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**A BIBLIOGRAPHY OF THERMOPHYSICAL  
PROPERTIES OF ARGON FROM 0 TO 300°K**

L. A. HALL, J. G. HUST, AND A. L. GOSMAN



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U. S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS

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\* NBS Group, Joint Institute for Laboratory Astrophysics at the University of Colorado.

\*\* Located at Boulder, Colorado.

# NATIONAL BUREAU OF STANDARDS

## *Technical Note 217*

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### A BIBLIOGRAPHY OF THERMOPHYSICAL PROPERTIES OF ARGON FROM 0 TO 300°K

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A BIBLIOGRAPHY OF THERMOPHYSICAL PROPERTIES OF ARGON  
FROM 0 TO 300°K<sup>1</sup>

L. A. Hall, J. G. Hust, and A. L. Gosman

A bibliography of 450 references is presented for mechanical, thermodynamic, and transport properties of argon from 0 to 300°K. Each article has been reviewed and coded with regard to properties studied, type of article (i.e., experimental, theoretical, etc.), and method of presentation of the data. The temperature and pressure ranges for each property under consideration are also given. An index was prepared according to property with 4 sub-categories: solid, liquid, gas up to 200°K, and gas above 200°K.

1. INTRODUCTION

The Compilation Unit of the Cryogenic Data Center has in its mission the critical evaluation of quantitative information from the world's literature related to the thermophysical properties of materials at cryogenic temperatures. At the outset of the study of a particular material, copies of the documents concerned with the properties are obtained and reviewed. As the task of document accumulation continues, a concerted effort is made to complete a systematic and thorough literature search on the selected topic. For argon, the collection of documents began over five years ago in conjunction with the data compilation presented in the "Compendium".<sup>2</sup> This bibliography on the properties of argon is the publication of the results, which provides a methodical organization of the literature on argon.

The initial literature search was conducted by the use of various abstracting journals, and in particular of Chemical Abstracts. Copies of each of the pertinent documents were obtained, and each document was reviewed and coded. In addition, all pertinent articles, which were referenced in these documents, were also obtained, reviewed, and coded. The search of Chemical Abstracts has been periodically up-dated.

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<sup>1</sup> This bibliography is a result of a study made under contract with the National Aeronautics and Space Administration.

<sup>2</sup> A Compendium of the Properties of Materials at Low Temperature (Phase I.) Part I. Properties of Fluids, V. J. Johnson, editor, Wright Air Development Division Tech. Rept. 60-56 (1960) 560 p.

## 2. FORMAT FOR LISTING CITATION AND DOCUMENT CONTENTS

The citations have been arranged alphabetically by first author and numbered. Late additions were inserted in alphabetical sequence and given the number of the preceding article followed by an A, B, etc. Only information from the article which concerns the properties of argon was noted in this bibliography.

The information given for each citation includes and is ordered as follows:

1. Author(s)
2. Title (original language) and translated title, if original is in a language other than English
3. Reference (If the same article is published in more than one place, each reference is cited.)
4. Chemical Abstract number or ASTIA number, when they are known
5. Properties studied for argon, state of substance, temperature and pressure ranges as available
6. Substances, other than argon, which are discussed in the article (Where no fluids are listed, the contents of the document are restricted to properties of argon only.)
7. Designation as to primary character of article
  - a. experimental
  - b. theoretical
  - c. compilation<sup>1</sup>
  - d. correlation
  - e. reference book<sup>2</sup>
8. Form in which data is reported
  - a. tabular - tables (number of values)
  - b. graphical
  - c. equations
9. Apparatus, if described or illustrated
10. Original language, if other than English.

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<sup>1</sup> In compilation, the bibliography number of the original article from which the data was obtained is listed.

<sup>2</sup> The amount of data in reference books is not given.



## 3. INDEX OF PROPERTIES

The bibliography is indexed according to property with sub-indexes for the state of the substance; i.e., solid, liquid, gas up to 200°K, and gas above 200°K. The letters E, T, C, and R following each citation number refer to the type of data; i.e., E = experimental, T = theoretical, C = compilation, correlation, calculation, and R = review, discussion, reference work. A few reference books were coded by property only and are designated by \*R following the citation number.

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## PROPERTY INDEX

## 1. DENSITY, P-V-T DATA, COMPRESSIBILITY FACTOR

18 C	19 C	20 E	21 E	24 T	26 T	48 C	49 E	81 C	87 C
88 T	95 E	98*R	101 E	102 C	103 E	104 E	105 R	112 T	126 T
130 E	131 E	134 E	142 R	144 T	146 R	153 C	166A E	167*R	171 T
173 E	174 T	175 E	176 E	177 E	178 C	179 E	180 C	189*R	193 E
204 C	206 E	236 E	237 T	238 R	239 T	244 C	247 C	253 C	255 C
263 E	269 C	274 E	279 C	280 C	285 E	289 C	290 E	293 T	299 C
300 C	307 E	308 E	310 E	311 E	312 T	318 C	322 E	324 C	328 C
329 E	338 E	346 E	350 E	376 R	377 E	384 E	385 E	394 E	396*R
401 C	405 T	413 T	425 T						

## SOLID

95 E	101 E	102 C	103 E	105 R	112 T	193 E	279 C	346 E	350 E
413 T									

## LIQUID

18 C	49 E	87 C	104 E	126 T	153 C	174 T	193 E	238 R	279 C
346 E	376 R	377 E	384 E	385 E	405 T	413 T			

## GAS (UP TO 200 DEGREES K)

24 T	48 C	49 E	87 C	88 T	134 E	144 T	153 C	174 T	175 E
177 E	180 C	193 E	204 C	236 E	237 T	238 R	239 T	244 C	247 C
253 C	289 C	290 E	293 T	322 E	394 E	401 C	413 T		

## GAS (ABOVE 200 DEGREES K)

19 C	20 E	21 E	24 T	26 T	48 C	49 E	81 C	87 C	88 T
130 E	131 E	134 E	153 C	166A E	171 T	173 E	174 T	175 E	176 E
177 E	178 C	179 E	180 C	204 C	206 E	236 E	237 T	239 T	244 C
247 C	253 C	255 C	263 E	269 C	274 E	279 C	285 E	289 C	290 E
293 T	299 C	307 E	308 E	310 E	311 E	322 E	328 C	329 E	338 E
401 C	413 T								

## PROPERTY INDEX (CONT.)

## 2. EQUATION OF STATE, VIRIAL COEFFICIENTS

2 T	22 T	23 T	24 T	25 T	26 T	27 T	31 C	32 T	34 T
55 T	60 E	67 T	80 T	88 T	89A T	92 T	105 R	110 C	147 T
160 T	164 T	165 T	167*R	171 T	172 T	178 C	195 T	197 T	198 T
199 T	204 C	205 E	216 T	231 T	234 T	236 E	250 R	254 T	265 E
274 E	278 R	289 C	290 E	292 T	328 C	334 R	364 T	364A T	365 T
381 E	385 E	394 E	395 T	399 T	402 E	423 T	425 T		

## SOLID

32 T    92 T    105 R    160 T    165 T    198 T    199 T    423 T

## LIQUID

2 T    231 T    236 E    385 E    399 T

## GAS (UP TO 200 DEGREES K)

24 T	25 T	31 C	60 E	67 T	88 T	164 T	178 C	204 C	205 E
234 T	236 E	254 T	289 C	290 E	292 T	334 R	364 T	364A T	365 T
381 E	395 T	399 T							

## GAS (ABOVE 200 DEGREES K)

24 T	25 T	26 T	31 C	34 T	60 E	67 T	88 T	164 T	171 T
172 T	205 E	236 E	250 R	254 T	274 E	289 C	290 E	292 T	334 R
364 T	364A T	365 T	381 E	395 T	399 T	402 E			

## PROPERTY INDEX (CONT.) .

## 3. EXPANSIVITY AND COMPRESSIBILITY

15 E	16 C	28 T	32 T	33 T	89A T	100 E	103 E	105 R	106 T
107 T	147 T	160 T	189*R	218 T	219 T	229 E	232 E	239 T	241 E
265 E	285 E	317B T	322 E	329 E	351 E	356 E	357 E	376 R	377 E
383 E	385 E	386 E	396*R	399 T	413 T	422 T	425 T	426 T	

## SOLID

15 E	16 C	28 T	32 T	33 T	89A T	100 E	103 E	105 R	106 T
160 T	229 E	351 E	356 E	357 E	413 T	422 T			

## LIQUID

15 E	229 E	241 E	376 R	377 E	383 E	385 E	386 E	399 T	413 T
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## GAS (UP TO 200 DEGREES K)

265 E	322 E	399 T	413 T
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## GAS (ABOVE 200 DEGREES K)

232 E	265 E	285 E	322 E	329 E	399 T	413 T
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## 4. VAPOR PRESSURE

## SOLID

41 E	45 E	70 E	85 E	86 E	98*R	99 R	115 R	127 T	133 E
167*R	243 C	279 C	308 E	317A T	362 C	391 T	396*R	414 C	420 C

## LIQUID

39 T	40 E	42 E	45 E	69 E	70 E	82 E	86 E	98*R	99 R
108 T	127 T	133 E	138 R	146 R	147 T	150 T	154 T	167*R	182 E
183 C	235 T	244 C	255 C	279 C	286 E	287 E	308 E	322 E	328 C
362 C	366A R	385 E	395 T	396*R	420 C				

## 5. MELTING PRESSURE

49 E	50 E	75 E	92 T	145 T	229 E	270 E	313 E	319 E	337 E
347 E	348 E								

## PROPERTY INDEX (CONT.)

## 6. SATURATION DENSITY

13 E	35 E	49 E	56 C	83 E	86 E	163 E	229 E	236 E	243 C
256 E	258 E	265 E	317B T	383 E					

## SOLID (SOLID-LIQUID TRANSITION)

49 E	229 E
------	-------

## LIQUID (SOLID-LIQUID TRANSITION)

49 E	229 E	317B T
------	-------	--------

## LIQUID (LIQUID-VAPOR TRANSITION)

13 E	35 E	56 C	83 E	86 E	236 E	243 C	256 E	258 E	265 E
383 E									

## GAS (LIQUID-VAPOR TRANSITION)

83 E	86 E	163 E	236 E	243 C	256 E	258 E	265 E
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## 7. LATENT HEATS

28 T	32 T	49 E	50 E	62 T	72 E	85 E	86 E	98*R	119 E
122 E	125 R	126 T	132 E	133 E	137 E	147 T	152 T	155 T	183 C
189*R	199 T	203 T	204A C	215A T	226 T	229 E	231 T	235 T	236 E
243 C	248 T	255 C	257 E	279 C	300 C	314 T	315 T	316 T	318 C
323*R	328 C	330 T	355 T	363*R	391 T	392 T	420 C		

## FUSION

49 E	50 E	62 T	72 E	98*R	122 E	125 R	132 E	133 E	147 T
183 C	189*R	204A C	215A T	229 E	243 C	255 C	315 T	323*R	363*R

## SUBLIMATION

28 T	32 T	85 E	98*R	189*R	199 T	314 T	316 T	391 T	420 C
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## VAPORIZATION

86 E	98*R	119 E	125 R	126 T	132 E	133 E	137 E	147 T	152 T
155 T	183 C	189*R	203 T	204A C	226 T	231 T	235 T	236 E	243 C
248 T	255 C	257 E	279 C	300 C	318 C	323*R	328 C	330 T	355 T
363*R	392 T	420 C							

## PROPERTY INDEX (CONT.)

## 8. FIXED POINTS

1 T	62 T	70 E	72 E	73 E	74 T	79 C	82 E	83 E	91 T
92 T	98*R	125 R	133 E	137 E	138 R	138A E	146 R	147 T	153 C
159 T	162 R	182 E	183 C	196 C	204 C	215A T	234 T	235 T	236 E
240 T	243 C	255 C	256 E	256A R	265 E	270 E	273 E	279 C	286 E
287 E	295 C	298 R	301 E	302 T	303 T	308 E	318 C	328 C	344 T
358 T	362 C	363*R	395 T	396*R					

## MELTING POINT (NORMAL)

62 T	72 E	73 E	98*R	125 R	159 T	183 C	243 C	255 C	279 C
286 E	303 T	318 C	363*R	395 T	396*R				

## BOILING POINT (NORMAL)

70 E	74 T	98*R	125 R	137 E	138 R	138A E	146 R	183 C	235 T
243 C	255 C	279 C	286 E	287 E	302 T	318 C	328 C	363*R	396*R

## TRIPLE POINT

70 E	72 E	73 E	91 T	92 T	98*R	133 E	137 E	138 R	138A E
146 R	182 E	204 C	256A R	270 E	273 E	279 C	301 E	363*R	396*R

## CRITICAL POINT

1 T	79 C	82 E	83 E	91 T	98*R	125 R	146 R	147 T	153 C
162 R	196 C	207 C	215A T	234 T	236 E	240 T	243 C	255 C	256 E
265 E	279 C	286 E	287 E	295 C	298 R	308 E	318 C	328 C	344 T
358 T	362 C	363*R	395 T						

## PROPERTY INDEX (CONT.)

## 9. SPECIFIC HEAT

4 E	9 C	11 E	18 C	22 T	28 T	45 E	68 E	72 E	89A T
98*R	104 E	105 R	118 E	119 E	120 T	122 E	123 E	125 R	126 T
128 E	132 E	133 E	135 T	143 T	147 T	160 T	166 E	167*R	168 C
178 C	185 C	189*R	193 E	194 E	199 T	212 C	220 T	221 E	224 T
227 E	228 E	233 R	235A E	236 E	238 R	239 T	241 E	255 C	257 E
261A R	266 C	267 C	268 C	269 C	277 C	279 C	281 E	304 T	316 T
317 T	323*R	343 E	361 E	363*R	368 E	369 E	373 T	377 E	383 E
385 E	386 E	394 E	395 T	396*R	399 T	401 C	412 E	413 T	415 E
422 T									

## SOLID

4 E	28 T	45 E	72 E	89A T	105 R	119 E	123 E	128 E	132 E
133 E	135 T	160 T	99 T	277 C	316 T	413 T	415 E	422 T	

## LIQUID

11 E	18 C	45 E	72 E	104 E	119 E	120 T	122 E	125 R	126 T
132 E	133 E	193 E	194 E	212 C	238 R	241 E	257 E	279 C	304 T
317 T	373 T	377 E	383 E	385 E	386 E	394 E	399 T	413 T	

## GAS (UP TO 200 DEGREES K)

11 E	118 E	143 T	166 E	168 C	178 C	193 E	194 E	212 C	220 T
224 T	236 E	238 R	257 E	266 C	279 C	304 T	317 T	394 E	395 T
399 T	413 T								

## GAS (ABOVE 200 DEGREES K)

9 C	68 E	118 E	143 T	166 E	168 C	178 C	185 C	212 C	221 E
224 T	227 E	228 E	235A E	236 E	255 C	261A R	266 C	267 C	268 C
269 C	279 C	281 E	317 T	343 E	361 E	368 E	369 E	399 T	401 C
412 E	413 T								

## PROPERTY INDEX (CONT.)

## 10. VELOCITY OF SOUND

10 T	14 E	15 E	33 T	100 E	104 E	141 E	149 E	151 C	167*R
218 T	219 T	228 E	235A E	236 C	241 E	243 C	266 C	281 E	283 T
352A E	360 E	361 E	376 R	377 E	378 E	379 E	380 E	381 E	383 E
385 E	386 E	390 E	413 T						

## SOLID

15 E	33 T	100 E	149 E	413 T
------	------	-------	-------	-------

## LIQUID

10 T	104 E	141 E	151 C	241 E	283 T	376 R	377 E	378 E	379 E
380 E	383 E	385 E	386 E	390 E	413 T				

## GAS (UP TO 200 DEGREES K)

236 E	266 C	380 E	381 E	413 T
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## GAS (ABOVE 200 DEGREES K)

14 E	228 E	235A E	236 E	243 C	266 C	281 E	352A E	360 E	361 L
380 E	413 T								

## 11. JOULE-THOMSON COEFFICIENTS, INVERSION CURVE

22 T	98*R	135B C	172 T	222 T	223 T	236 E	266 C	269 C	321 E
385 E	401 C								

## LIQUID

385 E
-------

## GAS (UP TO 200 DEGREES K)

135B C	236 E	266 C	321 E
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## GAS (ABOVE 200 DEGREES K)

135B C	172 T	236 E	266 C	269 C	321 E	401 C
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## PROPERTY INDEX (CONT.)

12. ENTROPY, ENTHALPY, INTERNAL ENERGY, FUGACITY,  
GIBB'S FUNCTION, HELMHOLTZ FUNCTION

22 T	28 T	74 T	78 T	89 C	98*R	112 T	143 T	148 T	159 T
167*R	173 E	174 T	185 C	189*R	204A C	224 T	236 E	237 T	238 R
239 T	244 C	247 C	255 C	266 C	267 C	268 C	269 C	316 T	317 T
323*R	363*R	399 T	401 C	413 T	425 T				

## SOLID

28 T	112 T	148 T	316 T	317 T	413 T
------	-------	-------	-------	-------	-------

## LIQUID

174 T	204A C	238 R	317 T	399 T	413 T
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## GAS (UP TO 200 DEGREES K)

78 T	143 T	174 T	224 T	236 E	237 T	238 R	266 C	399 T	413 T
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## GAS (ABOVE 200 DEGREES K)

89 C	143 T	173 E	174 T	185 C	224 T	236 E	237 T	255 C	266 C
267 C	268 C	269 C	399 T	401 C	413 T				

## PROPERTY INDEX (CONT.)

## 13. THERMAL CONDUCTIVITY

3 T	5 T	9 C	52 T	57 E	59 E	65 C	76 T	90 C	97 E
105 R	118 E	121 E	136 R	157 R	167*R	168 C	169 T	184 T	186 E
189*R	200 E	201 E	202 E	212 C	213 E	214 E	215 T	230 E	242 R
243 C	244 C	245 T	249A C	254 T	255 C	261 R	261A R	263 E	271 E
284 C	288 E	295 C	296 C	331 R	332 R	333 E	340 R	341 R	342 E
358 T	359 T	372 E	374 E	393 T	396*R	397 C	398 R	406 E	407 E
408 E	411 E	416 E	418 R	419 E	424 T				

## SOLID

105 R	215 T	230 E	406 E	407 E	408 E
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## LIQUID

5 T	57 E	184 T	186 E	212 C	214 E	242 R	331 R	374 E	419 E
424 T									

## GAS (UP TO 200 DEGREES K)

3 T	52 T	57 E	65 C	76 T	118 E	121 E	136 R	157 R	168 C
169 T	186 E	200 E	212 C	214 E	242 R	244 C	245 T	249A C	254 T
284 C	288 E	295 C	296 C	359 T	374 E	393 T	418 R	419 E	

## GAS (ABOVE 200 DEGREES K)

3 T	9 C	52 T	59 E	65 C	90 C	97 E	118 E	121 E	157 R
168 C	169 T	186 E	200 E	201 E	202 E	212 C	213 E	214 E	242 R
243 C	244 C	245 T	249A C	254 T	255 C	261 R	263 E	271 E	284 C
288 E	295 C	296 C	332 R	333 E	340 R	341 R	342 E	359 T	372 E
393 T	398 R	411 E	416 E						

## PROPERTY INDEX (CONT.)

## 14. VISCOSITY

3 T	5 T	6 T	8 T	9 C	17 R	36 T	43 T	44 E	52 T
53 T	65 C	77 T	79 C	93 T	114 T	118 E	121 E	124 C	125 R
126 T	129 E	129A E	134 E	135A E	157 R	167*R	168 C	169 T	170 T
187 E	189*R	191 E	195 T	196 C	206 E	207 E	208 E	209 E	210 C
211 C	212 C	225 E	240 T	242 R	244 C	249 E	251 R	254 T	255 C
259 T	261 R	264 E	271 E	279 C	282 T	288 E	297 R	309 E	310 E
320 E	325 C	326 C	327 E	335 E	336 E	339 E	345 C	358 T	359 T
366 C	366B T	367 R	382 E	387 E	387A E	388 E	389 E	396*R	400 C
403 T	417 E								

## LIQUID

5 T	6 T	36 T	44 E	124 C	125 R	126 T	135A E	196 C	211 C
212 C	242 R	251 R	259 T	279 C	282 T	320 E	326 C	327 E	366 C
387 E	417 E								

## GAS (UP TO 200 DEGREES K)

3 T	52 T	53 T	65 C	77 T	114 T	118 E	121 E	129 E	129A E
134 E	157 R	168 C	169 T	191 E	195 T	210 C	211 C	212 C	225 E
240 T	242 R	254 T	279 C	288 E	325 C	336 E	345 C	359 T	366 C
382 E	388 E	400 C							

## GAS (ABOVE 200 DEGREES K)

3 T	8 T	9 C	17 R	43 T	52 T	53 T	65 C	77 T	79 C
114 T	118 E	121 E	129 E	129A E	134 E	157 R	168 C	169 T	170 T
187 F	191 E	195 T	206 E	207 E	208 E	209 E	211 C	212 C	225 E
240 T	242 R	244 C	249 E	254 T	255 C	261 R	264 E	271 E	279 C
288 E	297 R	309 E	310 E	325 C	335 E	336 E	339 E	345 C	359 T
366 C	367 R	387A E	388 E	389 E	400 C				

## PROPERTY INDEX (CONT.)

## 15. PRANDTL NUMBER

167\*R 168 C 212 C 271 E

LIQUID

212 C

GAS (UP TO 200 DEGREES K)

168 C 212 C

GAS (ABOVE 200 DEGREES K)

168 C 212 C 271 E

## 16. SELF-DIFFUSION COEFFICIENT

3 T	7 C	9 C	37 E	52 T	66 E	170 T	254 T	259 T	358 T
409 E	410 C								

SOLID

37 E

LIQUID

66 E 259 T

GAS (UP TO 200 DEGREES K)

3 T 52 T 254 T 409 E

GAS (ABOVE 200 DEGREES K)

3 T 7 C 9 C 52 T 254 T 409 E 410 C

## PROPERTY INDEX (CONT.)

## 17. SURFACE TENSION

10 T	13 E	46 T	61 T	84 E	126 T	139 T	147 T	155 T	156 T
156A T	189*R	203 T	217 T	231 T	305 T	318 C	344 T	354 E	405 T

## 18. DIELECTRIC CONSTANT, CLAUSIUS-MOSSOTTI FUNCTION

47 E	51 C	54 E	71 E	92A T	116 E	117 E	158 E	188 E	189*R
190 E	252 C	258A T	260 E	261A R	272 E	275 C	294 E	421 E	

## LIQUID

252 C	260 E
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## GAS (ABOVE 200 DEGREES K)

47 E	54 E	71 E	92A T	116 E	117 E	158 E	188 E	190 E	258A T
272 E	421 E								

## 19. REFRACTIVE INDEX

29 E	58 E	96 E	116 E	117 E	140 E	192 E	261A R	262 E	275 C
306 E	350 E	352 E	365A E	365B T					

## SOLID

192 E	352 E
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## LIQUID

192 E
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## GAS (ABOVE 200 DEGREES K)

29 E	58 E	96 E	116 E	117 E	140 E	262 E	365A E	365B T
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## PROPERTY INDEX (CONT.)

20. LATTICE CHARACTERISTICS  
(CRYSTAL STRUCTURE, LIQUID STRUCTURE, DEBYE TEMPERATURE)

28 T	32 T	33 T	91 T	102 C	105 R	112 T	148 T	161 E	165 T
181 C	199 T	277 C	349 E						

## 21. GRUNEISEN'S PARAMETER

101 E	106 T
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## 22. CORRESPONDING STATES

30 C	33 T	38 T	48 C	65 C	67 T	76 T	77 T	78 T	79 C
87 C	88 T	105 R	109 C	110 C	111 T	111A T	112 T	135B C	147 T
151 C	153 C	154 T	171 T	222 T	236 E	237 T	240 T	245 T	246 T
253 C	270 E	277 C	280 C	289 C	291 T	295 C	300 C	312 T	317A T
317B T	318 C	345 C	366B T	375 C	392 T	423 T			

## 23. INTERMOLECULAR POTENTIAL

12 T	89A T	102 C	170 T	254 T	302 T	303 T	314 T	316 T	353 T
404 T									

## 24. DOCUMENTS NOT APPEARING IN THE CROSS-INDEX

63 E	64 E	94 T	113 E	276 E	370 E	371 T
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UBER DEN KOEFFIZIENTEN DER INNEREN REIBUNG VON REINEM ARGON UND REINEM HELIUM.  
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- 365B. TAUSZ, J. AND GORLACHER, H.  
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- 366A. THODOS, G.  
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 CONSTANT)(P=CONSTANT), SPECIFIC HEAT RATIO, ISOTHERMAL  
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