400	0.8083	1.823	4938	1.206	0.8403	1.855	4919	1.215
4600	0.7556	1.770	5124	1.208	0.7952	1.810	5090	1.214
4800	0.6978	1.711	5328	1.211	0.7447	1.759	5275	1.216
5000	0.6360	1.649	5549	1.216	0.6900	1.704	5475	1.220
5200	0.5721	1.585	5786	1.222	0.6323	1.645	5691	1.224
5400	0.5080	1.520	6037	1.230	0.5728	1.585	5920	1.230
5600	0.4456	1.457	6300	1.238	0.5135	1.526	6162	1.238
5800	0.3866	1.398	6572	1.248	0.4557	1.467	6414	1.246
6000	0.3323	1.343	6848	1.258	0.4008	1.412	6674	1.254
			<i>p</i> = 400 bar				<i>p</i> = 600 bar	
1500			3030	1.411			3100	1.442
1600			3113	1.401			3179	1.429
1700			3192	1.391			3257	1.417
1800			3269	1.381			3332	1.406
1900			3360	1.373			3435	1.396
2000			3418	1.365			3476	1.387
2200	0.9998	2.016	3558	1.350	0.9998	2.016	3614	1.370
2400	0.9992	2.015	3692	1.335	0.9994	2.015	3745	1.354
2600	0.9980	2.014	3817	1.320	0.9984	2.014	3869	1.339
2800	0.9958	2.012	3936	1.305	0.9966	2.013	3987	1.323
3000	0.9920	2.008	4050	1.289	0.9934	2.009	4099	1.307
3200	0.9859	2.002	4161	1.275	0.9885	2.004	4209	1.292
3400	0.9767	1.993	4272	1.260	0.9808	1.997	4318	1.278
3600	0.9635	1.979	4385	1.248	0.9701	1.986	4428	1.265
3800	0.9459	1.961	4504	1.238	0.9554	1.971	4542	1.254
4000	0.9229	1.938	4631	1.230	0.9363	1.952	4662	1.245
4200	0.8943	1.909	4768	1.224	0.9124	1.928	4789	1.238
4400	0.8598	1.875	4916	1.222	0.8836	1.899	4926	1.234
4600	0.8197	1.834	5076	1.221	0.8498	1.865	5074	1.231
4800	0.7743	1.788	5249	1.221	0.8109	1.825	5232	1.231
5000	0.7246	1.738	5437	1.224	0.7680	1.782	5402	1.232
5200	0.6714	1.685	5638	1.227	0.7213	1.735	5585	1.234
5400	0.6160	1.629	5852	1.232	0.6718	1.685	5779	1.237
5600	0.5597	1.572	6079	1.239	0.6206	1.634	5985	1.242
5800	0.5039	1.516	6316	1.246	0.5688	1.581	6201	1.248
6000	0.4497	1.461	6562	1.253	0.5172	1.529	6426	1.253
			<i>p</i> = 800 bar				<i>p</i> = 1000 bar	
1500			3167	1.471			3233	1.499
1600			3244	1.456			3307	1.483
1700			3319	1.443			3380	1.467
1800			3392	1.430			3452	1.454
1900			3493	1.419			3660	1.441
2000			3533	1.408			3589	1.429

continued

<i>T</i> , K	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>	<i>x</i> ₂	<i>M</i>	<i>u</i>	<i>k</i>
2200	0.9998	2.016	3668	1.389	0.9998	2.016	3721	1.408
2400	0.9994	2.015	3796	1.372	0.9994	2.015	3847	1.389
2600	0.9986	2.015	3919	1.355	0.9988	2.015	3967	1.372
2800	0.9970	2.013	4035	1.339	0.9974	2.013	4082	1.355
3000	0.9944	2.010	4147	1.323	0.9948	2.011	4193	1.338
3200	0.9899	2.006	4255	1.308	0.9910	2.007	4299	1.322
3400	0.9833	1.999	4362	1.293	0.9851	2.001	4404	1.307
3600	0.9739	1.990	4469	1.280	0.9765	1.992	4510	1.293
3800	0.9612	1.977	4580	1.268	0.9650	1.981	4618	1.281
4000	0.9444	1.960	4695	1.258	0.9501	1.966	4730	1.270
4200	0.9236	1.939	4817	1.251	0.9311	1.947	4847	1.262
4400	0.8981	1.913	4947	1.245	0.9080	1.923	4972	1.256
4600	0.8681	1.883	5084	1.242	0.8809	1.896	5105	1.251
4800	0.8337	1.848	5235	1.240	0.8495	1.864	5247	1.248
5000	0.7950	1.809	5394	1.239	0.8141	1.829	5398	1.247
5200	0.7528	1.767	5564	1.240	0.7753	1.790	5559	1.247
5400	0.7078	1.721	5745	1.243	0.7334	1.747	5731	1.249
5600	0.6604	1.674	5937	1.247	0.6892	1.703	5912	1.252
5800	0.6119	1.625	6139	1.251	0.6434	1.657	6102	1.255
6000	0.5630	1.576	6349	1.255	0.5968	1.610	6301	1.258

GSSSD Papers [10] and [11] give the tables of the recommended reference values for the viscosity and the thermal conductivity of both normal hydrogen and parahydrogen in liquid and gaseous state at temperatures between 14 and 1500 K and pressures up to 100 MPa, which are based on the correlation of the experimental results. For calculation of the dynamic viscosity η and the thermal conductivity λ coefficients in the above temperature and pressure ranges, except a small region in the immediate vicinity of the critical point ($32 < T < 34$ K and $21.9 < \rho < 41.7$ kg/m³), the equations (1) and (2) were suggested:

$$\eta(\tau, \omega) = \eta_0(\tau) + \Delta\eta(\tau, \omega), \quad (1)$$

$$\lambda(\tau, \omega) = \lambda_0(\tau) + \Delta\lambda(\tau, \omega) + \Delta\lambda_{cr}(\tau, \omega), \quad (2)$$

where $\tau = \frac{T}{T_{cr}}$, $\omega = \frac{\rho}{\rho_{cr}}$, $T_{cr} = 32.938$ K, $\rho_{cr} = 31.36$ kg/m³.

For calculation of the dynamic viscosity η_0 and thermal conductivity λ_0 coefficients for a dilute gas state the equations (3) and (4) were suggested:

$$\eta_0 = \sum_{i=-3}^4 a_i \tau^{i/2}, \quad (3)$$

$$\lambda_0 = v^\alpha \exp \left[\sum_{i=0}^{10} d_i \left(\frac{v-1}{v+1} \right)^i \right]. \quad (4)$$

Coefficients of the equations (3) and (4) are given below.

For normal hydrogen: $v = T/T_0$; $T_0 = 78.27$ K; $\alpha = 0.5$;

$$\begin{array}{lll}
 a_{-3} = -2.1505 & d_0 = 3.99674 & d_8 = -4.24750 \\
 a_{-2} = 10.727 & d_1 = 0.786042 & d_9 = 0 \\
 a_{-1} = -16.935 & d_2 = 0.585275 & d_{10} = 2.14535 \\
 a_0 = 0 & d_3 = 0.603390 & \\
 a_1 = 22.702 & d_4 = -2.26908 & \\
 a_2 = 2.2123 & d_5 = -1.20513 & \\
 a_3 = 0.34163 & d_6 = 3.49323 & \\
 a_4 = -0.043206 & d_7 = 1.57848 &
 \end{array}$$

For parahydrogen: $\alpha = 0.5$; $T_0 = 144.111$ K

$$\begin{array}{lll}
 a_{-3} = -2.0831 & d_0 = 4.81642 & d_8 = 42.3188 \\
 a_{-2} = 10.452 & d_1 = 0.912427 & d_9 = 0.470625 \\
 a_{-1} = -16.586 & d_2 = -3.11340 & d_{10} = -19.4017 \\
 a_0 = 0 & d_3 = -0.627128 & \\
 a_1 = 22.577 & d_4 = 14.8151 & \\
 a_2 = 2.2893 & d_5 = 0.907146 & \\
 a_3 = 0.32473 & d_6 = -36.0941 & \\
 a_4 = -0.041976 & d_7 = 0 &
 \end{array}$$

In Refs. [10] and [11] the excess viscosity $\Delta\eta$ and excess thermal conductivity $\Delta\lambda$ were represented by the relationships (5) and (6)

$$\Delta\eta(\tau, \omega) = \sum_{j=1}^{12} (b_\eta)_j \frac{\omega^{r_j}}{\tau^{t_j}}, \quad (5)$$

$$\Delta\lambda(\tau, \omega) = \sum_{j=1}^k (b_\lambda)_j \frac{\omega^{r_j}}{\tau^{t_j}}, \quad (6)$$

where $k = 12$ for parahydrogen and $k = 13$ for normal hydrogen. Coefficients of the equations (5) and (6) are given below.

Parameters of the equation for the excess viscosity of normal hydrogen

j	$(b)_j$	$(r)_j$	$(t)_j$
1	-9.22703×10^0	1	0
2	6.41602×10^1	1	1
3	-5.98018×10^1	1	2
4	2.89715×10^0	1	3
5	2.36429×10^1	2	0
6	-2.78870×10^0	3	0
7	-1.10595×10^2	3	1
8	1.11582×10^2	3	2
9	7.18928×10^1	4	1
10	-7.76971×10^1	4	2
11	-1.21827×10^1	5	1
12	1.47193×10^1	5	2

Parameters of the equation for the excess thermal conductivity of normal hydrogen

j	$(b)_j$	$(r)_j$	$(t)_j$
1	3.95603×10^1	1	0
2	-3.93423×10^1	1	1
3	-2.66967×10^1	2	0
4	1.12200×10^2	2	1
5	5.12681×10^1	3	0
6	-1.54657×10^2	3	1
7	1.46117×10^1	3	3
8	-2.39245×10^1	4	0
9	7.50322×10^1	4	1
10	-1.11972×10^1	4	3
11	4.25526×10^0	5	0
12	-1.22109×10^1	5	1
13	2.16582×10^0	5	3

Parameters of the equation for the excess viscosity of parahydrogen

j	$(b)_j$	$(r)_j$	$(t)_j$
1	-6.83664×10^0	1	0
2	4.30481×10^1	1	1
3	-3.59137×10^1	1	2
4	2.17531×10^1	2	0
5	-8.64940×10^1	3	1
6	8.40078×10^1	3	2
7	-3.27213×10^0	4	0
8	6.04973×10^1	4	1
9	-6.22615×10^1	4	2
10	9.91540×10^{-1}	5	0
11	-1.12094×10^1	5	1
12	1.26038×10^1	5	2

Parameters of the equation for the excess thermal conductivity of parahydrogen

j	$(b)_j$	$(r)_j$	$(t)_j$
1	5.75334×10^1	1	1
2	-4.65456×10^1	1	2
3	6.04345×10^1	2	0
4	-6.18123×10^1	2	1
5	7.72416×10^1	2	2
6	-2.05857×10^1	3	0
7	-6.21606×10^1	3	1
8	3.80967×10^0	4	0
9	5.49860×10^1	4	1
10	-2.27631×10^1	4	2
11	-1.03228×10^1	5	1
12	6.41638×10^0	5	2

For calculation of anomalous part of the thermal conductivity, within the uncertainty of ~ 30 percent, the equation (7) was used:

$$\Delta\lambda_{cr}(\tau, \omega) = A \exp(-x^2) \quad (7)$$

where $\tau < 1$ at $\tau = 2 - \tau$;

$$\begin{aligned} A &= c_1/(\tau + c_2) + c_3 + c_4\tau, \\ \omega' &= 1 + c_5(\tau - 1)^{1.5}. \end{aligned}$$

$$x = \begin{cases} c_6(\omega - \omega') & \text{at } \omega \geq \omega' \\ c_6(\omega - \omega') + c_7(\omega - \omega')^5 & \text{at } \omega < \omega' \end{cases}$$

where as $\Delta\lambda_{cr} = 0$ if either $A < 0$, or $(\omega - \omega') < 0$.

The coefficients of eq.(7) are as follows:

1) for normal hydrogen:

$$\begin{aligned} c_1 &= 0.507555 & c_5 &= -0.100959 \\ c_2 &= -0.981578 & c_6 &= 1.88149 \\ c_3 &= 2.62904 & c_7 &= 1.76917 \times 10^{-5} \\ c_4 &= -1.56554 \end{aligned}$$

2) for parahydrogen:

$$\begin{aligned} c_1 &= 0.507555 & c_5 &= -0.100959 \\ c_2 &= -0.981578 & c_6 &= 1.88149 \\ c_3 &= 2.62904 & c_7 &= 1.76917 \times 10^{-5} \\ c_4 &= -1.56554 \end{aligned}$$

Viscosity of normal hydrogen at saturation, 10^{-7} Pa· s [11]

$T, \text{ K}$	η'	η''
14	254.6	6.66
15	222.4	6.99
16	197.1	7.30
17	176.8	7.60
18	160.1	7.90
19	146.1	8.20
20	134.2	8.52
21	123.8	8.87
22	114.7	9.25
23	106.6	9.69
24	99.2	10.19
25	92.3	10.78
26	86.0	11.47
27	79.9	12.30
28	74.0	13.30
29	68.2	14.55
30	62.4	16.14
31	56.3	18.29
32	49.2	21.63

Viscosity of normal hydrogen in a monophase region, 10^{-7} Pa·s [11]

<i>T</i> , K	<i>p</i> , MPa				
	DS*	1	2	3	5
15	7.9	234.1	246.5	259.5	
17	9.0	186.4	196.7	207.3	229.3
20	10.6	141.6	149.8	158.0	174.7
30	15.5	65.1	75.1	82.4	94.6
40	20.0	22.1	28.4	40.9	57.7
50	24.0	25.9	29.0	38.1	41.9
60	27.8	29.3	31.5	34.1	39.6
70	31.4	32.6	34.2	36.1	40.2
80	34.8	35.7	36.9	38.4	41.6
100	41.1	41.6	42.4	43.3	45.5
120	47.0	47.3	47.8	48.4	49.9
140	52.5	52.7	53.0	53.4	54.5
160	57.7	57.9	58.1	58.4	59.1
180	62.8	62.8	63.0	63.2	63.8
200	67.6	67.7	67.8	67.9	68.3
250	79.2	79.1	79.1	79.2	79.4
300	90.0	89.9	89.9	89.9	89.9
400	110.0	110.0	109.9	109.9	109.8
500	128.6	128.6	128.5	128.4	123.3
600	146.0	145.9	145.9	145.8	145.7
700	162.4	162.4	162.3	162.2	162.1
800	178.0	177.9	177.9	177.8	177.7
1000	206.8	206.8	206.7	206.7	206.6
1200	232.9	232.8	232.8	232.7	232.7
1500	267.1	267.1	267.0	267.0	266.9
<i>T</i> , K	10	15	20	25	30
17	289.5				
20	218.5	265.2	314.3		
25	155.0	185.9	217.6	249.9	282.9
30	120.5	144.5	168.2	191.9	215.6
40	82.2	101.5	119.0	135.5	151.6
50	61.8	78.6	93.6	107.5	120.6
60	52.6	65.7	78.5	90.6	102.0
70	49.7	59.4	69.7	80.0	90.0
80	49.3	56.9	65.0	73.6	82.2
100	51.1	56.5	62.2	68.2	74.5
120	54.1	58.5	62.9	67.5	72.4

* DS designates a dilute - gas state

continued

<i>T</i> , K	<i>p</i> , MPa				
	10	15	20	25	30
140	57.8	61.4	65.0	68.8	72.8
160	61.7	64.7	67.8	71.0	74.4
180	65.8	68.3	71.0	73.8	76.7
200	69.9	72.0	74.3	76.8	79.4
250	80.3	81.7	83.3	85.1	87.1
300	90.5	91.4	92.6	94.0	95.5
350	100.4	101.0	101.9	102.9	104.1
400	110.0	110.4	111.0	111.8	112.8
500	128.3	128.5	128.8	129.3	129.9
600	145.6	145.7	145.9	146.2	146.5
700	162.0	162.0	162.1	162.2	162.5
800	177.6	177.5	177.5	177.6	177.8
1000	206.4	206.3	206.3	206.3	206.3
1200	232.5	232.4	232.3	232.3	232.3
1500	266.8	266.6	266.5	266.5	266.4
<i>T</i> , K	40	50	60	80	100
25	350.4				
30	263.4	311.7	360.8		
40	182.4	212.1	241.0	297.1	352.7
50	145.1	167.8	189.1	228.1	263.4
60	123.3	142.8	160.7	192.4	219.4
70	109.0	126.5	142.5	170.7	194.1
80	99.0	114.9	129.7	155.8	177.5
100	87.5	100.6	113.1	136.2	156.1
120	82.6	93.2	103.8	124.1	142.5
140	81.1	89.9	98.9	116.6	133.3
160	81.4	88.9	96.6	112.2	127.3
180	82.8	89.3	96.0	109.7	123.4
200	84.8	90.5	96.5	108.7	121.1
250	91.3	95.7	100.3	110.0	119.9
300	98.8	102.4	106.2	114.1	122.3
350	106.8	109.7	112.9	119.6	126.6
400	115.0	117.4	120.1	125.9	132.0
500	131.4	133.2	135.2	139.6	144.3
600	147.6	148.9	150.4	153.8	157.6
700	163.2	164.2	165.3	168.1	171.2
800	178.3	179.0	179.9	182.1	184.7
1000	206.6	207.0	207.5	209.0	210.8
1200	232.4	232.6	232.9	233.9	235.2
1500	266.4	266.5	266.7	267.2	268.1

Overall accuracy of the dynamic viscosity values of normal hydrogen, %

T, K	p, MPa					
	*DS	1	5	10	50	100
15	2.7	10.5				
20	2.2	7.4	6.4	5.4		
30	1.7	3.8	3.1	2.9	3.2	
50	1.5	2.3	2.9	2.7	2.8	4.6
100	1.4	1.5	1.8	2.0	2.3	4.1
300	0.7	0.7	0.8	0.8	1.0	1.4
800	1.6	1.6	1.6	1.6	1.7	1.8
1500	4.4	4.4	4.4	4.4	4.5	4.5

*DS designates a dilute - gas state

Dynamic viscosity of saturated parahydrogen [10]

T, K	η' , 10^{-7} Pa·s	η'' , 10^{-7} Pa·s
14	240.0	6.94
15	210.3	7.36
16	186.8	7.76
17	167.8	8.15
18	152.1	8.54
19	139.0	8.95
20	127.7	9.36
21	118.0	9.81
22	109.5	10.28
23	101.9	10.79
24	95.0	11.36
25	88.7	12.00
26	82.8	12.73
27	77.2	13.57
28	71.8	14.57
29	66.5	15.78
30	61.1	17.31
31	55.4	19.35
32	48.8	22.52

Viscosity of parahydrogen in a monophase region, 10^{-7} Pa·s [10]

T, K	p, MPa				
	DS	1	2	3	5
15	8.0	224.1	238.5	253.5	
17	9.1	178.9	190.7	202.6	227.4
20	10.6	136.0	145.1	154.1	172.4
25	13.2	94.1	101.6	108.6	121.9

continued

<i>T</i> , K	<i>p</i> , MPa				
	DS	1	2	3	5
30	15.6	63.7	73.6	80.9	93.1
40	20.0	22.0	28.2	40.8	57.8
50	24.1	25.6	28.4	32.3	41.6
60	27.9	29.1	30.9	33.2	38.6
70	31.5	32.3	33.7	35.3	39.1
80	34.8	35.5	36.5	37.7	40.7
100	41.1	41.5	42.1	42.9	44.8
120	47.0	47.2	47.6	48.1	49.4
140	52.5	52.7	52.9	53.3	54.2
160	57.8	57.9	58.0	58.3	58.9
180	62.8	62.9	63.0	63.1	63.6
200	67.7	67.7	67.8	67.9	68.2
250	79.2	79.2	79.2	79.2	79.4
300	90.0	90.0	89.9	89.9	90.0
350	100.3	100.2	100.2	100.2	100.2
400	110.1	110.0	110.0	110.0	109.9
500	128.6	128.6	128.5	128.5	128.5
600	146.0	146.0	145.9	145.9	145.8
700	162.6	162.4	162.4	162.3	162.3
800	178.0	178.0	177.9	177.9	177.8
1000	206.9	206.8	206.8	206.7	206.7
1200	232.9	232.9	232.8	232.8	232.7
1500	267.1	267.1	267.1	267.0	267.0
<i>T</i> , K	10	15	20	25	30
17	293.7				
20	219.6	269.1	320.5		
25	153.8	185.8	218.1	251.0	284.2
30	119.1	143.3	167.0	190.7	214.4
40	81.8	100.6	117.7	133.9	149.7
50	62.0	78.4	92.9	106.4	119.2
60	52.6	65.9	78.3	90.0	101.1
70	49.3	59.5	69.7	79.7	89.4
80	48.6	56.8	65.1	73.5	81.9
100	50.3	56.1	62.0	68.1	74.4
120	53.5	58.0	62.7	67.4	72.3
140	57.3	60.9	64.3	68.7	72.7
160	61.4	64.3	67.6	70.9	74.4
180	65.5	68.0	70.8	73.7	76.7
200	69.8	71.8	74.2	76.8	79.4
250	80.3	81.7	83.3	85.2	87.2
300	90.6	91.5	92.7	94.1	95.7
350	100.5	101.2	102.1	103.2	104.4
400	110.1	110.6	111.3	112.1	113.1
500	128.5	128.7	129.1	129.7	130.3
600	145.8	145.9	146.1	146.5	146.9

continued

T, K	p, MPa				
	10	15	20	25	30
700	162.2	162.2	162.4	162.6	162.9
800	177.7	177.7	177.8	177.9	178.2
1000	206.6	206.5	206.5	206.6	206.7
1200	232.6	232.6	232.5	232.5	232.6
1500	266.9	266.8	266.7	266.7	266.7
T, K	40	50	60	80	100
25	352.0				
30	261.9	309.7	358.2		
40	180.2	209.7	238.7	295.3	352.0
50	143.4	166.2	188.0	228.9	267.3
60	122.1	141.7	160.2	194.3	225.4
70	108.0	125.5	142.1	172.7	200.3
80	98.3	114.0	129.1	157.3	183.0
100	87.0	99.8	112.3	136.6	159.4
120	82.3	92.6	103.0	123.7	143.9
140	80.9	89.4	98.1	115.8	133.5
160	81.4	88.6	96.0	111.2	126.7
180	82.8	89.1	95.6	108.9	122.5
200	84.9	90.5	96.2	108.0	120.1
250	91.5	95.9	100.4	109.7	119.1
300	99.1	102.7	106.5	114.1	121.9
350	107.2	110.2	113.3	119.9	126.6
400	115.4	117.9	120.6	126.3	132.2
500	131.9	133.7	135.8	140.2	144.9
600	148.1	149.4	151.0	154.5	158.3
700	163.7	164.7	166.0	168.8	172.0
800	178.8	179.6	180.5	182.8	185.5
1000	207.0	207.5	208.1	209.7	211.6
1200	232.8	233.1	233.5	234.6	236.0
1500	266.8	266.9	267.2	267.8	268.8

Overall accuracy of the dynamic viscosity values of parahydrogen, %

T, K	p, MPa					
	PC	1	5	10	50	100
15	2.9	2.1				
20	2.4	1.6	1.1	1.0		
30	1.9	2.3	1.4	1.2	3.4	
50	1.6	2.6	2.4	1.9	3.9	10.5
100	1.5	1.8	2.3	2.2	1.8	6.9
300	0.7	0.7	0.8	0.9	1.2	1.4
800	1.6	1.6	1.6	1.7	1.8	1.9
1500	4.4	4.4	4.4	4.4	4.5	4.5

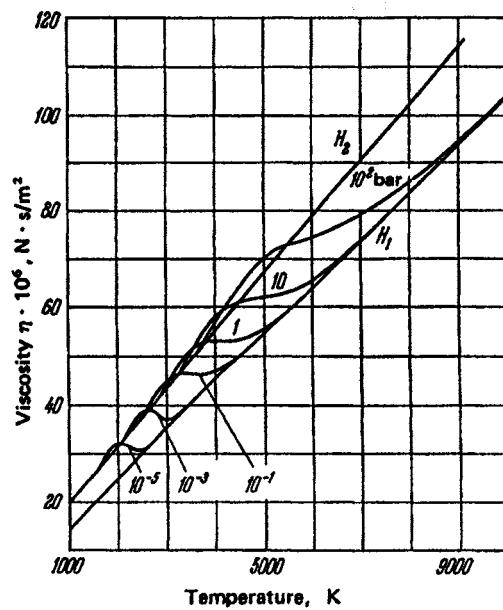


Fig. 4: Viscosity η of dissociated hydrogen
(H_1 is atomic and H_2 is molecular hydrogen).

Viscosity $\eta \cdot 10^8$ (Pa·s) of dissociated hydrogen [13]

p , bar →	10^{-5}	10^{-4}	10^{-3}	10^{-2}	0.1	1	10	100	200
T , K	1997	1997	1997	1997	1997	1997	1997	1997	1997
1000	1997	1997	1997	1997	1997	1997	1997	1997	1997
1200	2262	2262	2262	2262	2262	2262	2262	2262	2262
1400	2507	2507	2507	2507	2507	2507	2507	2507	2507
1600	2740	2738	2737	2737	2737	2737	2737	2737	2737
1800	2988	2972	2965	2962	2962	2961	2961	2961	2961
2000	3215	3227	3200	3188	3183	3182	3181	3181	3181
2200	3123	3459	3475	3441	3425	3419	3417	3417	3417
2400	3038	3413	3728	3721	3682	3665	3659	3657	3657
2600	3172	3308	3770	3995	3957	3919	3904	3899	3898
2800	3359	3365	3423	3762	4207	4234	4180	4154	4150
3000	3565	3576	3675	4131	4497	4474	4421	4398	4395
3200	3773	3777	3813	4073	4636	4756	4690	4651	4645
3400	3973	3974	3988	4112	4642	5008	4966	4906	4896
3600	4164	4165	4171	4229	4601	5189	5245	5168	5152
3800	4348	4348	4351	4379	4604	5271	5514	5437	5415

continued

p , bar → T , K	10^{-5}	10^{-4}	10^{-3}	10^{-2}	0.1	1	10	100	200
4000	4529	4529	4531	4545	4674	5273	5749	5708	5680
4200	4708	4708	4708	4716	4791	5255	5934	5981	5951
4400	4886	4886	4886	4891	4935	5266	6054	6247	6221
4600	5061	5061	5061	5064	5091	5319	6114	6499	6486
4800	5237	5237	5237	5239	5256	5411	6138	6727	6742
5000	5414	5414	5414	5415	5426	5533	6152	6925	6981
5200	5591	5591	5591	5592	5600	5674	6178	7087	7199
5400	5770	5770	5770	5770	5776	5828	6229	7214	7390
5600	5950	5950	5950	5951	5955	5993	6306	7309	7548
5800	6136	6136	6136	6136	6139	6167	6412	7384	7681
6000	6326	6326	6326	6327	6329	6350	6541	7449	7790

Viscosity $\eta \cdot 10^7$ (Pa·s) of ionized hydrogen at high temperatures [14]

p , atm → T , K	0.001	0.01	0.1	1	10	p , atm → T , K	0.001	0.01	0.1	1	10
6000	628	632	633	633	633	19000	14.6	18.0		41.0	170
7000	669	716	729	731	732	20000	16.0	20.0	26.0	44.5	135
8000	489	718	804	825	831	21000	18.0	22.0	28.0	44.6	115
9000	214	537	796	898	925	22000				45.3	103
10000	62.0	273	639	913	1000	23000	22.0	27.0	33.0		96.4
11000	21.4	115.0	402	805	1037	24000				50.8	93.3
12000	10.1	53.0	218	625	1016	25000	26.0	32.0	40.0		93.6
13000	7.5	23.0	111	420	923	26000				58.0	95.1
14000	7.4	15.0	59.0	263	764	27000	32.0	38.0	47.0		97.8
15000	8.6	11.8	36.0	162	594	28000				66.0	96.5
16000			26.9	104	426	29000	37.0	44.0	54.0	71.0	122
17000	11.5	14.0	24.3	72.0	306	30000	39.0	47.0	57.0	76.0	119
18000			24.1	55.6	226						

Thermal conductivity of normal hydrogen at saturation, mW/(m·K) [11]

T , K	λ'	λ''	T , K	λ'	λ''
14	81.1	11.4	24	102.2	19.4
15	86.8	12.1	25	100.7	20.7
16	91.6	12.8	26	98.7	22.2
17	95.5	13.5	27	96.3	24.0
18	98.6	14.2	28	93.5	26.2

continued

<i>T</i> , K	λ'	λ''	<i>T</i> , K	λ'	λ''
19	100.9	14.9	29	90.4	29.0
20	102.5	15.6	30	87.0	32.8
21	103.3	16.4	31	83.7	38.4
22	103.5	17.3	32	82.0	48.8
23	103.1	18.3			

Thermal conductivity of normal hydrogen in a monophase region, mW/(m·K) [11]

<i>T</i> , K	<i>p</i> , MPa							
	DS*	1	2	3	5	10	15	20
15	12.4	86.7	86.8	87.0				
17	14.0	96.4	97.3	98.2	100.1	105.0		
20	16.3	104.7	106.9	109.0	112.8	120.9	127.6	133.2
25	20.3	104.5	109.3	113.5	120.6	134.6	145.4	154.1
30	24.2	89.5	99.3	106.3	117.2	136.9	151.7	163.7
40	31.1	36.1	51.8	74.7	95.5	125.0	145.8	162.7
50	37.4	41.1	47.7	57.1	77.0	109.1	132.3	151.3
60	43.6	46.7	51.1	56.8	69.9	98.3	120.6	139.7
70	49.6	52.3	55.8	59.9	69.3	92.9	113.1	131.0
80	55.7	58.2	61.1	64.3	71.5	90.9	109.0	125.5
100	68.4	70.6	72.8	75.2	80.2	94.0	108.2	122.0
120	81.8	83.7	85.6	87.5	91.5	102.2	113.5	124.9
140	95.3	97.0	98.6	100.3	103.6	112.4	121.6	131.2
160	108.5	110.0	111.5	113.0	115.9	123.3	131.1	139.3
180	121.3	122.6	124.0	125.3	127.9	134.4	141.2	148.2
200	133.5	134.7	136.0	137.2	139.5	145.3	151.3	157.5
250	161.6	162.7	163.7	164.7	166.6	171.2	175.8	180.6
300	186.8	187.7	188.6	189.4	191.1	195.0	198.8	202.7
350	209.8	210.6	211.4	212.1	213.6	217.0	220.2	223.5
400	231.2	231.9	232.6	233.2	234.5	237.5	240.4	243.3
500	270.6	271.2	271.7	272.3	273.3	275.8	278.2	280.5
600	307.6	308.0	308.5	309.0	309.8	312.0	314.0	315.9
700	343.4	343.8	344.2	344.6	345.4	347.2	349.0	350.7
800	378.9	379.2	379.6	379.9	380.6	382.3	383.9	385.4
1000	450.0	450.2	450.5	450.8	451.4	452.7	454.0	455.3
1200	521.7	521.9	522.2	522.4	522.9	524.0	525.1	526.2
1500	629.9	630.1	630.3	630.5	630.9	631.8	632.7	633.6

*DS designates a dilute - gas state

continued

T, K	p, MPa						
	25	30	40	50	60	80	100
15							
17							
20							
25	161.2	167.1	175.6				
30	173.7	182.2	195.4	204.8	211.1		
40	177.1	189.8	211.2	228.4	242.5	263.0	275.9
50	167.9	182.7	208.6	230.9	250.3	282.3	307.3
60	156.6	171.9	199.5	223.9	246.0	284.9	318.0
70	147.2	162.2	189.5	214.3	237.3	279.2	316.9
80	140.7	154.9	181.0	205.1	227.9	270.4	310.0
100	135.1	147.4	170.6	192.3	213.1	253.0	291.8
120	136.0	146.8	167.3	186.6	205.1	241.0	276.4
140	140.8	150.2	168.4	185.7	202.4	234.5	266.3
160	147.6	155.9	172.1	187.8	202.9	232.0	260.6
180	155.5	162.8	177.4	191.7	205.5	232.2	258.2
200	163.9	170.4	183.6	196.7	209.4	234.0	257.9
250	185.5	190.6	201.0	211.6	222.1	242.8	262.8
300	206.6	210.7	219.2	228.0	236.9	254.6	271.9
350	226.8	230.2	237.3	244.7	252.3	267.7	283.0
400	246.1	249.1	255.1	261.5	268.0	281.5	295.1
500	282.8	285.1	289.8	294.7	299.7	310.4	321.3
600	317.9	319.8	323.6	327.6	331.7	340.3	349.4
700	352.4	354.0	357.3	360.6	364.1	371.3	378.9
800	386.8	388.3	391.2	394.1	397.0	403.2	409.7
1000	456.5	457.7	460.0	462.3	464.7	469.4	474.5
1200	527.2	528.2	530.2	532.2	534.1	538.0	542.1
1500	634.5	635.3	636.9	638.5	640.1	643.2	646.3

Overall accuracy of the thermal conductivity values of normal hydrogen, %

T, K	p, MPa					
	DS*	1	5	10	50	100
15	3.9	7.1				
20	3.0	2.0	1.9	2.1		
30	2.4	2.5	1.7	1.9	6.8	
50	2.1	2.5	2.6	2.6	5.9	9.1
100	2.0	2.1	2.2	2.3	3.0	4.8
300	1.5	1.5	1.6	1.6	1.7	2.1
800	2.2	2.2	2.2	2.3	2.3	2.4
1500	5.1	5.1	5.1	5.1	5.2	5.2

* DS designates a dilute - gas state

Thermal conductivity of parahydrogen at saturation, mW/(m·K) [10]

T , K	λ'	λ''	T , K	λ'	λ''
14	75.9	10.96	24	100.9	20.05
15	82.6	11.69	25	99.7	21.58
16	88.0	12.40	26	98.1	23.35
17	92.3	13.13	27	96.1	25.43
18	95.7	13.89	28	93.6	27.92
19	98.3	14.69	29	90.8	30.97
20	100.1	15.55	30	87.7	34.90
21	101.2	16.49	31	84.5	40.45
22	101.6	17.54	32	82.5	50.35
23	101.5	18.72			

Thermal conductivity of parahydrogen in a monophase region, mW/(m·K) [10]

T , K	p , MPa							
	DS*	1	2	3	5	10	15	20
15	12.3	83.0	83.6	84.5				
17	14.0	93.4	94.6	95.9	98.9	108.1		
20	16.5	102.1	104.2	106.3	110.5	121.1	131.8	142.6
25	20.4	102.9	107.1	110.8	117.4	131.7	144.1	155.3
30	24.1	89.9	98.4	104.5	114.3	132.9	147.8	160.7
40	31.0	37.6	53.6	74.5	94.0	121.5	141.3	157.7
50	37.5	41.9	49.0	58.4	76.6	106.6	128.7	147.0
60	44.2	47.4	52.1	58.0	70.7	97.2	118.4	136.8
70	51.8	54.2	57.7	61.9	71.4	93.9	113.1	130.3
80	60.4	62.3	65.1	68.3	75.9	95.2	112.4	128.0
100	80.3	81.6	83.4	85.6	90.8	105.4	119.5	132.8
120	101.2	102.2	103.5	105.1	108.9	120.3	132.1	143.6
140	120.1	120.8	121.8	123.0	126.0	135.1	145.1	155.1
160	135.4	135.9	136.7	137.7	140.0	147.5	156.1	164.8
180	147.2	147.7	148.3	149.1	151.0	157.3	164.6	172.4
200	156.6	156.9	157.5	158.1	159.7	165.0	171.4	178.3
250	175.2	175.5	175.8	176.3	177.4	181.1	185.7	190.9
300	193.3	193.4	193.7	194.0	194.8	197.5	201.1	205.2
350	212.5	212.7	212.8	213.1	213.7	215.8	218.6	221.8
400	232.5	232.6	232.7	232.9	233.4	235.0	237.3	240.0
500	271.8	271.9	272.0	272.1	272.4	273.6	275.1	277.0
600	309.1	309.2	309.2	309.3	309.5	310.4	311.5	312.9
700	344.9	344.9	345.0	345.0	345.2	345.8	346.7	347.8
800	380.0	380.0	380.1	380.1	380.3	380.7	381.4	382.3
1000	450.0	450.1	450.1	450.1	450.2	450.5	451.0	451.5
1200	519.6	519.6	519.6	519.6	519.7	519.9	520.2	520.7
1500	619.7	619.7	619.7	619.7	619.8	619.9	620.1	620.4

* DS designates a dilute - gas state

continued

T, K	p, MPa						
	25	30	40	50	60	80	100
15							
17							
20							
25	165.6	175.3	192.8				
30	172.2	182.5	200.3	215.3	228.1		
40	171.9	184.5	206.0	223.6	238.1	259.7	273.8
50	163.0	177.3	202.0	222.7	240.0	266.8	285.1
60	153.2	168.1	194.4	216.9	236.4	267.9	291.0
70	146.1	160.7	187.0	210.3	231.0	265.6	292.7
80	142.7	156.5	182.0	205.0	226.0	262.3	291.9
100	145.2	157.2	179.9	201.1	221.0	257.3	289.0
120	154.5	164.9	184.9	204.0	222.1	256.1	287.2
140	164.8	174.1	192.0	209.1	225.6	256.8	286.1
160	173.5	182.0	198.2	213.7	228.7	257.4	284.6
180	180.2	187.8	202.7	217.0	230.8	257.2	282.5
200	185.3	192.3	206.1	219.3	232.1	256.6	280.1
250	196.5	202.1	213.5	224.6	235.5	256.5	276.5
300	209.6	214.2	223.7	233.3	242.8	261.1	278.8
350	225.5	229.3	237.4	245.7	254.0	270.3	286.1
400	243.0	246.2	253.1	260.4	267.8	282.4	296.7
500	279.2	281.6	286.8	292.4	298.3	310.3	322.3
600	314.5	316.4	320.4	324.9	329.7	339.7	349.9
700	349.0	350.5	353.7	357.4	361.3	369.8	378.5
800	383.3	384.5	387.1	390.1	393.5	400.6	408.3
1000	452.2	453.0	454.9	457.1	459.5	464.9	470.8
1200	521.2	521.8	523.1	524.8	526.6	530.8	535.4
1500	620.7	621.1	622.1	623.2	624.5	627.5	630.9

Overall accuracy of the thermal conductivity values of parahydrogen, %

T, K	p, MPa					
	DS*	1	5	10	50	100
15	4.0	2.9				
20	3.4	1.7	1.6	1.9		
30	2.6	2.7	1.5	1.7	4.0	
50	2.2	3.3	2.9	2.3	4.2	5.8
100	1.8	2.1	2.2	2.0	2.6	5.9
300	1.0	1.0	1.1	1.1	1.3	1.8
800	2.1	2.1	2.1	2.1	2.2	2.3
1500	5.2	5.2	5.2	5.2	5.2	5.2

* DS designates a dilute - gas state

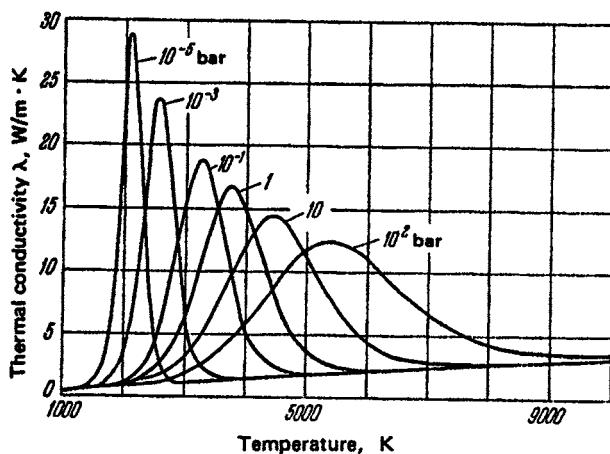


Fig. 5: Thermal conductivity of dissociated hydrogen as a function of temperature with pressure as a parameter.

Thermal conductivity λ (W/(m·K)) of dissociated hydrogen [13]

p , bar →	10^{-5}	10^{-4}	10^{-3}	10^{-2}	0.1	1	10	100	200
T , K	0.7222	0.6304	0.6013	0.5921	0.5892	0.5883	0.5880	0.5879	0.5879
1400	1.951	1.071	0.7910	0.7021	0.6739	0.6650	0.6622	0.6613	0.6612
1600	7.848	3.080	1.485	0.9724	0.8095	0.7578	0.7415	0.7363	0.7356
1800	23.07	9.687	3.795	1.770	1.114	0.9050	0.8387	0.8178	0.8149
2000	24.72	22.12	9.589	3.834	1.838	1.190	0.9829	0.9174	0.9085
2200	7.330	23.93	19.07	8.149	3.381	1.745	1.215	1.047	1.024
2400	2.154	9.991	23.51	14.87	6.203	2.755	1.597	1.224	1.173
2600	1.285	3.347	14.80	20.75	10.49	4.418	2.203	1.474	1.374
2800	1.165	1.711	6.255	19.43	15.49	6.871	3.115	1.827	1.649
3000	1.186	1.349	2.890	12.12	18.78	10.02	4.396	2.311	2.018
3200	1.235	1.291	1.837	6.269	17.72	13.40	6.067	2.951	2.500
3400	1.291	1.312	1.523	3.456	13.09	16.00	8.077	3.763	3.110
3600	1.346	1.355	1.444	2.301	8.326	16.68	10.26	4.747	3.853
3800	1.402	1.406	1.447	1.847	5.185	15.05	12.31	5.887	4.725
4000	1.457	1.459	1.479	1.677	3.477	11.99	13.87	7.145	5.712
4200	1.512	1.513	1.523	1.627	2.612	8.849	14.56	8.461	6.785
4400	1.566	1.567	1.572	1.630	2.186	6.387	14.22	9.748	7.902
4600	1.620	1.621	1.624	1.657	1.983	4.715	12.97	10.89	8.996
4800	1.675	1.675	1.677	1.697	1.895	3.663	11.19	11.80	10.01
5000	1.730	1.730	1.731	1.744	1.868	3.022	9.297	12.38	10.87
5200	1.785	1.785	1.786	1.794	1.875	2.642	7.596	12.57	11.52
5400	1.841	1.841	1.842	1.847	1.901	2.421	6.214	12.37	11.90
5600	1.898	1.898	1.899	1.903	1.939	2.300	5.158	11.84	12.01
5800	1.957	1.957	1.958	1.960	1.986	2.241	4.384	11.05	11.83

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