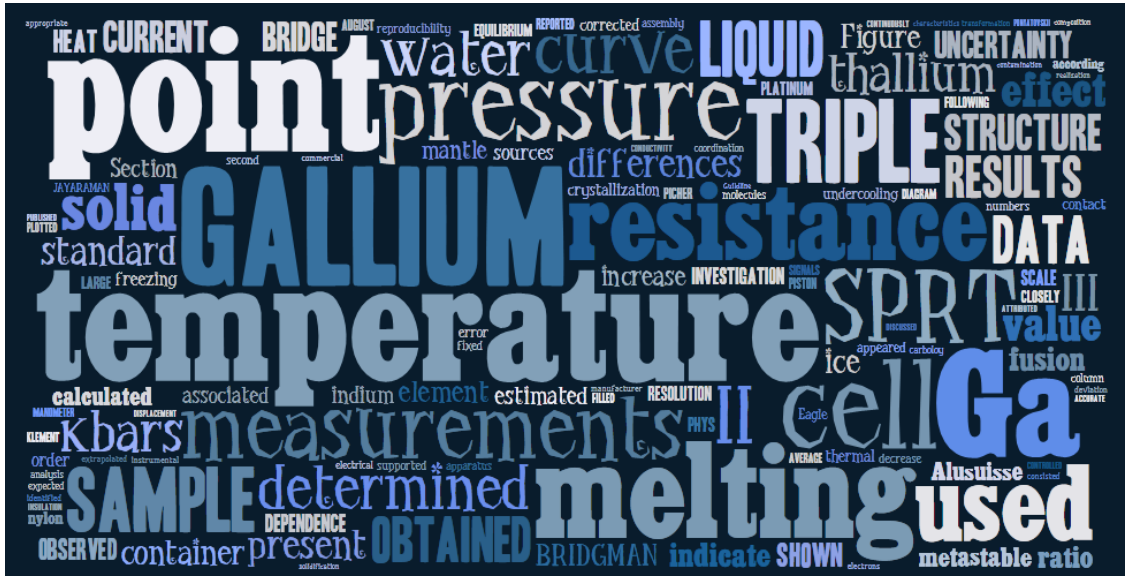
S.Ayrinhac
simon.ayrinhac@upmc.fr

Compilation of thermodynamic and elastic data of liquid Ga



UPMC
SORBONNE UNIVERSITÉS

Table of contents

Physical / chemical properties

- General properties
- Reactivity / corrosion
- Phase diagram
  - solid phases : Ga-I / Ga-II
  - metastable phases
  - Triple point
  - Critical point
  - Melting line at negative pressures

Elastic properties

- Adiabatic sound velocity
- Dispersion curve
- Sound attenuation
- Viscosity

Thermodynamical properties

- Density ρ
- Thermal expansion α_P
- Isobaric heat capacity C_P

Optical properties

- Refractive index (n,k)

Electrical properties

- Electrical resistivity

Physical properties

back to the table of contents

Atomic number	31
Atomic weight	69.72
Density (at 20°C), kg/m^3	5900
Melting point, °C	29.78
Boiling point, °C	2300
Latent heat of melting, J/kg	8.03×10^4
Linear expansion coefficient (at 20°C), °C^{-1}	1.8×10^5
Specific heat (at 0–16°C), J/kg K	0.373×10^3
Thermal conductivity coefficient, W/m K	29.308–37.681
Electrical resistivity, Ohm m	4.5×10^{-7}
Temperature coefficient of electric resistance (at 0–16°C), °C^{-1}	3.96×10^3
Brinell hardness, kg/m^2	2.5×10^6
Compressibility coefficient (at 20°C), m^3/kg	2×10^{-10}
Tensile strength, kg/m^2	$(2.0–3.8) \times 10^6$
Elongation per unit length, %	2–40

Liquid Gallium: Potential Uses as a Heat-Transfer Agent
V. Ya. Prokhorenko *et al*, *High Temperature,*
38*(6) 954-968 (2000)*

T, K	303	350	400	450	505	550	600	650	700
a, m s^{-1}	2874	2864	2855	2841	2827	2816	2801	2767	2774
ρ, kg m^{-3}	6112	6084	6054	6020	5982	5950	5915	5880	5845
$\kappa \times 10^{-4}$, K^{-1}	0.978	0.985	0.991	1.163	1.170	1.176	1.183	1.190	1.198
c_p, J kg^{-1} K^{-1}	367.0	366.5	366.0	365.5	365.0	364.5	364.0	363.5	363.0
$\gamma = c_p/c_v$	1.065	1.076	1.087	1.134	1.151	1.165	1.181	1.197	1.213
c_v, J kg^{-1} K^{-1}	344.6	341.0	337.0	322.0	317.1	312.9	308.2	303.7	299.2
$(c_p-c_v)/c_p$	0.061	0.068	0.079	0.120	0.131	0.142	0.153	0.164	0.176
$\beta_s \times 10^{11}$, m^2 N^{-1}	1.981	2.004	2.026	2.058	2.092	2.119	2.155	2.189	2.223
$\beta_t \times 10^{11}$, m^2 N^{-1}	2.110	2.156	2.202	2.334	2.408	2.469	2.545	2.620	2.696

Liquid Gallium: Potential Uses as a Heat-Transfer Agent
V. Ya. Prokhorenko *et al*, *High Temperature,*
38*(6) 954-968 (2000)*

TABLE I. Physical properties of liquid gallium at 30 °C.

Property	Source	Value
Dynamic viscosity, η	Ref. 30	2.13×10^{-3} N s m^{-2}
Density, ρ	Ref. 30	6.11×10^{3} kg m^{-3}
Heat capacity, c_p	Ref. 30	0.36×10^{3} J kg^{-1} K^{-1}
Thermal conductivity, λ	Ref. 30	28.33 W m^{-1} K^{-1}
Thermal expansion coefficient, β	Ref. 30	1.17×10^{-4} K^{-1}
Kinematic viscosity, ν	$=\eta/\rho$	3.5×10^{-7} m^2/s
Thermal diffusivity, κ	$=\lambda/c_p\rho$	1.29×10^{-5} m^2/s
Prandtl number, Pr	$=\nu/\kappa$	0.027
Temperature coefficient of surface tension $\gamma=\partial\sigma/\partial T$	Ref. 16 $(4\div40\ ^\circ C)$ Ref. 17 $(200\div600\ ^\circ C)$	0.0068 N m^{-1} K^{-1} 0.00606 N m^{-1} K^{-1}
Aspect ratio, A	$=R/H$	10
Relative thickness of the bottom, $\overline{h}$	$=h/H$	0.25
Relative thickness of the wall, $\overline{d}$	$=d/H$	0.25

Experimental and numerical study of anomalous thermocapillary convection in liquid Gallium

Janis Priede, Andreas Cramer, Andris Bojarevics, Alexander Yu. Gelfgat, Pinhas Z. Bar-Yoseph, Alexander L.Yarin, and Gunter Gerbeth

Physics of Fluids **11**, 3331 (1999)

doi: 10.1063/1.870192

TABLE I. Physical constants of gallium.

Temperature (°C)	ρ[a] (g/cm³)	η_s[b] (cP)	c[c] (m/sec)	K[d] (erg/cm·sec·°C) (×10⁷)	β[e] (×10⁴)	C_P[f] (cal/g·°C)
30	6.0947	2.06	2873	0.304	1.2613	0.092264
40	6.0859	1.97	2870	0.314	1.2537	0.092259
50	6.0796	1.90	2867	0.320	1.2460	0.092253
60	6.0715	1.84	2864	0.328	1.2386	0.092248
70	6.0639	1.77	2861	0.336	1.2310	0.092243
80	6.0573	1.71	2858	0.340	1.2235	0.092237

[a] W. H. Hoather, Proc. Phys. Soc. (London) **48,** 706 (1936).
[b] F. Gutman and L. M. Simmons, J. Appl. Phys. **23,** 977–978 (1952).
[c] Technical Report No. 5, Office of Naval Research, Contract Nonr 2577 (01).
[d] L. J. Briggs, J. Chem. Phys. **26,** 786 (1957).
[e] W. H. Hoather, Proc. Phys. Soc. (London) **48,** 705–756 (1936).
[f] N. M. Kochetkova and T. N. Rezukhina, Voprosy Met. i Poluprovod., Akad. Nauk SSSR **34,** 7 (1961).

Ultrasonic Absorption in Liquid Gallium
J. L. HUNTER AND K. S. HOVAN
John Carroll University, Cleveland, Ohio
(1964)

Table 1
Physical properties of liquid and solid gallium

Physical property	Symbol	Units	Value
Liquid gallium			
Density	ρ	kg/m^3	6.095×10^{3}[a,b]
Dynamic viscosity	μ	kg/(m s)	1.96×10^{-3}[a], 1.8×10^{-3}[b]
Kinematic viscosity	$\nu = \mu/\rho$	m^2/s	3.22×10^{-7}[a], 2.95×10^{-7}[b]
Melting temperature	T_f	°C	29.771[b], 29.78[c], 29.76[d]
Boiling temperature	T_e	°C	2203[c], 2204[d]
Thermal expansion coefficient	α	K^{-1}	1.26×10^{-4}[e]
Thermal conductivity	k	W/(m K)	30.6[e] (at 30 °C), 28.68[b] (at 77 °C)
Specific heat	C	(J/kg K)	381.5[b], 397.6[f]
Thermal diffusivity	$\kappa = k/\rho C$	m^2/s	$1.18 \times 10^{-5} \leq \kappa \leq 1.36 \times 10^{-5}$
Prandtl number	Pr	ν/κ	$0.022 \leq Pr \leq 0.027$
Electrical conductivity	σ	$(\mathrm{m}\Omega)^{-1}$	3.87×10^{6}[b], 3.85×10^{6}[c]
Magnetic diffusivity	$\lambda = 1/\mu_0\sigma$	m^2/s	0.21
Magnetic Prandtl number	P_m	ν/λ	$1.4 \times 10^{-6} \leq P_m \leq 1.53 \times 10^{-6}$
Compressional wave velocity	V_P	m/s	2873[h] (at 30 °C), 2860[i] (at 30 °C)
	Crystal axis		
	a	*b*	*c*
Solid gallium, Ga_α			
Length (nm)	0.45186[b]	0.45258[b]	0.76602[b]
Thermal conductivity k (W/(m K))	88.4[b]	40.8[b]	16.0[b]
Electrical conductivity σ $((\mathrm{m}\Omega)^{-1})$	12.3×10^{6}[b]	5.7×10^{6}[b]	1.8×10^{6}[b]
Latent heat of fusion L (kJ/kg)		79.8[b], 80.16[c]	
Compressional wave velocities V_P (m/s)	4080[f], 4151[g]	3860[f], 3948[g]	4760[f], 4823[g]

[a] Spells (1936).
[b] Sabot and Lauvray (1995).
[c] Cubbery (1979).
[d] Lide (1995).
[e] Okada and Ozoe (1992).
[f] Roughton and Nash (1962).
[g] Lyall and Cochran (1971).
[h] Beyer and Ring (1972).
[i] Brito et al. (2001).

Reactivity/corrosion of liquid Ga

↑ back to the table of contents

No reaction	
Alloy-Nb5Mo1Zr	Luebbers (1995)
Cd (?)	Yvon (1979)
Hg (?)	Yvon (1979)
KCl	Leabetter (1969)
Mo	Bove (2005)
polymers	Narh (1998)
refractory metals	Hampel (1961)
Si	{brevet}
Re	Yvon (1979)
Steel – Inconel625	Luebbers (1995)
Ta	Fujinaga (2003)
Teflon	Tsuji (1989)
Ti (up to 450°C)	Jackson (1966)
Ti (up to 570 °C)	Lobova
W (?)	Yvon (1979)

Reaction	
Al	
Au	{Brevet}
Cr	Barbier (1998)
Fe	Barbier (1998)
Fe (0.4um/h@30°C)	Luebbers (1995)
Ni	Barbier (1998)
Ni (2um/h@400°C)	Luebbers (1995)
Pd	
Zn	Barbier (1998)

→ An overview is given by Prokhorenko *et al* (2000)

Phase diagram

back to the table of contents

Jayaraman *et al* (1963)

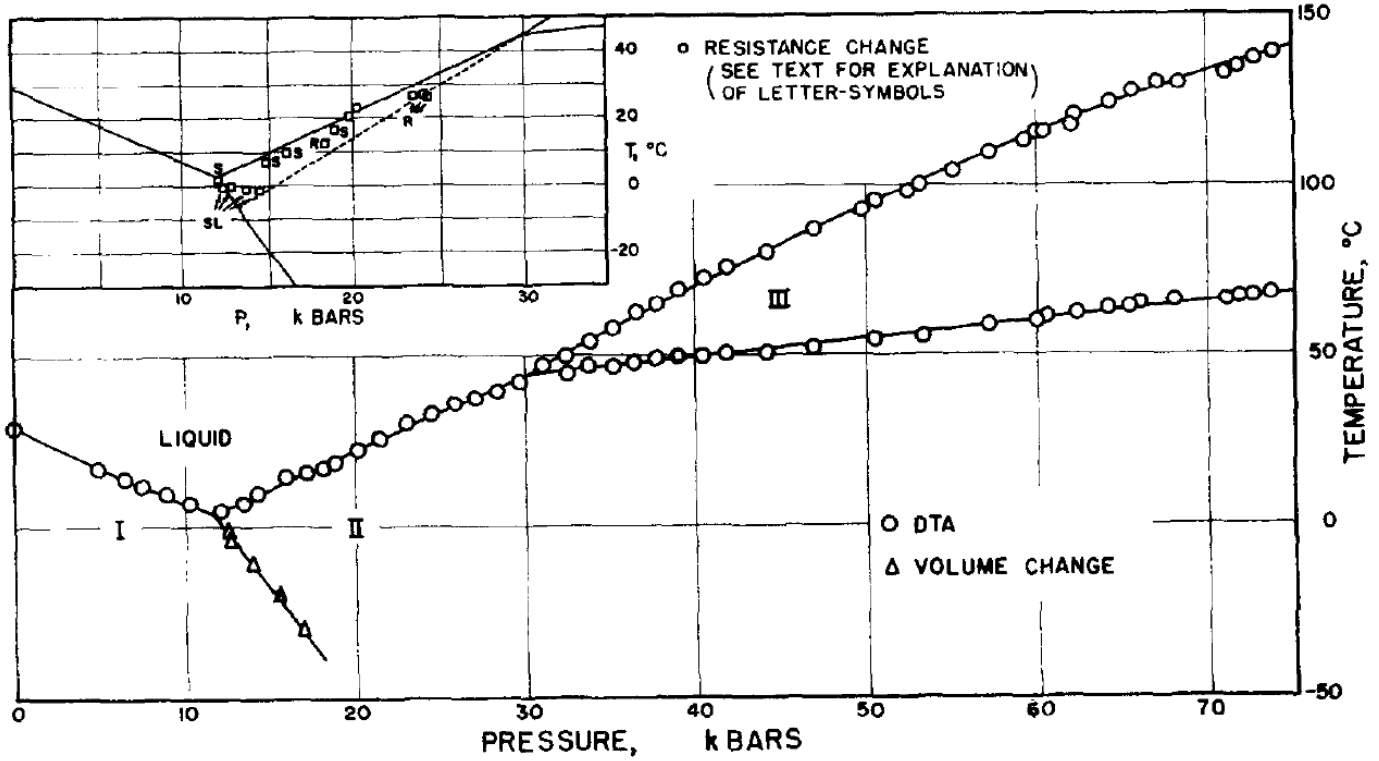


FIG. 5. Equilibrium phase diagram of gallium. The inset shows the nonequilibrium points from the present work (cf. text) relative to the equilibrium phase boundaries; the dotted line represents the metastable extrapolation of the Ga III melting curve.

Fusion curves and polymorphic transitions of the group III elements—aluminum, gallium, indium and thallium—at high pressures
A.Jayaraman, W. Klement, R. C. NEWTON and G. C. Kennedy
J. Phys. Chem. Solids
24 *7-18 (1963)*

Melting line

Fusion curves and polymorphic transitions of the group III elements—aluminum, gallium, indium and thallium—at high pressures
A.Jayaraman, W. Klement, R. C. NEWTON and G. C. Kennedy
J. Phys. Chem. Solids
24 *7-18 (1963)*

P(GPa)	T(°C)
-0,00927	29,361
0,48054	17,503
0,6394	14,24
0,74381	12,142
0,88014	10,033
1,0163	7,2358
1,1982	5,112
1,3309	7,1327
1,4137	10,087
1,5836	15,077
1,707	16,413
1,803	17,528
1,8672	19,113
2,0049	22,738
2,1378	25,905
2,2939	30,441
2,4359	33,147
2,5735	36,542
2,6969	37,878
2,8251	39,9
2,9579	42,609
3,0913	47,611
3,2287	50,318
3,3711	54,629
3,5087	58,254
3,642	62,798
3,7657	65,28
3,8899	69,826
4,0411	73,217
4,1832	76,382
4,4122	80,435
4,6874	87,455
4,9759	92,865
5,0495	95,593
5,2416	98,283
5,3151	100,32
5,5076	104,62

P(GPa)	T(°C)
5,723	109,59
5,9245	113,2
5,9889	115,7
6,0436	115,45
6,1991	117,46
6,2181	120,9
6,4287	124,27
6,5571	127,67
6,7037	130,37
6,8359	130,1
7,1056	132,99
7,1744	135,03
7,2753	137,52
7,3852	139,32
3,2367	45,04
3,3603	47,523
3,5062	47,016
3,6295	48,123
3,7621	49,685
3,8854	50,103
4,0313	50,055
4,1728	50,926
4,4055	51,079
4,684	52,594
5,0356	54,772
5,3277	55,823
5,716	58,907
5,9899	59,964
6,0495	61,55
6,2276	62,409
6,4058	63,956
6,5336	64,373
6,5977	65,728
6,7985	66,35
7,0995	66,481
7,1772	67,144
7,2594	67,805
7,3645	68,459

Ga-I (solid phase)

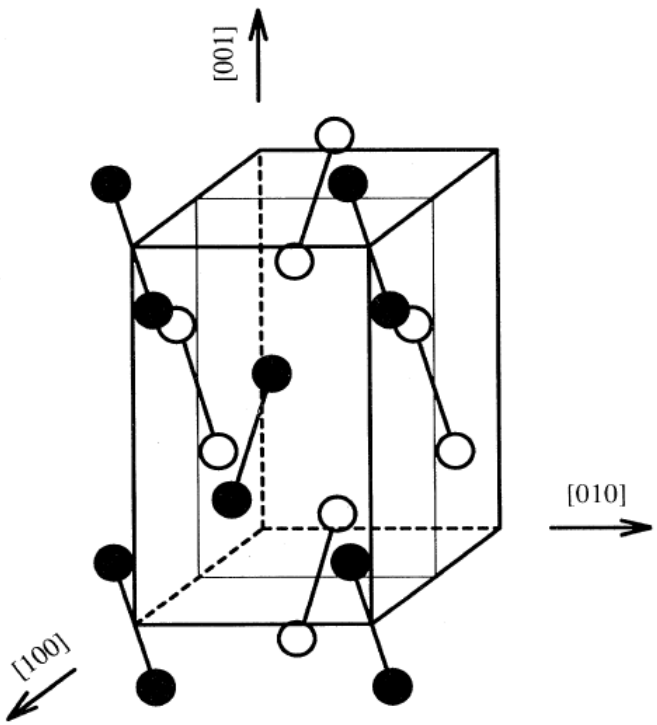


FIG. 1. Face-centered orthorhombic cell of α-Ga. Each site is occupied by a Ga_2 dimer. Filled circles represent atoms lying on the (100) plane at $x=a$, while open circle atoms lie on the next lower plane at $x=a/2$. Atoms in the $x=0$ plane are in the same positions of those at $x=a$ and are not shown.

The positions of the eight atoms in the orthorhombic unit cell (twice as large as the primitive cell) are functions of u and v in the form[5]

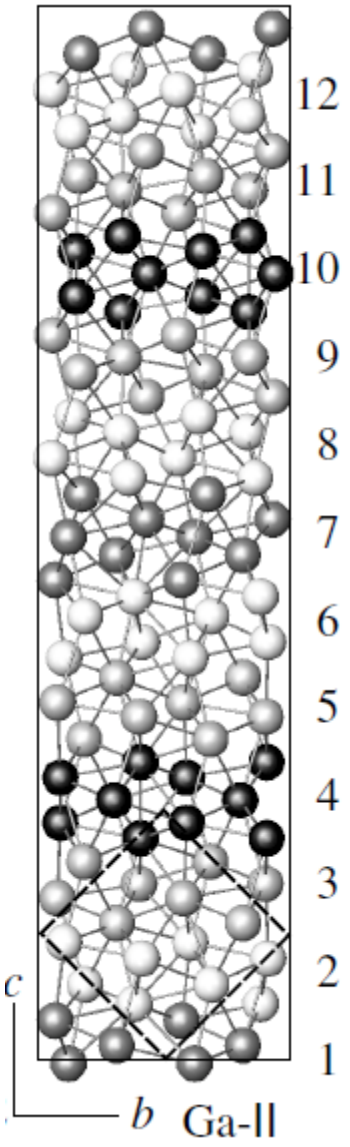
$$(0,u,v) \quad (\tfrac{1}{2},u,\tfrac{1}{2}+v) \quad (\tfrac{1}{2},\tfrac{1}{2}+u,-v) \quad (0,\tfrac{1}{2}+u,\tfrac{1}{2}-v)$$
$$(0,-u,-v) \quad (\tfrac{1}{2},-u,\tfrac{1}{2}-v) \quad (\tfrac{1}{2},\tfrac{1}{2}-u,v) \quad (0,\tfrac{1}{2}-u,\tfrac{1}{2}+v)$$

with the experimental values $u=0.0785$ and $v=0.1525$ (x,y,z, are intended to be multiplied by a, b, c,

Ab initio calculations of structural and electronic properties of gallium solid-state phases
M. Bernasconi, G.L. Chiarotti, E. Tosatti
Phys. Rev. B, **52**, 14 (1995)

Ga-II (solid phase)

Structural Complexity in Gallium under High Pressure: Relation to Alkali Elements
O. Degtyareva, M. I. McMahon, D. R. Allan, and R. J. Nelmes
Phys. Rev. Lett.
93 205502 (2004)



Metastable phases (supercooling)

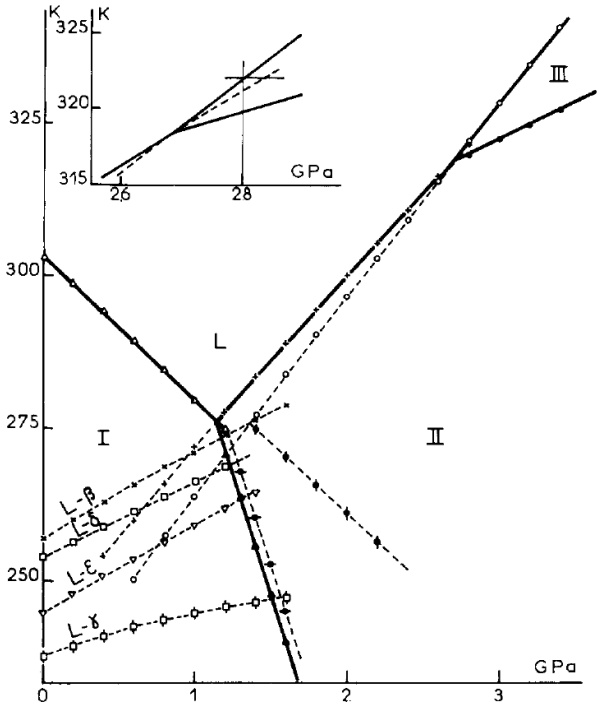
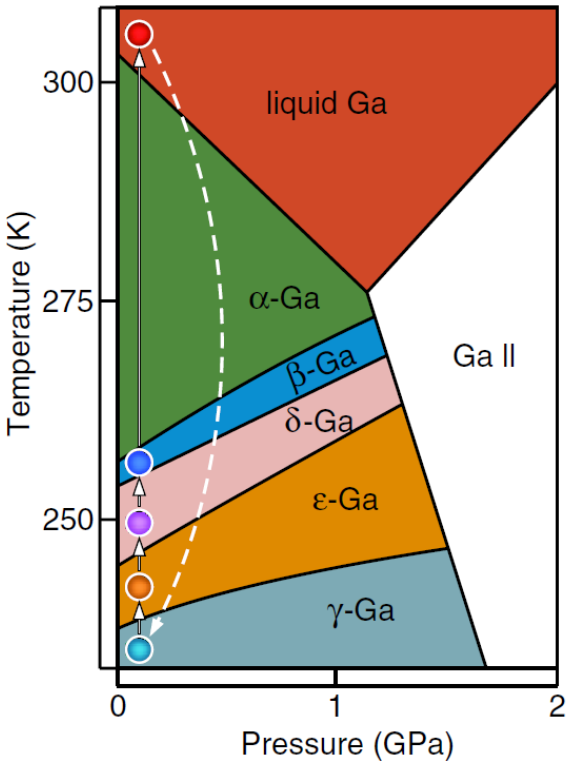


FIG. 2. Equilibrium phase diagram of gallium. The inset shows the liquid–Ga(II)–Ga(III) triple point; the dotted lines represent the metastable equilibrium phase boundaries.



L. Bosio, C. R. Acad. Sci. **270**, 1453 (1970)
L. Bosio, J. Chem. Phys. **68**, 1221 (1978)

Japanese Journal of Applied Physics **48** 03A065 (2009)

« One remarkable property of gallium, which can conveniently be mentioned here and which was very noticeable during this work, is the great tendency of the metal to supercool. Two of the dilatometers were left at room-temperature for several months after the measurements had been taken, and the gallium still showed no signs of solidifying. » W.H.Hoather (1936)

Crystal structures of Ga(II) and Ga(III)
Louis Bosio
J. Chem. Phys. **68**, 1221 (1978)
doi: 10.1063/1.435841

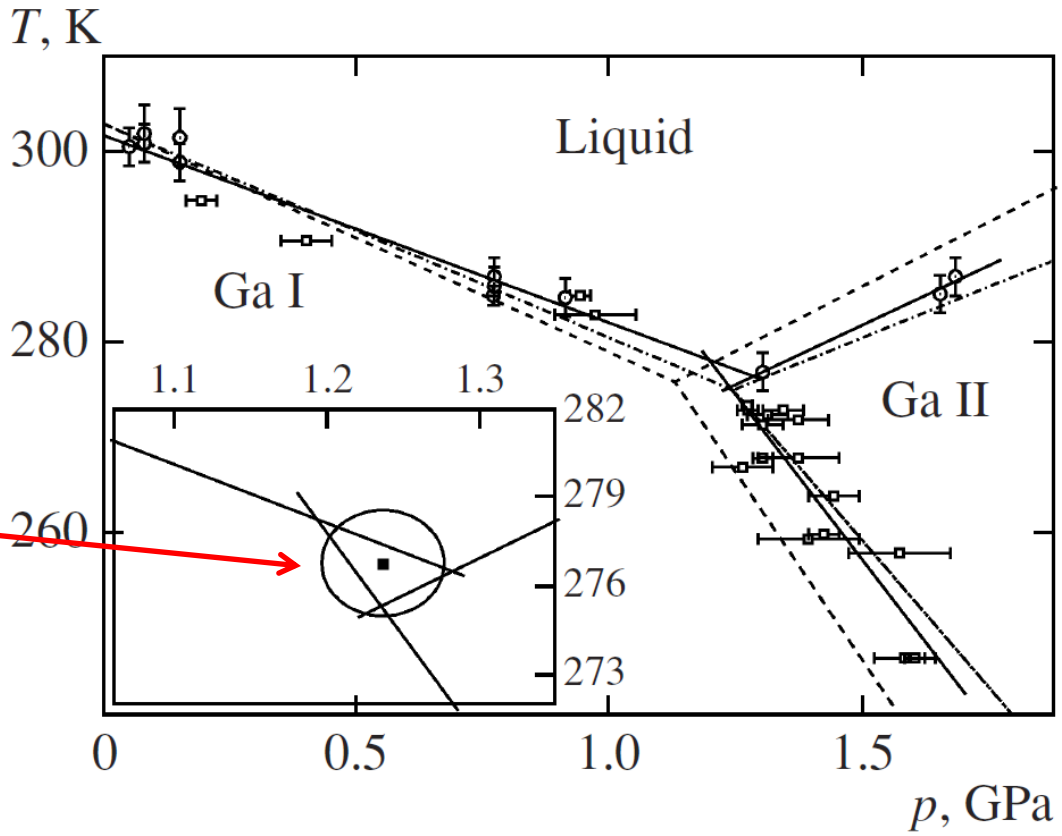
P(GPa)	T(°C)
0,00318	29,77
0,18759	25,47
0,39365	20,9
0,58894	16,06
0,78962	11,36
0,99034	6,38
1,1422	3,02
1,3898	10,31
1,589	15,7
1,7882	21,23
1,9928	26,89
2,1866	32,15
2,3913	37,55
2,5905	43,08
2,7143	46,18
2,795	49,01
2,9887	55,22
3,1878	61,42
3,3815	67,49
2,7899	46,59
2,995	49,29
3,1892	51,59
3,3943	54,16
3,6101	56,86
1,197	-2,49
1,2953	-9,49
1,3938	-17,57
1,4977	-25,64
1,5961	-33,31
1,6726	-39,23

Triple point in liquid Ga

Triple point

$P = 1.24 \pm 0.4\ \text{GPa}$

$T = 277 \pm 2\ \text{K}$

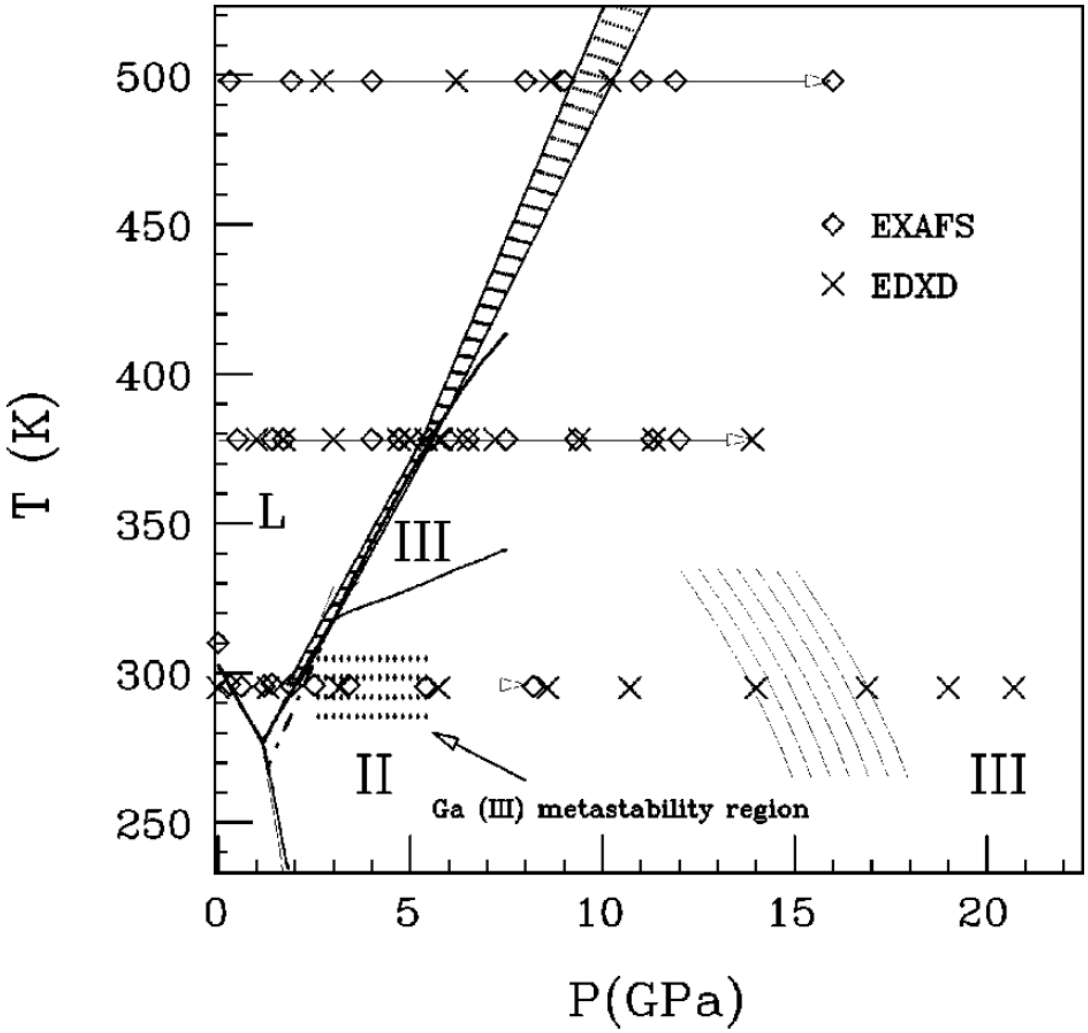


Elastic Properties of Crystalline and Liquid Gallium at High Pressures
A. G. Lyapin, E. L. Gromnitskaya, O. F. Yagafarov, O. V. Stal'gorova, and V. V. Brazhkin
JOURNAL OF EXPERIMENTAL AND THEORETICAL PHYSICS Vol. 107 No. 5 2008

Critical point in liquid Ga

Tc=5000 K
Pc=0.076 GPa
$\rho_n c$ = 0.01474 at./A^3 (critical numerical density)
$\rho c = \rho_n c\ (10^{24}/N_A)$ mol/cm^3 = 0.02448 mol/cm^3
$V_m c$=40.85 cm^3/mol (molar volume)
$\rho c = M/V_m c$ = 1706 kg/m^3 (critical density)
Zc=PcVc/RTc=0.075

Russian Journal of Physical Chemistry
80(4) 509-522 (2006)
The embedded atom model for liquid metals: Liquid gallium and bismuth
D. K. Belashchenko, O. I. Ostrovskii

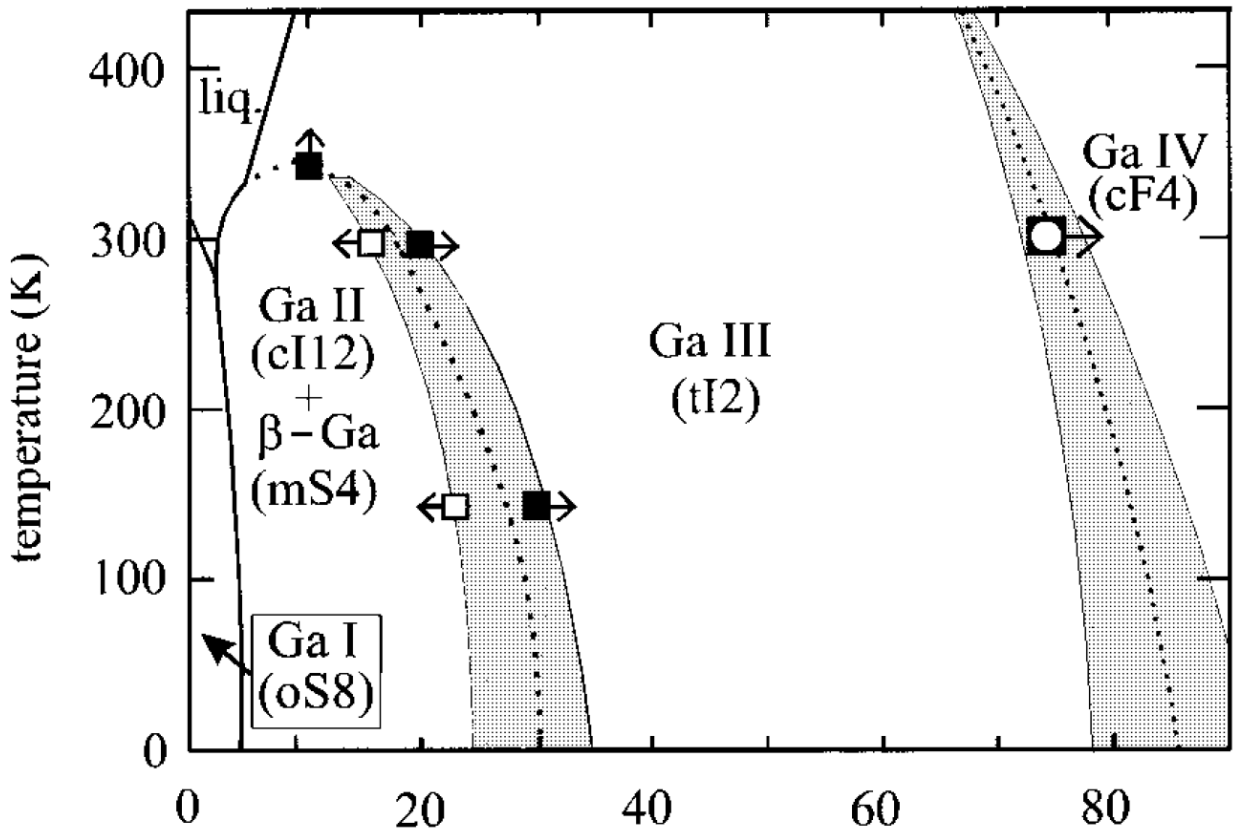


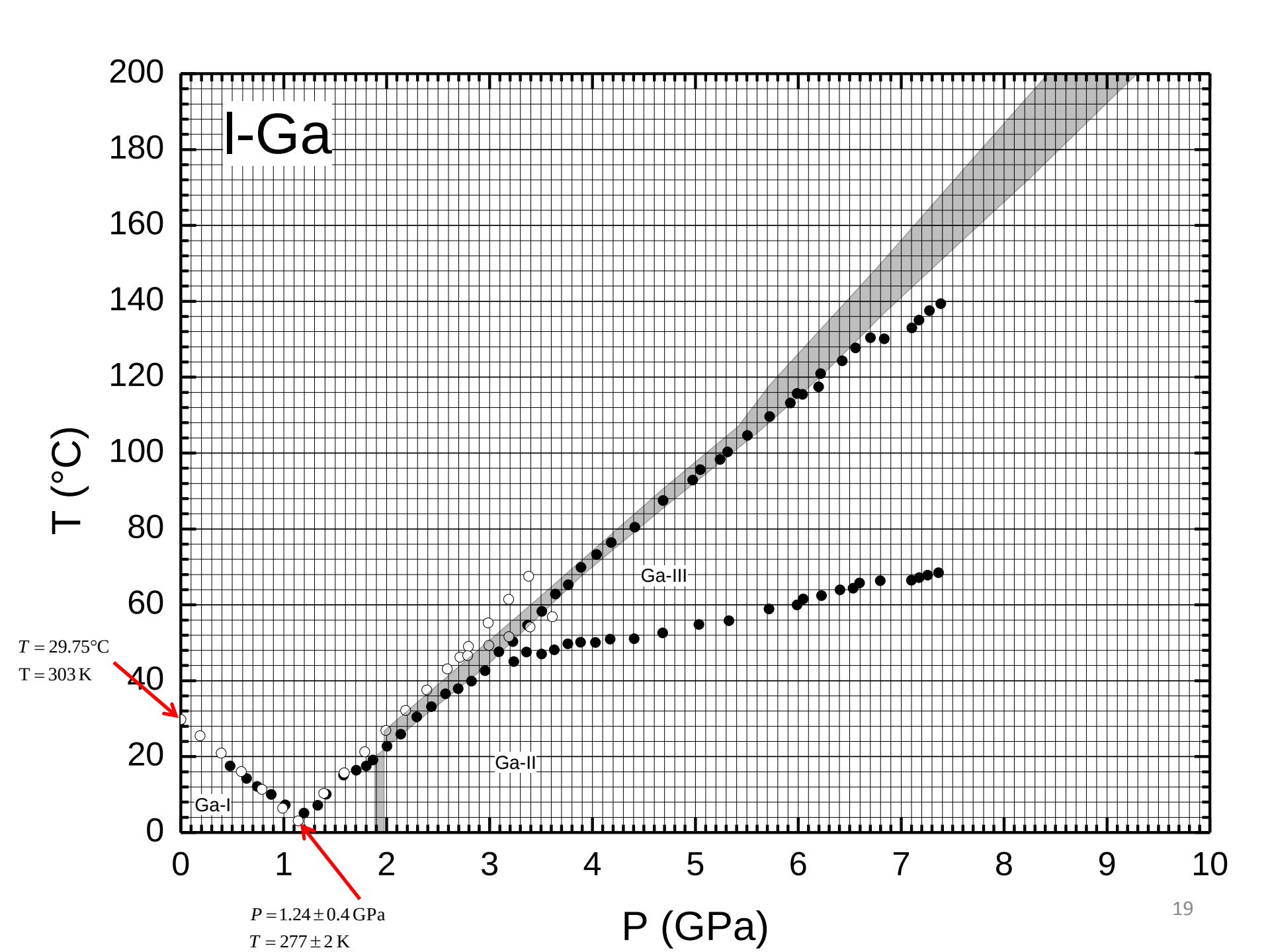
High-pressure and high-temperature x-ray absorption study of liquid and solid gallium
Lucia Comez, Andrea Di Cicco, Jean Paul Itié and Alain Polian
Phys.Rev.B, **65**, 014114 (2001)

(shaded area)

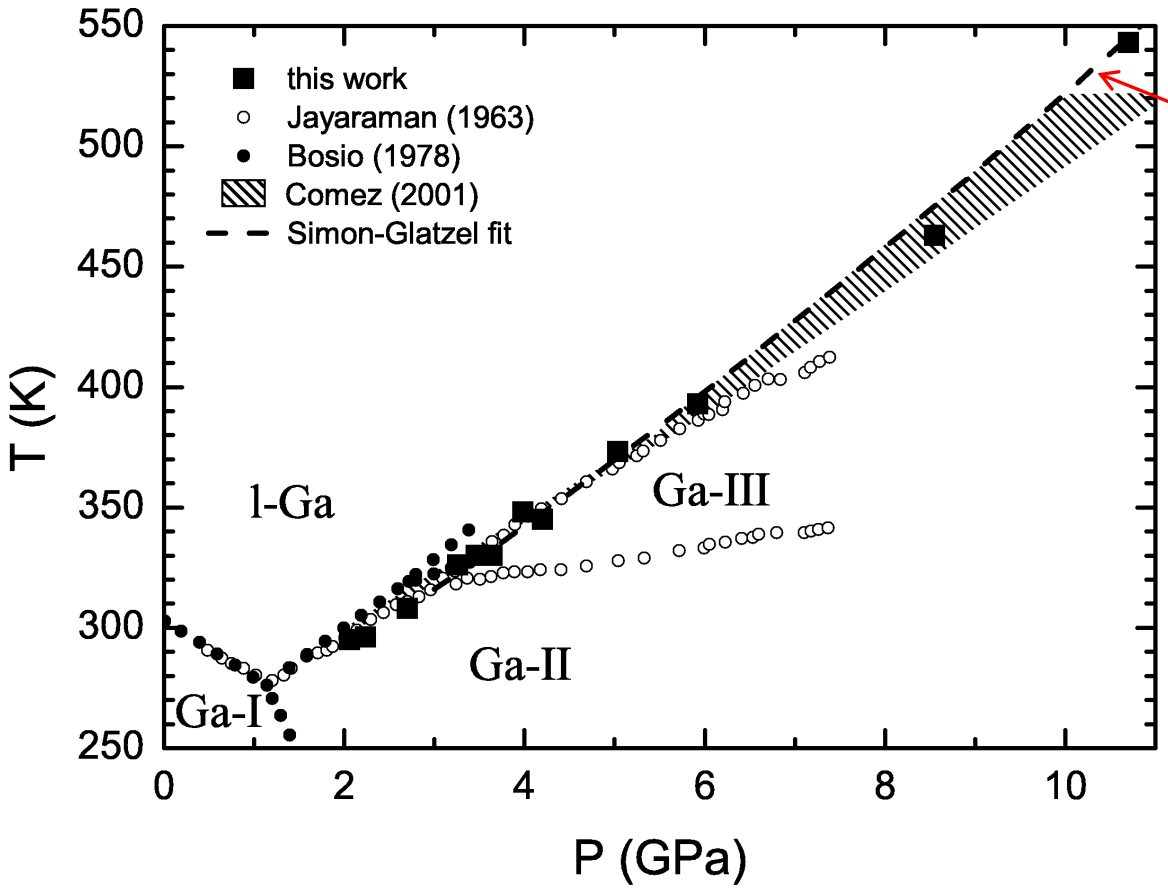
P(Gpa)	T(°C)
1.976	26.77
3.4431	60.95
4.6707	90.14
5.4192	107.03
5.7186	117.79
6.7665	148.89
7.8144	181.15
8.503	202.27
9.0419	218.79
10.03	249.12
11.228	249.51
10.689	235.3
9.1617	196.51
8.2635	172.7
7.6048	156.19
6.8263	136.6
6.3174	122.78
6.018	115.1
5.6287	105.88
4.7605	87.07
3.8922	67.48
2.9641	43.67
2.2754	28.69
1.8862	19.86
1.976	26.77

Effect of pressure on the atomic volume of Ga and Tl up to 68 GPa
Olaf Schulte and Wilfried B. Holzapfel
PRB **55** (13) 8122 (1997)




l-Ga
T (°C)
P (GPa)
Ga-I
Ga-II
Ga-III
$T = 29.75°C$
$T = 303\,K$
$P = 1.24 \pm 0.4\,GPa$
$T = 277 \pm 2\,K$

S.Ayrinhac *et al* (2015)



Simon-Glatzel equation

$$T = T_t\left[\frac{P - P_t}{a} + 1\right]^{1/c}$$

a= 24 GPa

c=0.51

P_t=3 GPa

T_t=316 K

S Ayrinhac *et al, J. Phys.: Condens. Matter* **27** 275103 (2015)

Melting line between Ga-I and l-Ga at negative pressures up to -15 MPa

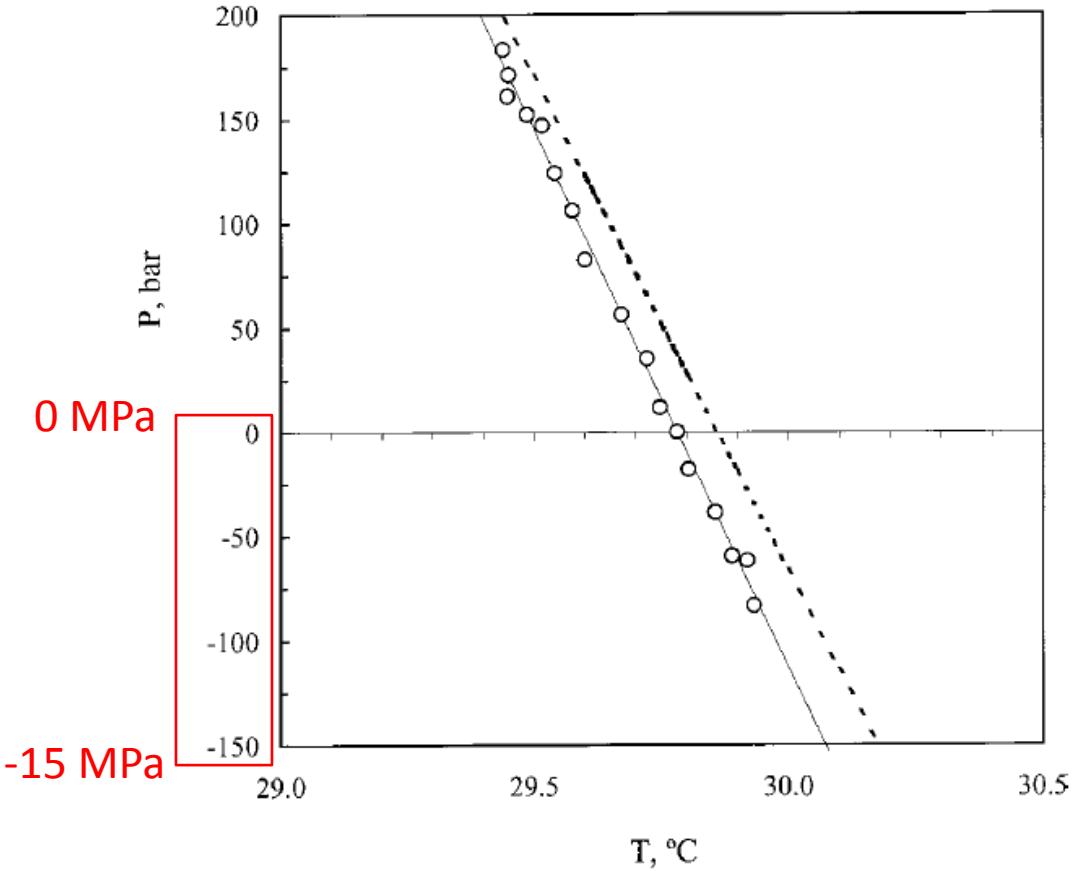
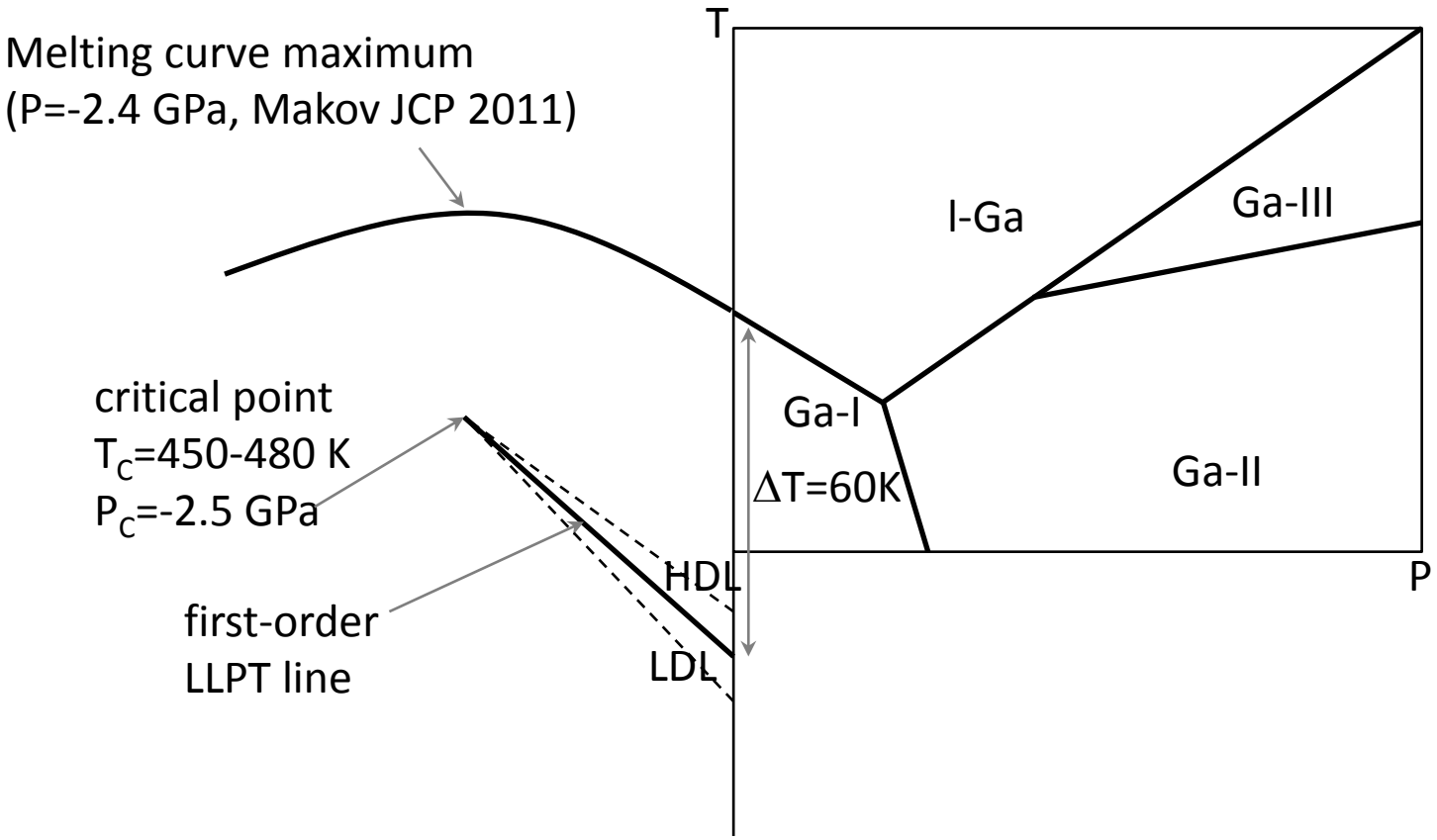


Fig. 5. Melting curve of gallium(I) at positive and negative pressures. (○) experimental, this work; thin line is a least-squares fitting to our data; thick dashed line, from Ref. 22.

Water and Gallium at Absolute Negative Pressures
H. I. M. Veiga, L. P. N. Rebelo, M. Nunes da Ponte, and J. Szydlowski
International Journal of Thermophysics **22** (4) 1159 (2001)

Ref.22 = A. Jayaraman *et al* J. Phys. Chem. Solids **24** 7-18 (1963)

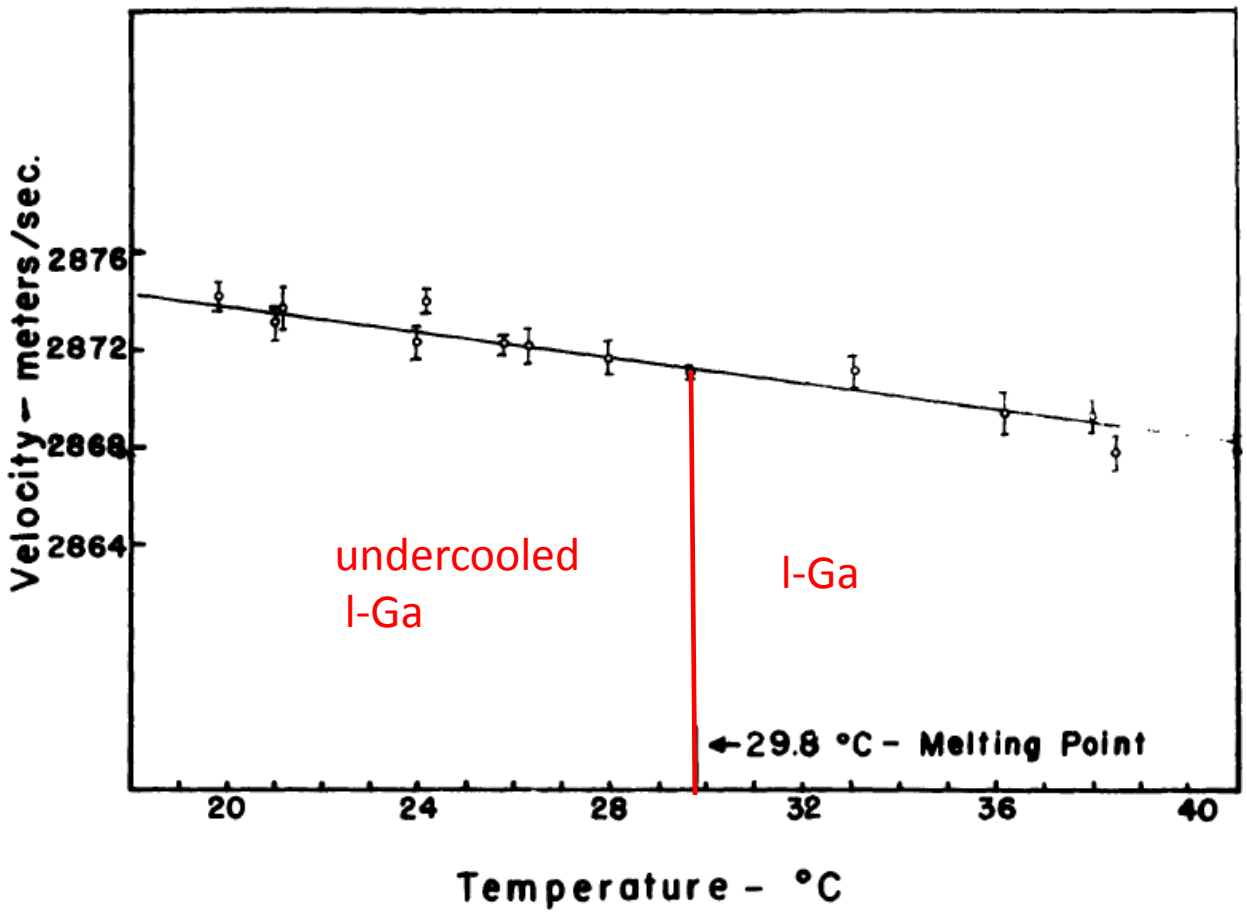
Liquid-liquid phase transition (LLPT) in metastable domain by simulations



Theoretical evidence for a first-order liquid-liquid phase transition in gallium
Carvajal Jara, Diego Alejandro and Fontana Michelon, Mateus and Antonelli, Alex and de Koning, Maurice, JCP **130** 221101 (2009)

Sound velocity

back to the table of contents



Measurements of the velocity and aborption of ultrasound in liquid gallium
R.L.Proffit and E.F.Carome (1962)
Technical Report No 5 (Ft. Belvoir, VA: Defense Technical Information Center)

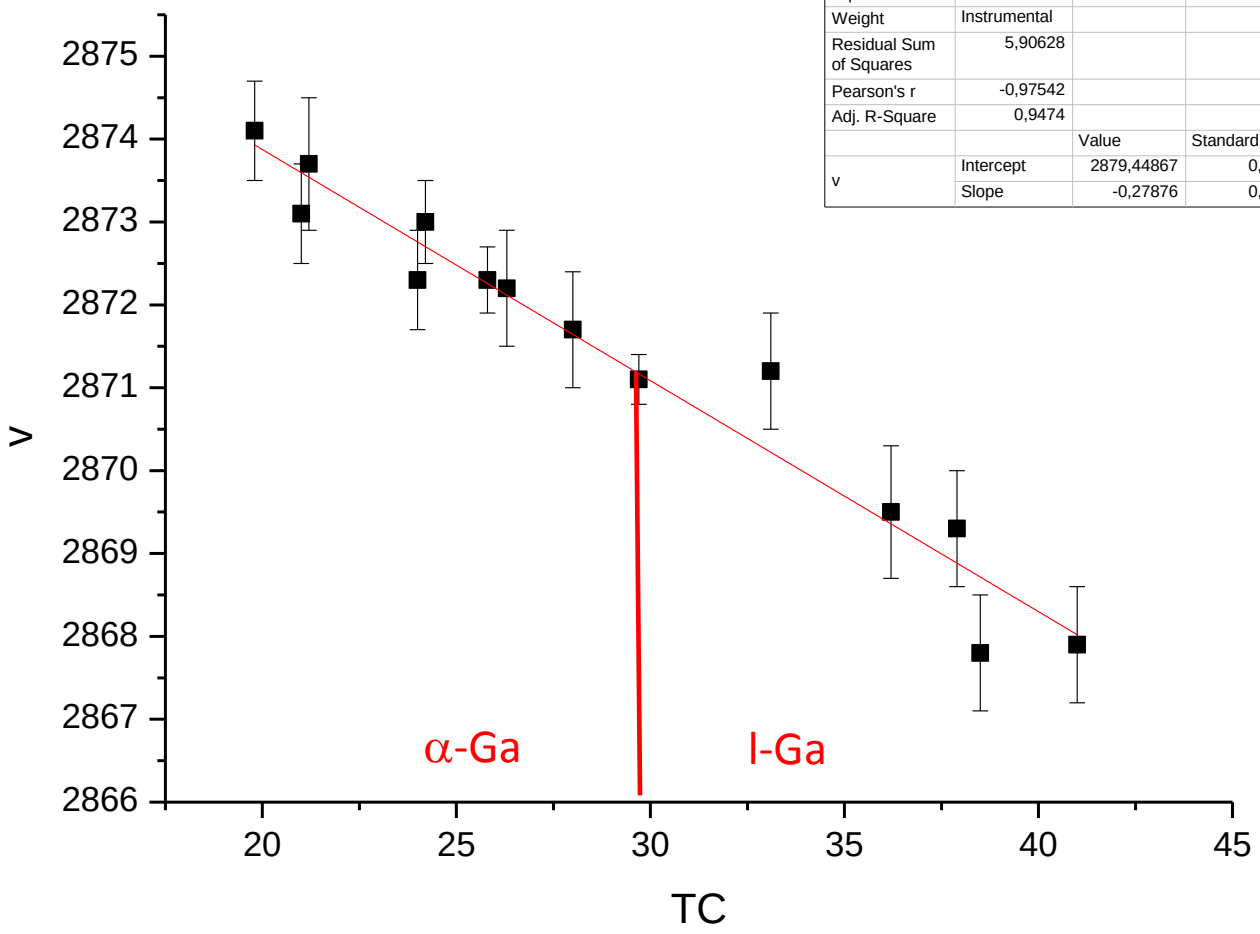
Experimental data

T(°C)	VL	ΔVL
19.8	2874.1	0.6
21	2873.1	0.6
21.2	2873.7	0.8
24	2872.3	0.6
24.2	2873	0.5
25.8	2872.3	0.4
26.3	2872.2	0.7
28	2871.7	0.7
29.7	2871.1	0.3
33.1	2871.2	0.7
36.2	2869.5	0.8
37.9	2869.3	0.7
38.5	2867.8	0.7
41	2867.9	0.7

Linear fit of the data (done with ORIGIN software)

V_L=2879.44867-0.27876 T(°C)

Equation	y = a + b*x		
Weight	Instrumental		
Residual Sum of Squares	5,90628		
Pearson's r	-0,97542		
Adj. R-Square	0,9474		
		Value	Standard Error
v	Intercept	2879,44867	0,52511
	Slope	-0,27876	0,01818



Measurements of the velocity and aborption of ultrasound in liquid gallium
R.L.Proffit and E.F.Carome (1962)
Technical Report No 5 (Ft. Belvoir, VA: Defense Technical Information Center)

O.J.Kleppa (1950)

This value is lower than Proffit&Carome

TABLE II. Sound velocities and temperature gradients.

Metal	m.p. t°C	u (m/sec.)	$\frac{du}{dt}$ (m sec.$^{-1}$ deg.$^{-1}$, approx.)	Temp. Range m.p. to °C
Zn	420	2790±60	—	480
Ga	30	2740±50	—	50
Cd	321	2200±20	−0.5	360
In	156	2215±20	−0.5	260
Sn	232	2270±20	−0.7	380
Tl	302	1625±15	—	310
Pb	327	1790±15	−0.5	380
Bi	271	1635±15	−0.5	365
Na	98	2395±25	−0.3	235
K	64	1820±20	−0.5	160
Rb	39	1260±10	−0.4	160
Cs	29	967±10	−0.3	130

[7] T. W. Richards and S. Boyer, J. Am. Chem. Soc. **43**, 294 (1921).

O.J.Kleppa, J. Chem. Phys. **18** 1331 (1950)

B. P. Pashaev (1980)

TABLE 1. Values of Velocity of Ultrasound and Electrical and Thermal Conductivity for Gallium, Indium, and Thallium

Metal	Property	Polynomial	Temp. range, °K	Remarks
	$\rho \cdot 10^8$, Ω · m	$(25,85 \pm 0,05) + (1,914 \pm 0,01) 10^{-2} (T - 302,9)$	302,9—1000	Av. result
	λ, W/m · °K	$(7,6 \pm 0,4) + (7,92 \pm 1) 10^{-2} T - (2,6 \pm 1) 10^{-5} T^2$	310—800	Our result
Ga	C, m/sec	$(2869,8 \pm 5) - (0,210 \pm 0,003)(T - 302,9)$	302,9—373	»
	C, m/sec	$(2855,0 \pm 5) - (0,246 \pm 0,003)(T - 373)$	373—493	»
	C, m/sec	$(2825,5 \pm 5) - (0,268 \pm 0,005)(T - 493)$	493—700	»
	$\rho \cdot 10^8$, Ω · m	$(32,38 \pm 0,05) + (2,52 \pm 0,01) 10^{-2} (T - 429,8)$	429,8—1000	Av. result
In	λ, W/m · °K	$(31,5 \pm 1,6) + (4,28 \pm 0,04) 10^{-2} (T - 440)$	440—800	Our result
	C, m/sec	$(2312 \pm 4) - (0,300 \pm 0,003)(T - 429,8)$	429,8—1000	»
	C, m/sec	$2313 \pm 1,5) - (0,299 \pm 0,0015)(T - 429,8)$	429,8—1000	Av. result
	$\rho \cdot 10^8$, Ω · m	$(76,48 \pm 0,08) + (2,78 \pm 0,03) 10^{-2} (T - 577)$	577—1000	Av. result
Tl	λ, W/m · °K	$(18,4 \pm 0,9) + (2,66 \pm 0,03) 10^{-2} (T - 587)$	587—800	Our result
	C, m/sec	$(1659,6 \pm 3,2) - (0,231 \pm 0,1)(T - 577)$	577—1120	[32,35]

Ga, v (m/s)

2869.8-0.210*(x+273.15-302.9)

2855.0-0.246*(x+273.15-373)

2825.5-0.268*(x+273.15-493)

THERMOPHYSICAL PROPERTIES OF POLYVALENT METALS AND THEIR ALLOYS IN THE SOLID AND LIQUID STATES

B. P. Pashaev, D. K. Palchaev,

E. G. Pashuk, and V. G. Revelis (1980)

V. Ya. Prokhorenko (2000)

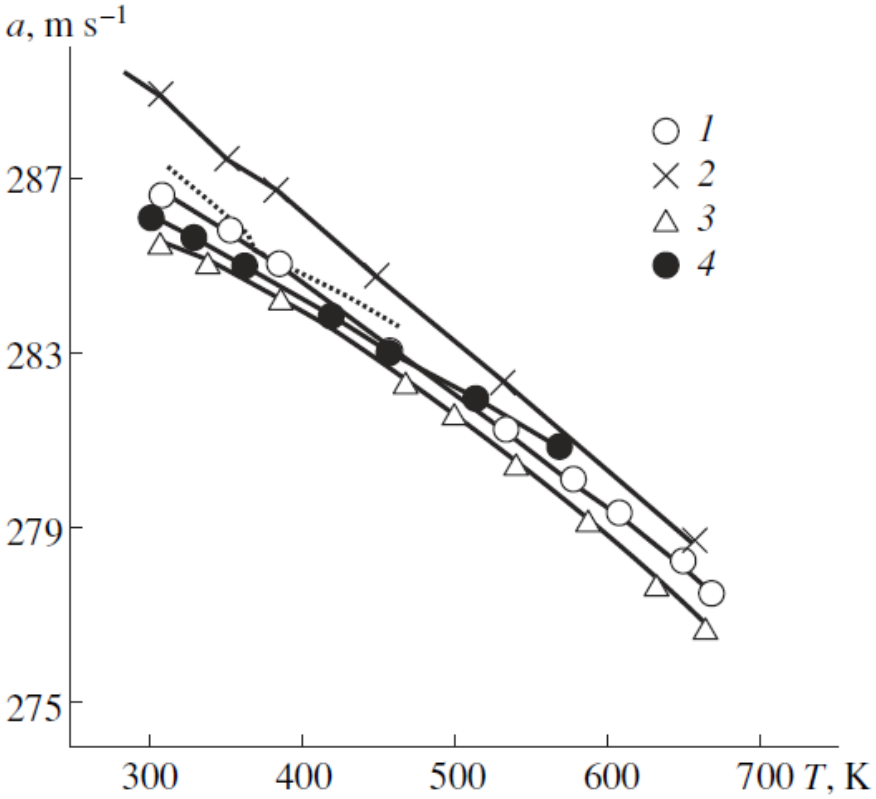
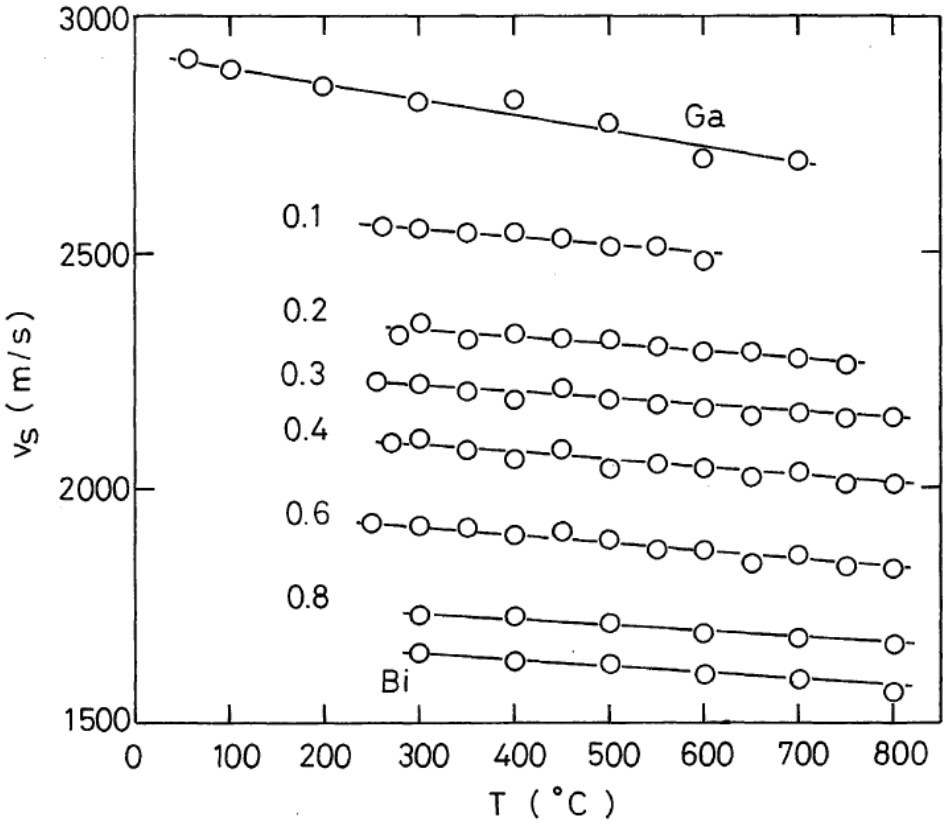


Fig. 8. The sound velocity in liquid gallium: (*1*) [40, 45], (*2*) [38], (*3*) [47], (*4*) [46].

V. Ya. Prokhorenko, *High Temperature,* **38** (6) 954–968 (2000)

M.Inui (1992)

Ultrasonic Velocity and Density Measurement of Liquid $Bi_{1-x}Ga_x$



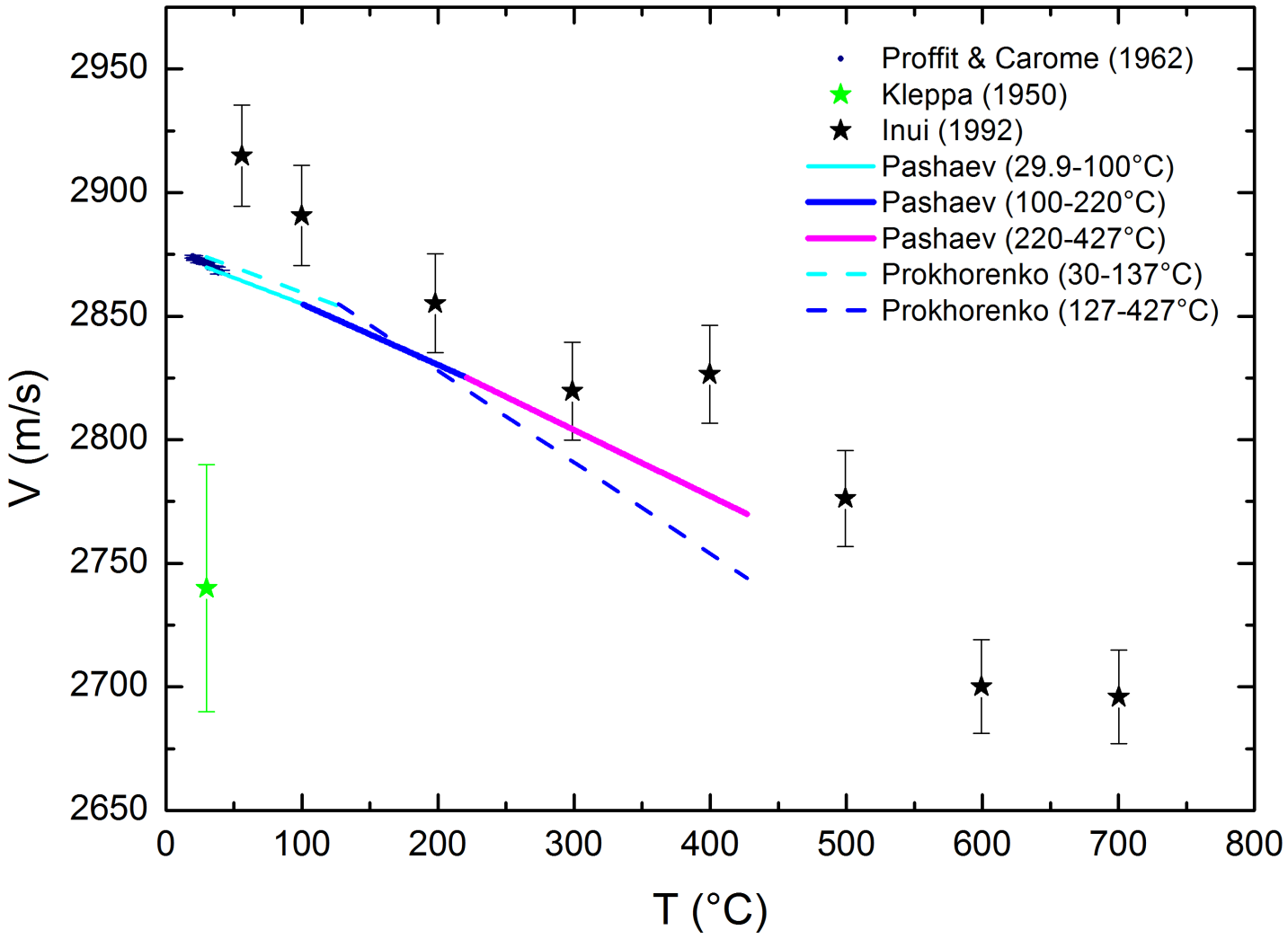
T(°C)	T(K)	v (m/s)	dv (m/s)
55.899	329.049	2914.9	20.4043
99.885	373.035	2890.7	20.2349
197.94	471.09	2855.2	19.9864
298.74	571.89	2819.7	19.7379
399.54	672.69	2826.6	19.7862
499.43	772.58	2776.3	19.4341
599.31	872.46	2700.2	18.9014
700.11	973.26	2696	18.872

M.Inui *et al* JPSJ (1992)

Fig. 2. Temperature dependence of sound velocity of liquid $Bi_{1-x}Ga_x$.

	Value	Standard Error
Intercept	2930.76201	13.25072
Slope	-0.33956	0.03091

Sound velocity (synthesis from literature)



Another articles about sound velocity

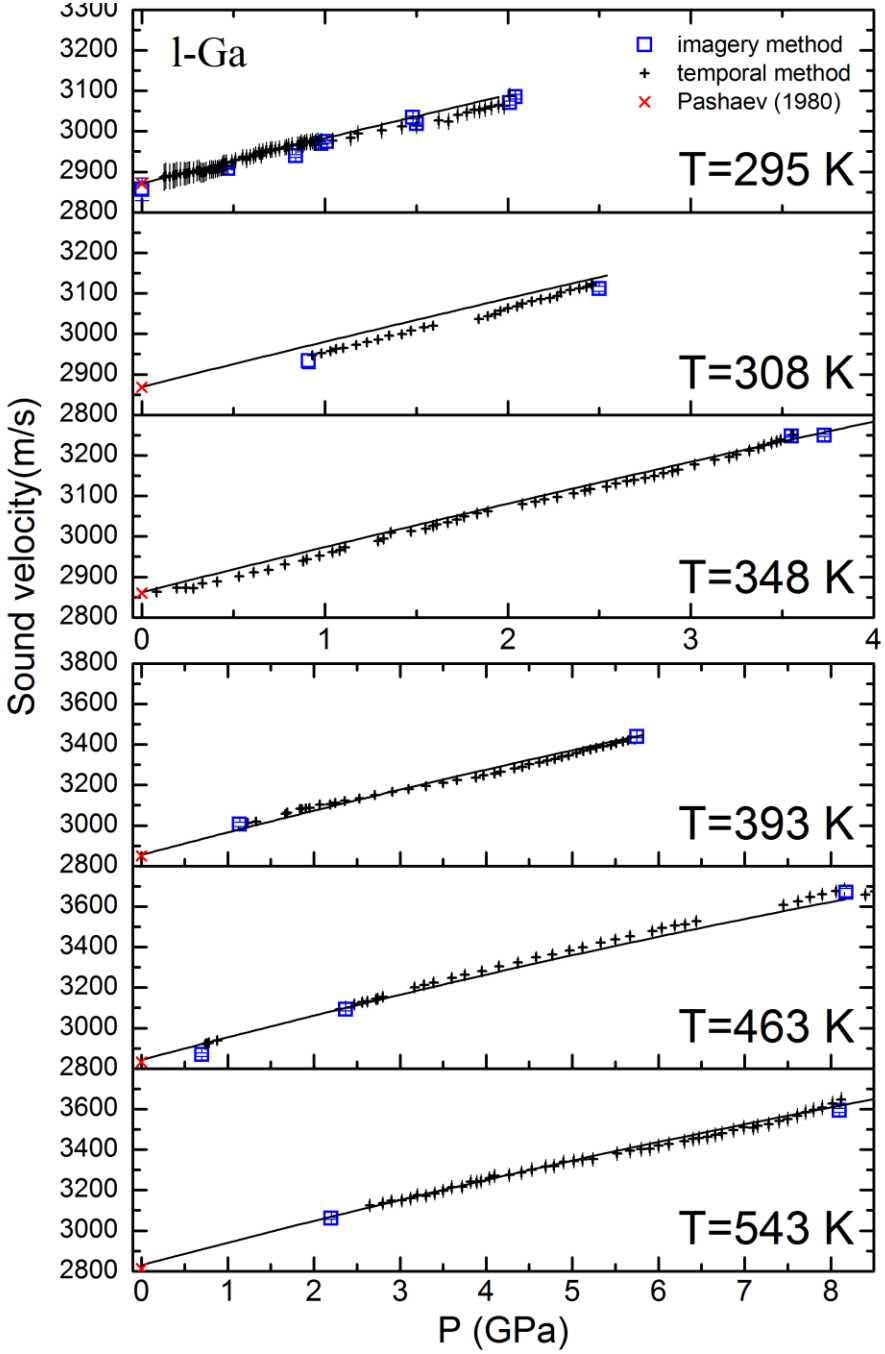
• A-M. A. Magomedov, M. A. Ismailov, and B. P. Pashaev, *High Temp. Engl. Transl.* **13**, 1024 (1975)
[Teplofiz. Vys. Temp. 13, 1106 (1975)].

• Brito *et al* (2001)

• Beyer & Ring

• *Review of data for velocity of sound in pure liquid metals and metalloids*
S. Blairs
52 (6) 321-344
DOI: http://dx.doi.org/10.1179/174328007X212490

S.Ayrinhac *et al* (2015)



S Ayrinhac *et al, J. Phys.: Condens. Matter* **27** 275103 (2015)

Dispersion curve

back to the table of contents

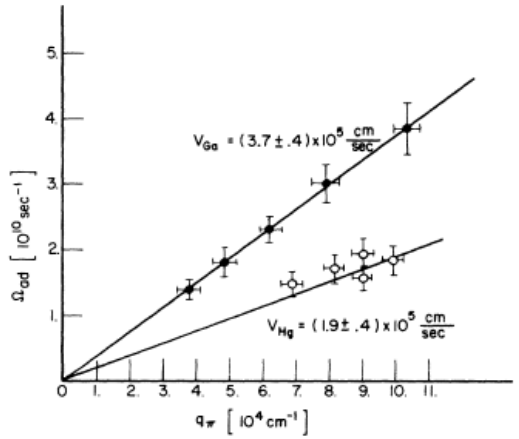


FIG. 6. Measured acoustic dispersion curves for liquid mercury and gallium; v is the velocity of sound of angular frequency Ω_{ad} and propagation constant q_π; the open circles refer to mercury, the solid circles to gallium.

Brillouin scattering from isotropic metals
Jan G. Dil and Edward M. Brody
Phys. Rev. B 14, 5218 – Published 15 December 1976

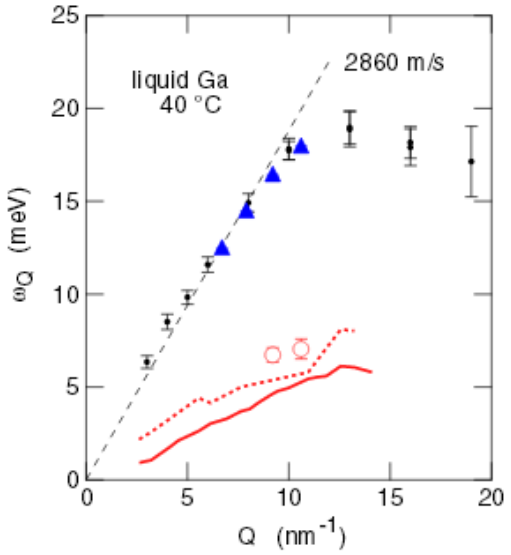


FIG. 2 (color online). Dispersion relation of transverselike (open circles) and longitudinal (solid triangles) modes obtained from the fits. The solid curve gives the peak energies of the transverse current spectra, and the dotted curve is those of the quasitransverse branch seen in the longitudinal current spectra, both obtained by an orbital-free *ab initio* MD simulation. See the text for details.

Sound attenuation

back to the table of contents

$1GHz \rightarrow \alpha = 0.025 \mu m^{-1}$

$10GHz \rightarrow \alpha = 0.250 \mu m^{-1}$

Proffit&Carome

α . The value obtained at 205 Mc was only 8.5± 0.8 db/cm, corresponding to $\frac{\alpha}{\nu^2} = 2.5 \times 10^{-17} cm^{-1} sec^2$, at 30°C.

The theoretical Stokes-Kirchoff value for $\frac{\alpha}{\nu^2}$ is given by

$$\frac{\alpha}{\nu^2} = \frac{8\pi^2}{3} \frac{\eta}{\rho v^3} + \frac{2\pi^2(\gamma-1)T}{3} \qquad (3)$$

$$= (0.42 + 1.2)\ cm^{-1}\ sec^2$$

T8. Classical Ultrasonic Absorption in Liquid Gallium. JOSEPH L. HUNTER AND KENNETH S. HOVAN (nonmember), *John Carroll University, Cleveland, Ohio.*—Because of the high values of wave velocity and density and the low value of viscosity in gallium, the Stokes–Kirchoff value of α/f^2 is only 1.6×10^{-17} $\sec^2$ cm^{-1}, of which approximately 75% is due to the thermal term. Measurements at 270 Mc/sec over a temperature range of 30°–60°C have checked this value to an accuracy of 2%. Velocity measurements were also carried out over this range. The accuracy of the measurement and the certainty of the physical constants entering into the classical value are discussed. The measurement was made over an inch of path length, and the attenuation in this distance was approximately 29 dB. As far as is known, this is the lowest value of ultrasonic absorption occurring in liquids. [Work supported in part by the U. S. Office of Naval Research.]

Classical Ultrasonic Absorption in Liquid Gallium
Joseph L. Hunter and Kenneth S. Hovan
J. Acoust. Soc. Am. **36**, 1040 (1964)
http://dx.doi.org/10.1121/1.2143329

TABLE II. Stokes–Kirchhoff and experimental values of absorption.[a]

Temperature (°C)	α_s	α_H	α_{CL}	Uncertainty in α_{CL}/f^2	α_{exp}/f^2	Excess absorption
30	0.373	1.11	1.48	0.074	1.58	0.10
40	0.368	1.19	1.56	0.078	1.62	0.06
50	0.367	1.24	1.61	0.080	1.69	0.08
60	0.364	1.31	1.67	0.083	1.75	0.08
70	0.359	1.37	1.73	0.086	1.79	0.06
80	0.354	1.43	1.78	0.089	1.84	0.06

[a] All values $\times 10^{-17}$ sec^2 cm^{-1}.

The classical value of the sound absorption coefficient for liquids is given by the Stokes–Kirchhoff equation

$$\frac{\alpha_{CL}}{f^2}=\frac{\alpha_s}{f^2}+\frac{\alpha_H}{f^2}=\frac{2\pi^2}{\rho c^3}\left(\frac{4}{3}\eta_s+\frac{c^2KT\beta^2}{JC_p^2}\right), \quad (1)$$

where α_{CL} is the classical absorption coefficient, f is the frequency, α_H is the absorption due to heat conduction, α_s is the absorption due to shear processes, ρ is the density, c is the sound velocity, η_s is the shear viscosity, K is the thermal conductivity, β is the thermal coefficient of expansion, T is the absolute temperation, C_P is the specific heat at constant pressure, and J is the mechanical equivalent of heat.

physical constants. The experimental accuracy is approximately 2%.

The system was checked by measuring the absorption in distilled water between 20° and 30°C. The values agreed with the accepted results of Pinkerton[5] within his quoted experimental accuracy of less than 2%.

It is interesting that the measured value is so close to the Stokes–Kirchhoff value, in view of the fact that the absorption is extremely low.

The authors are greatly indebted to Professor Edward F. Carome of John Carroll University for procuring the gallium and to the Aluminum Company of America for making it available.

This research was supported in part by the U.S. Navy through the Acoustics Branch of the Office of Naval Research.

Ultrasonic Absorption in Liquid Gallium

J. L. HUNTER AND K. S. HOVAN

John Carroll University, Cleveland, Ohio

(Received 17 August 1964)

Viscosity

back to the table of contents

Table 3. Viscosity of gallium

Temperature (°C.)	Time (sec.)	η/ρ (Stokes)	Density ρ	Viscosity η (poise)
[30]	—	—	—	0·02037
52·9	165·2	0·003115	6·080	0·01894
97·7	142·3	0·002668	6·042	0·01612
102	141·7	0·002656	6·041	0·01604
149	125·7	0·002341	6·005	0·01406
200	193·1*	0·002120	5·972	0·01266
203	112·5	0·002082	5·970	0·01243
301	95·5	0·001743	5·905	0·01029
402	139·6*	0·001504	5·840	0·008783
402	84·3	0·001517	5·840	0·008858
500	78·7	0·001404	5·779	0·008113
500	131·5*	0·001409	5·779	0·008141
600	126·0*	0·001345	5·720	0·007694
600	75·9	0·001347	5·720	0·007705
604	123·0*	0·001310	5·718	0·007491
806	67·1	0·001164	5·604	0·006524
1010	103·3*	0·001077	5·492	0·005915
1100	62·3	0·001062	5·445	0·005783

* Readings taken with viscometer-inclination of 0°. All the rest were taken with an inclination of 5°.

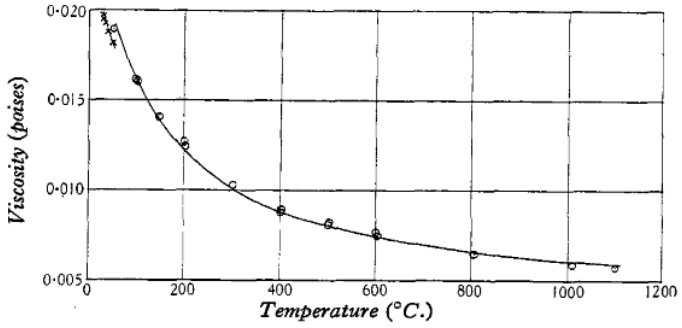


Figure 3.

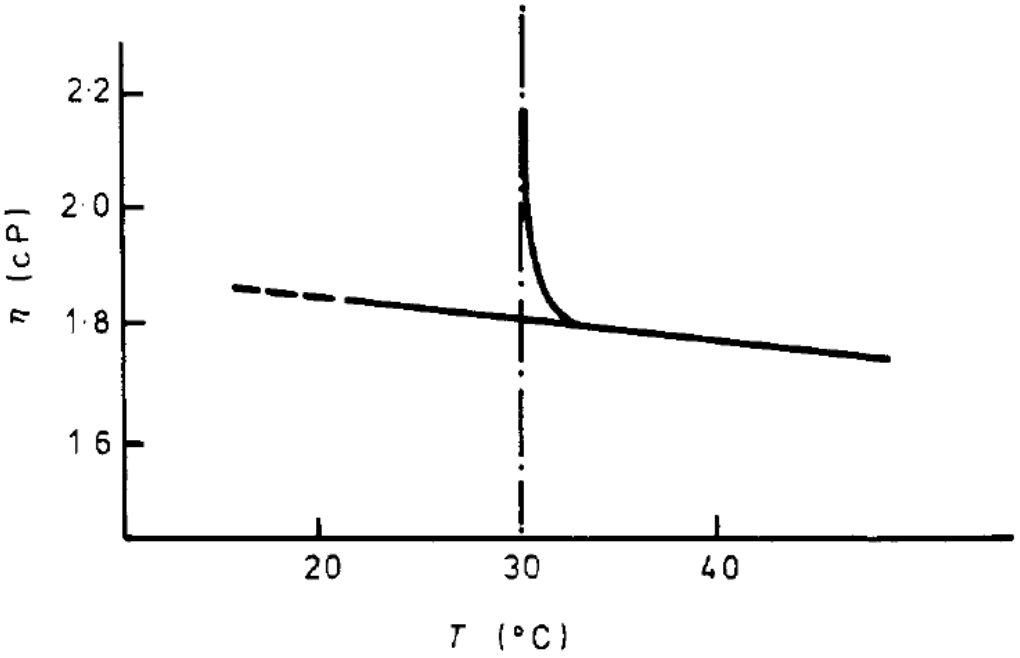


Figure 5. Dependence on temperature of the viscosity coefficient, as given by Predel and Arpshofen (1968).

R Kofman *et al J. Phys. F: Met. Phys.*
9 2345 (1979) doi:10.1088/0305-4608/9/12/007

Predel B and Arpshofen I 1968 *Z. Naturf.* **23** 2052

Assael (2012)

Gallium							
Primary data							
Tippelskirch[91]	1976	Oscillating cup (Abs)	99.99	0.5	42	P	307–800
Genrikh[92]	1972	Vibration method (Rel)	99.9	1.5	33	P	337–366
Menz[83]	1966	Double capillary (Abs)	na	2.0	4	D	449–602
Secondary data							
Iida[79]	1980	Oscillating cup (Rel)	99.99	na	6	P	293–1293
Iida[80]	1975	Capillary (Abs)	99.99	0.5	14	P	305–547
Spells[31]	1935	Capillary (Rel)	na	na	17	P	326–1373

J. Phys. Chem. Ref. Data **41** 033101 (2012);
http://dx.doi.org/10.1063/1.4729873

•TIPPELSKIRCH, H. V. Viscosities of Cesium Vapor to 1620 K and of Liquid Gallium to 1800 K. *Berichte der Bunsengesellschaft für physikalische Chemie*, 1976, vol. 80, no 8, p. 726-729.

Isobaric heat capacity C_P

back to the table of contents

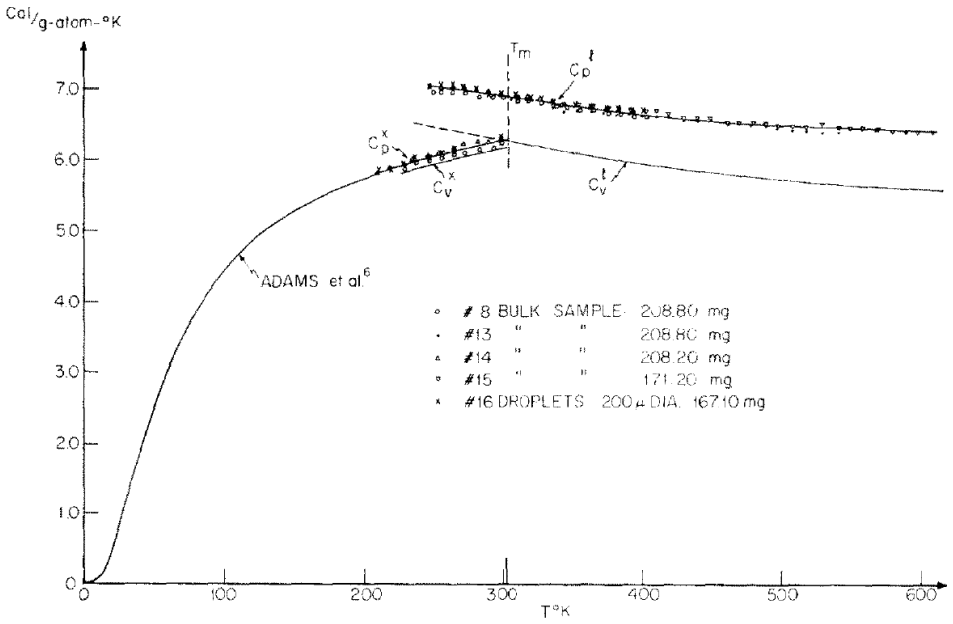


FIG. 3. The specific heat, C_p, and calculated values of specific heat at constant volume, C_v, of pure gallium. l designates the liquid and x the crystalline phase (Ga-I). T_m (= 303°K) is the melting point of pure gallium.

Chen *et al* (1968)

C_P (T)= 8.28-6.10e-3*T+5e-6*T^2 $\pm$ 0.1 cal/g-atom-°K

Conversion to S.I. units :

C_P(J/kg.K)= C_P(cal/g-atom-°K)*(4182/69.723)

gram atom = one mole of atoms of an element.
http://www.thefreedictionary.com/gram+atom

Nota : the value CP=370 J/kg.K often found on the web is **in solid**

The specific heat of tin and gallium in their stable and undercooled pure liquid states
H.S.Chen *et al*, Acta Metallurgica, **16(3)** 369–373 (1968)

Takahashi *et al* (1983) (C_P(T) in J.g/atom.K)

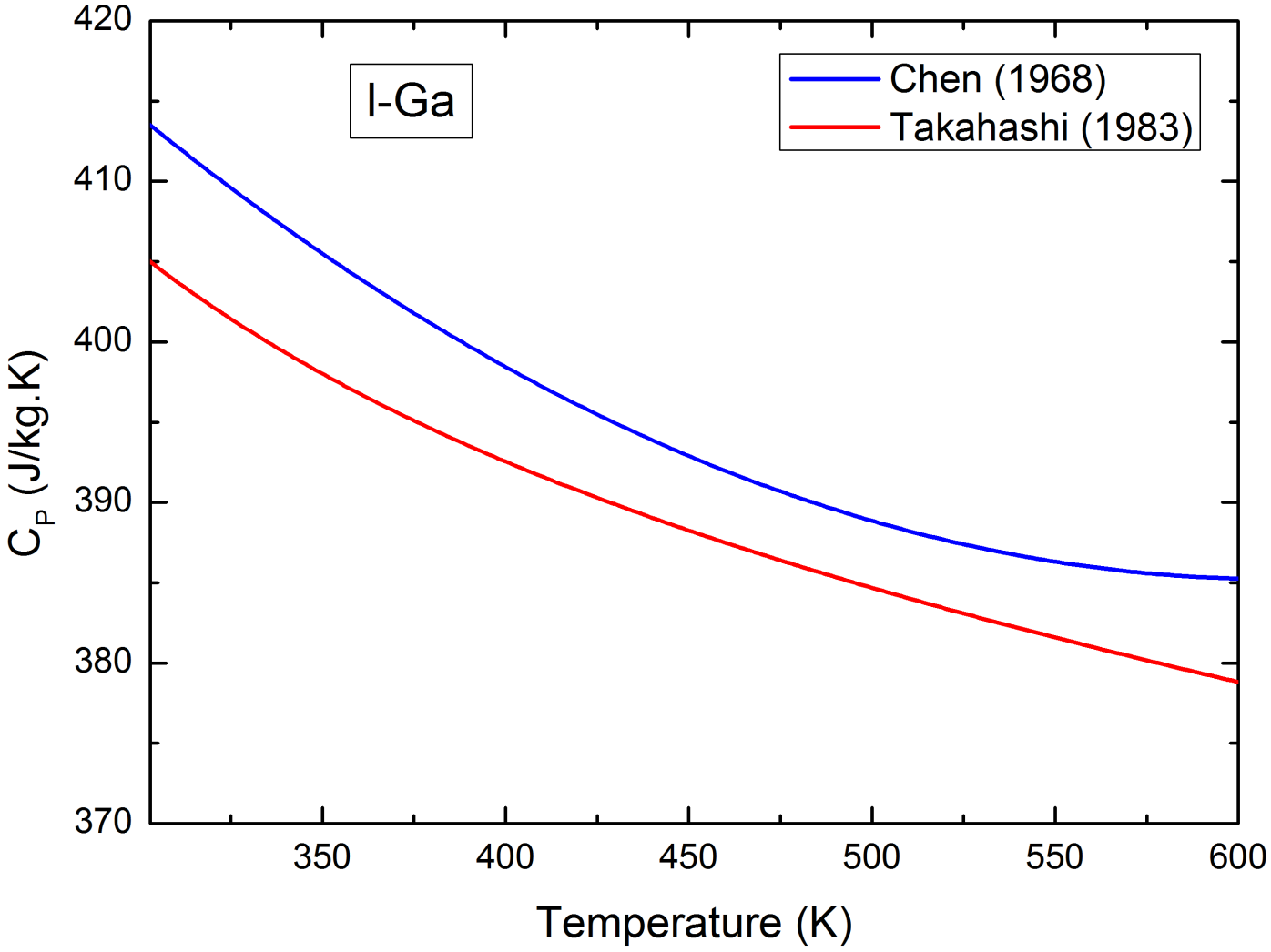
Y. Takahashi, H. Kadokura, and H. Yokokawa, *J. Chem. Therm. 15:65 (1983).*

Smoothed heat capacities for liquid gallium from data of Takahashi *et al*. are given by

$$C_p = 27.49 - 2.426 \times 10^{-3}T + 1.361 \times 10^5/T^2 \qquad (5)$$

in which we have corrected a decimal point misplaced in the original paper [16]. The equation covers the temperature range 250–600 K.

International Journal of Thermophysics, Vol. 5, No. 2, 1984
Thermodynamic Properties by Levitation Calorimetry
V. High-Temperature Heat Content of Liquid Gallium I
R. L. Montgomery, P. C. Sundareswaran, D. W. Ball, and J. L. Margrave


I-Ga
Chen (1968)
Takahashi (1983)
C_P (J/kg.K)
420
410
400
390
380
370
350
400
450
500
550
600
Temperature (K)

The Heat Capacity of Gallium from 15 to 320°K. The Heat of Fusion at the Melting Point

George B. Adams Jr., Herrick L. Johnston , Eugene C. Kerr

J. Am. Chem. Soc., 1952, 74 (19), pp 4784–4787
DOI: 10.1021/ja01139a017
Publication Date: October 1952

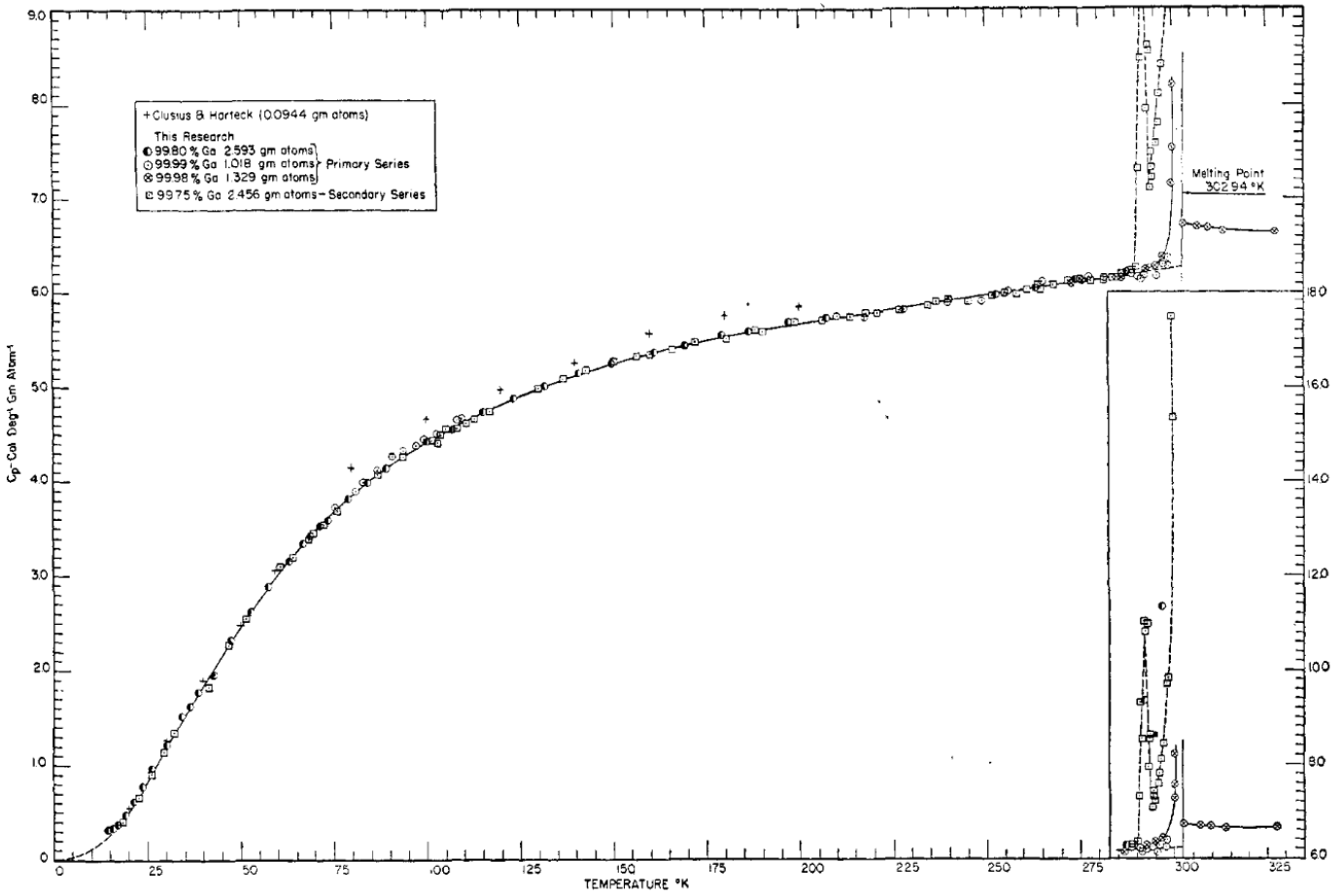


Fig. 2.—Heat capacity of gallium.

6.1. Main group 0: inorganic compounds

6.1.1. Sub group 01: elements

6.1.1.1. Gallium (1-009)

Name:	Gallium
Formula:	Ga
CAS-RN:	7440-55-3
Group No:	1-009

Experimental heat capacities (1.9.1)

Reference	Note	*T*/K	nPts		Err/%	Pur/%	Method	Type	Calor.	Cal. Method
1933ROT/MEY2	N	298.1–313.1	2		n/a	n/a	n/a	*p*	DSIO	1933ROT/MEY2
1934ROT/MEY	N	298.1–373.1	2	S	n/a	n/a	n/a	avg	DSIO	1933ROT/MEY2
1952ADA/JOH		306.9–322.8	4		n/a	99.98	melpt	*p*	BSAO	1952ADA/JOH
1969BOI/BRO		302.9–307.6	7		0.40	99.9999	anal	*p*	BDCT	1965STE/CAL
1983TAK/KAD		298.3–613.4	87		1.00	99.9999	anal	*p*	BDHO	1979TAK/YOK
1984AMI/MIN		304.4–319.2	27		n/a	99.9999	anal	*p*	BSAO	1979AMI/LEB

Reference	Notes
1933ROT/MEY2	constant value calculated from temperature dependence of enthalpy by the authors; correct data in 1934ROT/MEY
1934ROT/MEY	corrected datum in 1933ROT/MEY2; a constant value calculated from temperature dependence of enthalpy by the authors

Heat Capacity of Liquids: Critical Review and Recommended Values. Supplement II
Zabransky, M (Zabransky, Milan); Kolska, Z (Kolska, Zdenka); Ruzicka, V (Ruzicka, Vlastimil, Jr.); Domalski, ES (Domalski, Eugene S.)
JOURNAL OF PHYSICAL AND CHEMICAL REFERENCE DATA **39** (2010)

Density

back to the table of contents

W.H.Hoather (1936)
Defrain(1960)
V.H.Köster, F.Hensel, E.U.Franck (1970)
M.Inui (1992)
K.Tamura *et al* JNCS (1993)
Prokhorenko *et al* (2000)
Lyapin (2008)
S. D. Crockett and C.W.Greeff (2009) (SESAME)
H.Geng (2010)
Giordano (2011)
Assael (2012)
T.Yu (2012)
Yagafarov (2012)
Li(2014)
S.Ayrinhac *et al* (2015)

W.H.Hoather (1936)

volume of gallium.

§ 6. RESULTS

The results in the fifth column of table 1 are given as the ratio V_2/V_1, where V_1 is the volume of gallium at the initial temperature 32·38° C. and V_2 is the volume at a higher temperature t. Values for the coefficient of expansion of the quartz were taken from the tables.

By the method of least squares, the following equation has been found for the ratio V_2/V_1:

$$\frac{V_2}{V_1} = 0{\cdot}99587 + \frac{1}{10^6}(128{\cdot}40\,t - 0{\cdot}03780\,t^2 + 0{\cdot}00003401\,t^3 - 0{\cdot}00000001250\,t^4) \quad \ldots(1).$$

* The figures given on p. 704 are for the second calibration.

The values obtained for the density* of gallium, corrected to 29·8° C., are as follows:

Density by weight thermometer	6·0946 g./ml.
Density by first dilatometer	6·0953 g./ml.
Mean density at 29·8° C.	6·0949 g./ml.
Value obtained by Richards and Boyer at 29·8° C. ...	6·0947 g./ml.
Density at 32·38° C.	6·0930 g./ml.

Values for the density of gallium at temperatures up to 1000° C. can be calculated from equation (1).

@ 302.8 K

W.H.Hoather , *The density and coefficient of expansion of liquid gallium over a wide range of temperature*, *Proc. Phys. Soc.* **48** 699 (1936) doi:10.1088/0959-5309/48/5/303

Defrain (1960)

La transformation de la phase solide instable en phase solide stable se fait avec une forte dilatation que nous avons mesurée au moyen d'un dilatomètre à alcool [2]. A — 22 °C, les masses spécifiques respectives des phases solide stable, solide instable et liquide sont : 5,92 g/cm³, 6,23 g/cm³ [2] et 6,135 g/cm³ ; celles du solide stable et du liquide sont en accord avec les données de la littérature [4], [5], [6].

Sur quelques propriétés thermodynamiques d'une phase solide du gallium instable à la pression atmosphérique

A. Defrain et I. Epelboin

J. Phys. Radium **21**, 76-77 (1960)

doi: 10.1051/jphysrad:0196000210107601

Köster (1970)

Technique : pycnometer (relative density)

$$\rho = 6{,}11564 - 7{,}37437 \cdot 10^{-4} t + 1{,}37767 \cdot 10^{-7} t^2 + 1{,}347 \cdot 10^{-5} p.$$

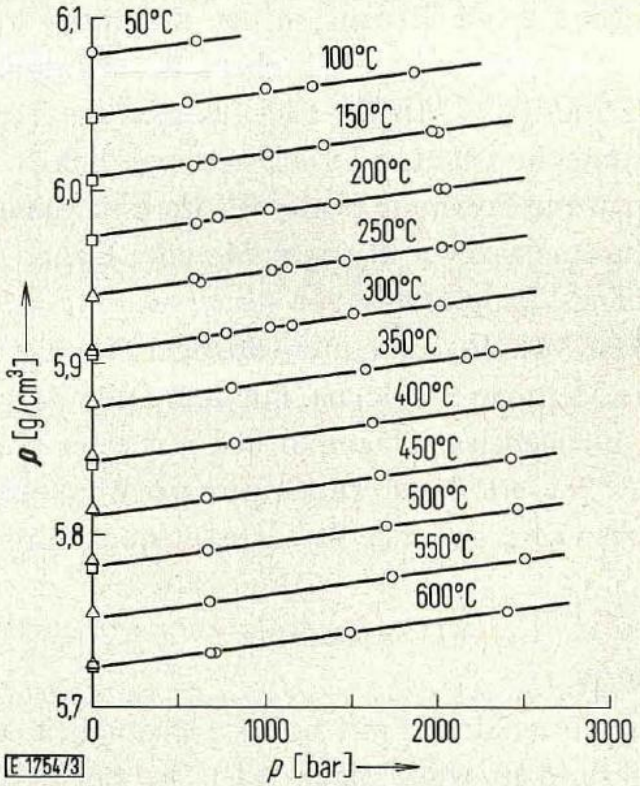


Tabelle 2

Ausgeglichene Werte der Dichte des Galliums als Funktion von Druck und Temperatur

t °C \ p bar	1	500	1000	1500	2000	2500
50	6,0791	6,0858				
100	6,0433	6,0500	6,0567	6,0635	6,0702	6,0769
150	6,0081	6,0148	6,0216	6,0283	6,0350	6,0418
200	5,9737	5,9804	5,9871	5,9939	5,9906	6,0073
250	5,9399	5,9466	5,9534	5,9601	5,9668	5,9735
300	5,9068	5,9135	5,9203	5,9270	5,9337	5,9405
350	5,8744	5,8811	5,8879	5,8946	5,9013	5,9081
400	5,8427	5,8494	5,8562	5,8629	5,8696	5,8764
450	5,8117	5,8184	5,8252	5,8319	5,8386	5,8454
500	5,7814	5,7881	5,7948	5,8016	5,8083	5,8150
550	5,7517	5,7584	5,7652	5,7719	5,7786	5,7854
600	5,7228	5,7295	5,7362	5,7430	5,7497	5,7564

H. Köster, F. Hensel, and E. U. Franck,
Ber. Bunsen-Ges. Phys. Chem. **74**, 43 (1970)

M.Inui (1992)

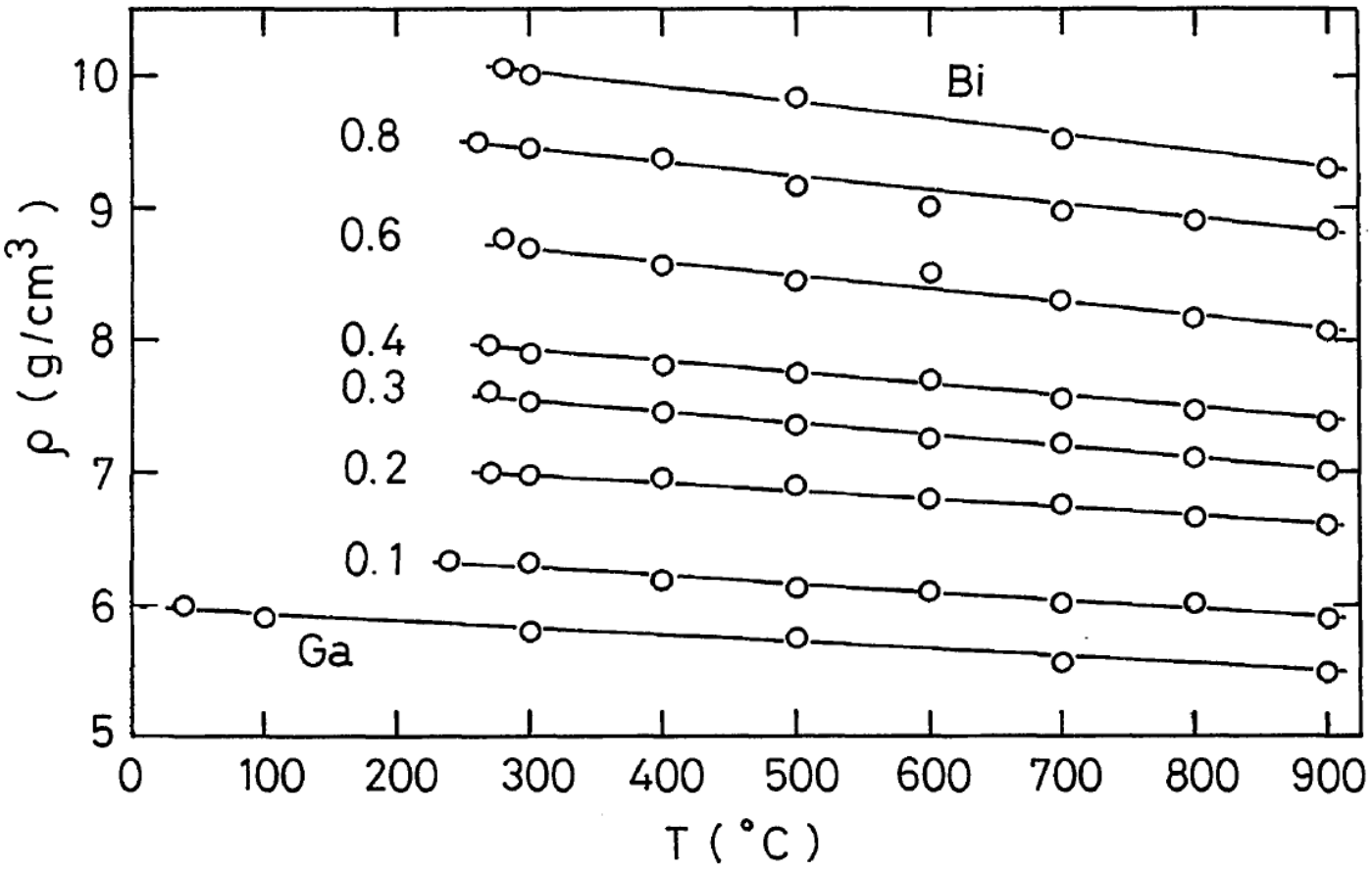


Fig. 5. Temperature dependence of density of liquid $Bi_{1-x}Ga_x$.

K.Tamura (1993)

Expanded Gallium at high T

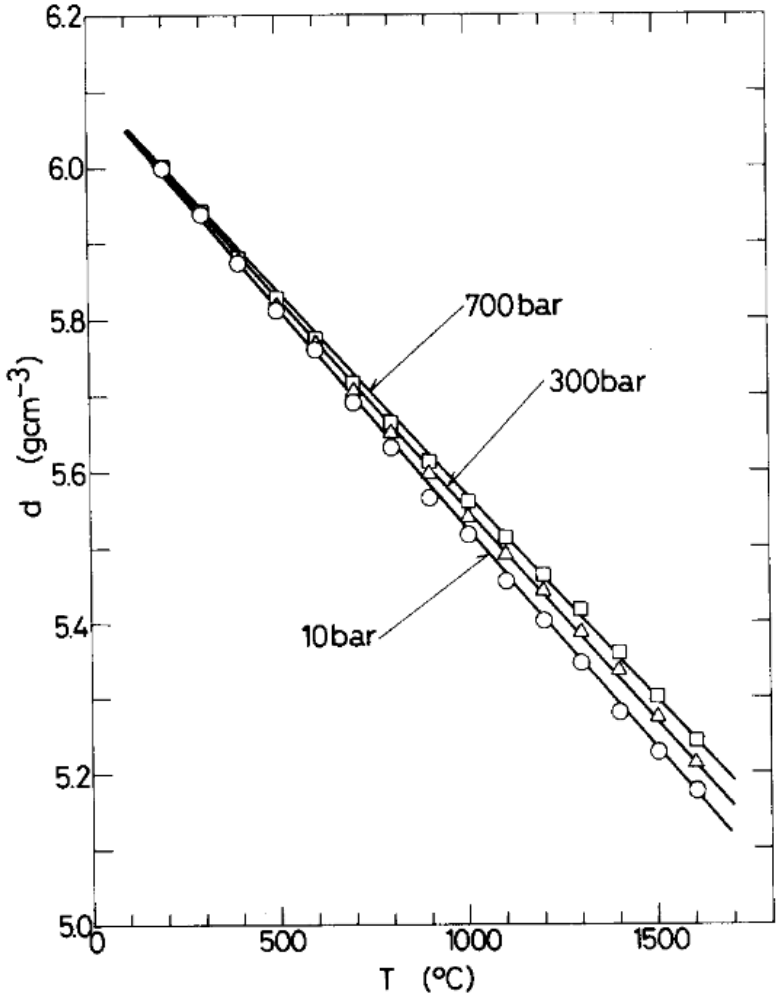


Fig. 1. Density of expanded liquid Ga as a function of temperature. Circles, ○, △, □: the data at 10, 300 and 700 bar, respectively.

Kozaburo Tamura, Shinya Hosokawa *X-ray diffraction measurements for expanded liquid gallium*, JNCS **156–158** (2), 650-653 (1993)

V.Ya.Prokhorenko (2000)

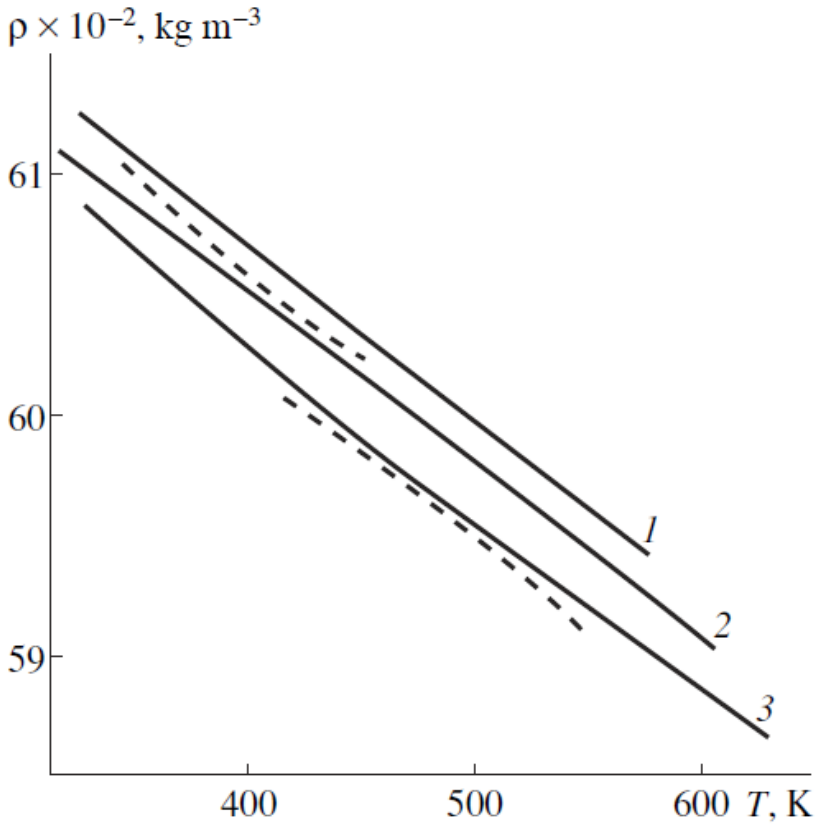
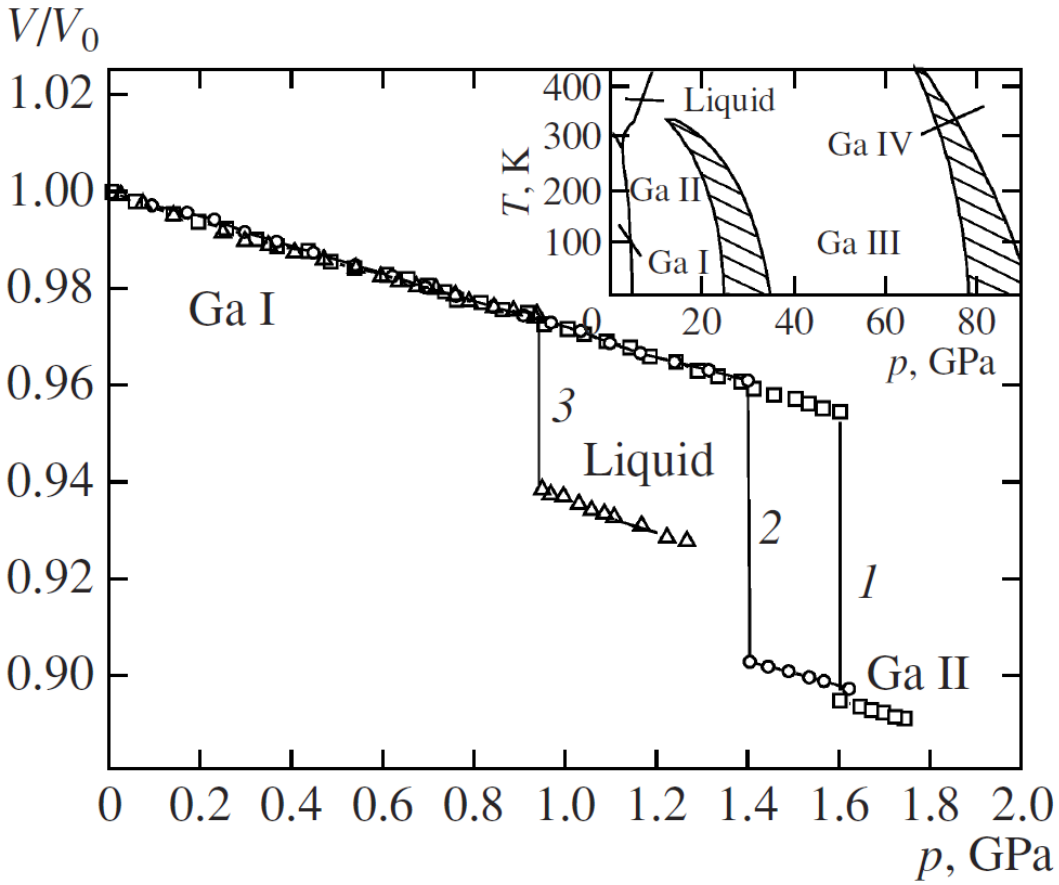


Fig. 7. The density of liquid gallium: (*1*) [41], (*2*) [40], (*3*) [42].

V. Ya. Prokhorenko, *High Temperature,* **38**(6) 954–968 (2000)

G.Lyapin (2008)

Technique : ultrasonic piezometer (isothermal compression, 5 MHz, change in the sample length & time of travel)



T=285 K (11.85 °C)

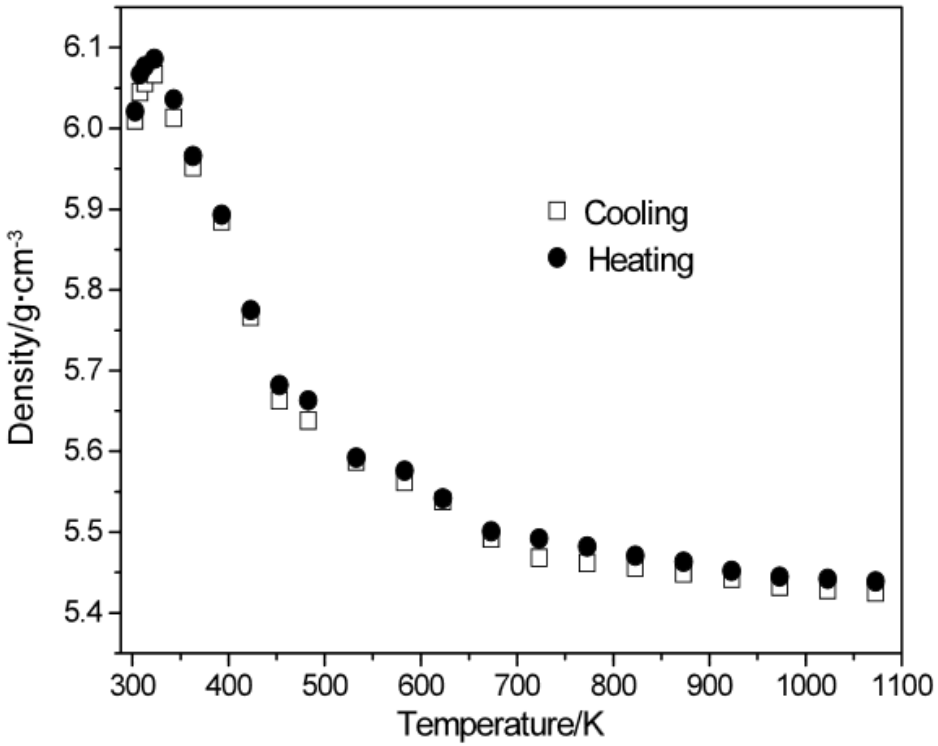
ρ_0(Ga-I)=5904 kg/m^3

(ref.: V.Y.Prokhorenko *et al* (2000), table 9)

P(GPa)	V/V_0
0.94831	0.93811
0.96613	0.93709
0.99465	0.93674
1.0285	0.93488
1.057	0.93386
1.0856	0.933
1.107	0.93249
1.1658	0.93061
1.2228	0.92807
1.2656	0.92721

G. Lyapin, E. L. Gromnitskaya, O. F. Yagafarov, O. V. Stal'gorova, V. V. Brazhkin
Elastic properties of crystalline and liquid gallium at high pressures
Journal of Experimental and Theoretical Physics
107 (5) 818-827 (2008)

H.Geng (2010)



a Relation between density and temperature of Ga melt

H.Geng
Applied Physics A
98 (1) 227-232 (2010)

V.M.Giordano (2011)

the width. We can investigate the density dependence of the dispersion curves by looking at the behavior of the maximum of the longitudinal dispersion curve ν_{MAX} (see inset of Fig. 2). The density of liquid Ga is 6.095 g/cm^3 at the room pressure melting point, and can be estimated to be 6.33 and 6.73 g/cm^3 at 0.8 GPa and 295 K and at 6.1 GPa and 393 K, respectively.[21] ν_{MAX} is found to depend linearly on the density, as predicted by a simple quasiharmonic approximation;[22] moreover, the intercept of the best fitting line is compatible with zero, and indeed we have verified that the acoustic dispersions collapse on each other once scaled by the density.

(21)S. D. Crockett andC.W.Greeff, AIPConf. Proc. **1195, 1191 (2009).**

P (Gpa)	T(°C)	ρ
0	29.8	6095
0.8	21.85	6330
6.1	119.85	6730

Inelastic x-ray scattering study of liquid Ga: Implications for the short-range order
Valentina M. Giordano and Giulio Monaco
PRB **84**, 052201 (2011)

Assael (2012)

Gallium

Primary data							
Yagodin[23]	2008	γ-Ray (Abs)	99.999	0.2	50	D	526–1501
Stankus[24]	1991	γ-Ray (Abs)	99.9997	0.2	15	E	310–1000
Alchagirov[25]	1974	Areometer (Abs)	na	0.1	11	E	310–773
Nal'giev[26]	1973	Pycnometer (Abs)	99.99	na	10	P	303–723
Koster[27]	1970	Pycnometer (Abs)	99.999	0.03	12	P	323–873
Nizhenko[28]	1965	Sessile drop (Abs)	na	0.03	11	E	380–1580
Secondary data							
Geng[29]	2010	Archimedean	99.9	5	20	D	312–1073
Yatsenko[30]	1972	Sessile drop (Abs)	na	1.5	18	D	327–1179
Spells[31]	1935	na	na	na	17	P	326–1373

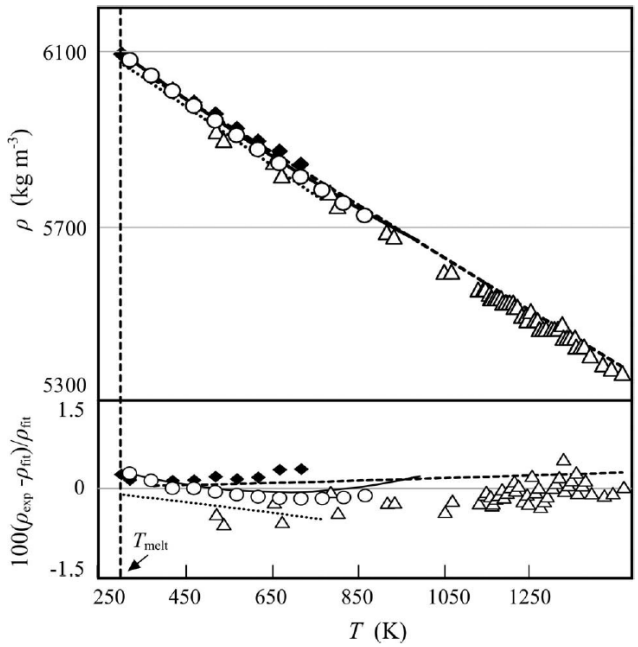
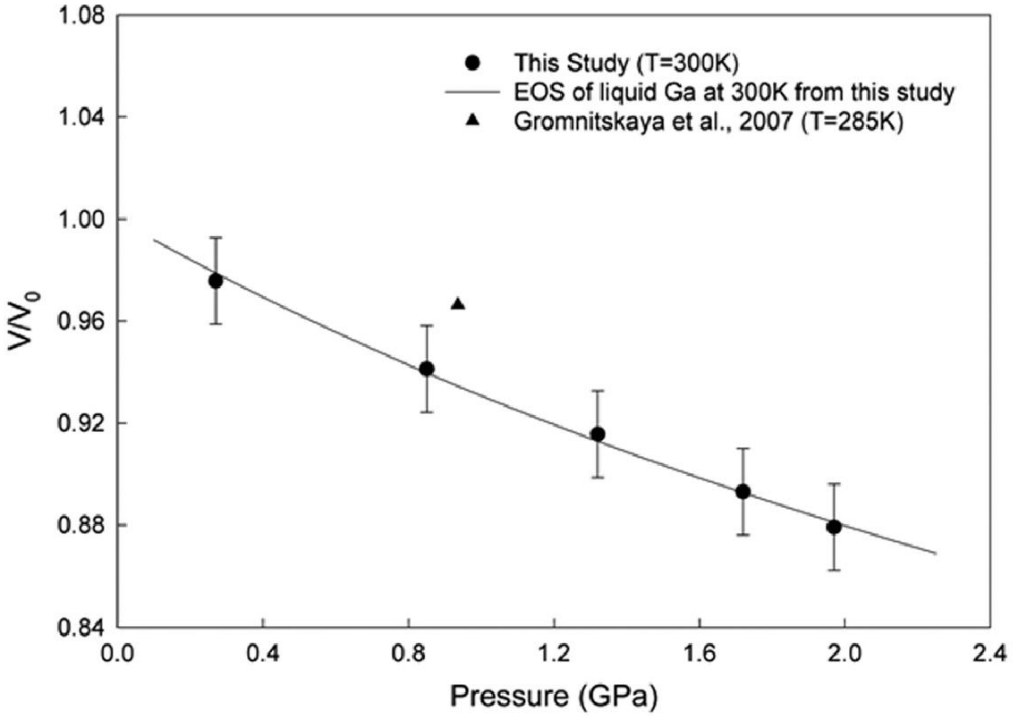


FIG. 3. Primary density data and their percentage deviations from Eq. (1) for liquid gallium as a function of temperature. Yagodin *et al.*[23] (Δ), Stankus and Tyagel'sky[24] (——), Alchagirov[25] (···), Nal'giev and Ibragimov[26] (♦), Nizhenko *et al.*[28] (- -), Köster *et al.*[27] (○).

J. Phys. Chem. Ref. Data 41, 033101 (2012); http://dx.doi.org/10.1063/1.4729873

T.Yu (2012)

Technique : reverse Monte Carlo modeling from X-ray scattering data

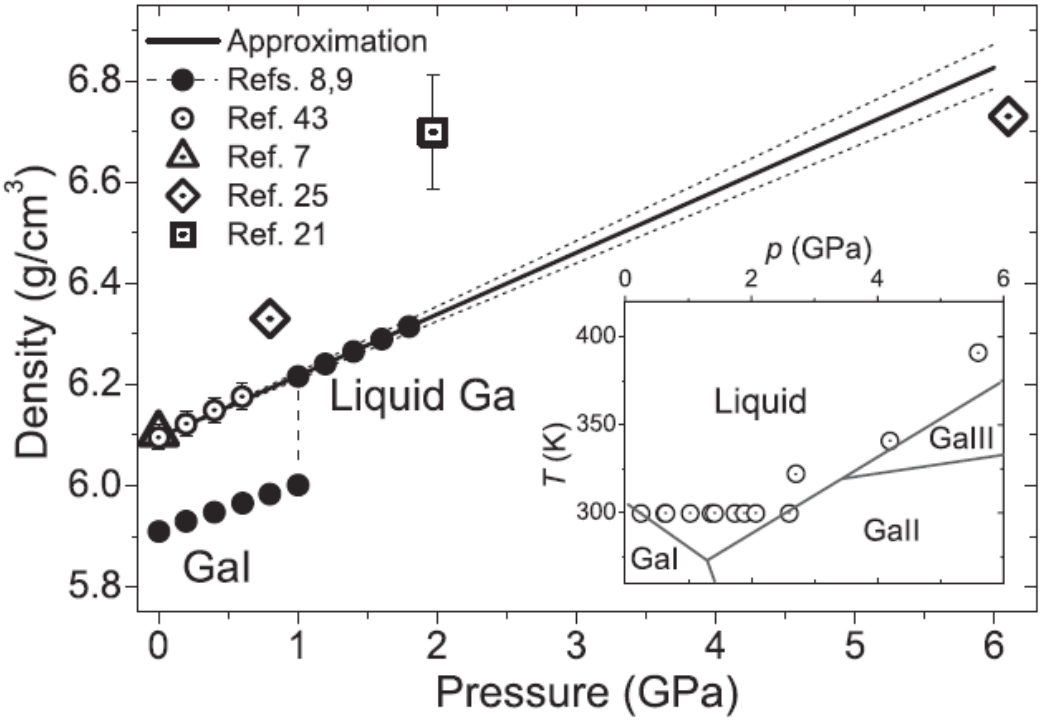


Software : WINDIG
T=300 K
ρ_0(l-Ga,29.8°C)=6095 kg/m^3

P(GPa)	V/V0	ΔV/V0	ρ	Δ ρ
0.27221	0.97579	0.01699	6246.22101	108.75628
0.85207	0.94121	0.01699	6475.7412	116.93013
1.32223	0.91564	0.01699	6656.54624	123.51439
1.72073	0.89308	0.017	6824.65835	129.87013
1.9723	0.8791	0.01684	6933.22716	132.81259

Tony Yu, Jiuhua Chen, Lars Ehm, Shu Huang, Quanzhong Guo *et al*.
Study of liquid gallium at high pressure using synchrotron x-ray
J. Appl. Phys. **111**, 112629 (2012)
doi: 10.1063/1.4726256

O.F.Yagafarov (2012)

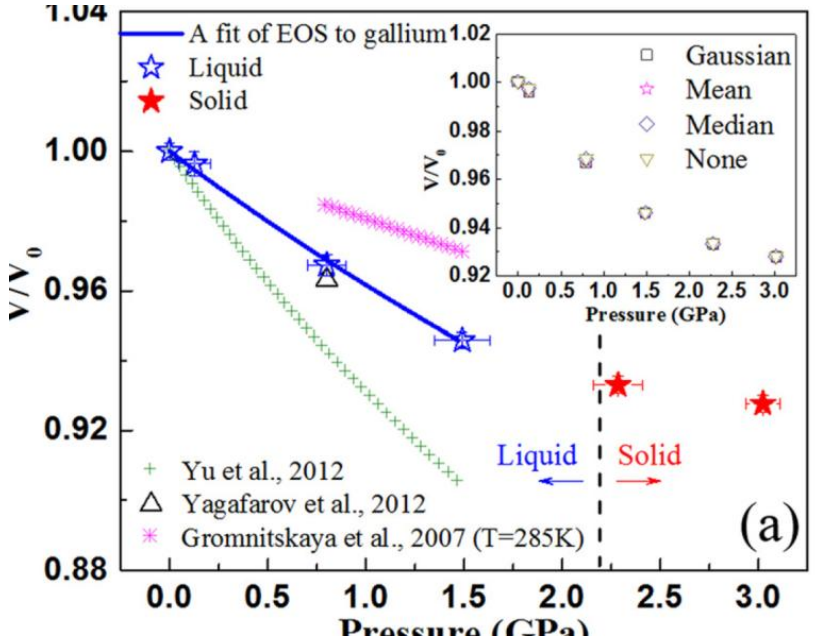


O. F. Yagafarov Y. Katayama, V. V. Brazhkin, A. G. Lyapin, and H. Saitoh
Energy dispersive x-ray diffraction and reverse Monte Carlo structural study of liquid gallium under pressure
Phys. Rev. B **86**, 174103 (2012)

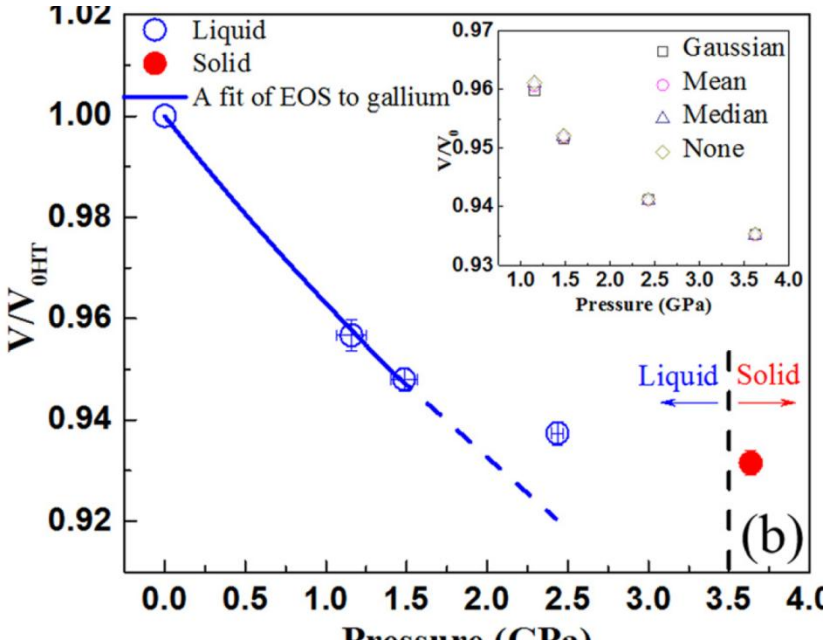
Li (2014)

Technique : synchrotron X-ray microtomography

T=300 K



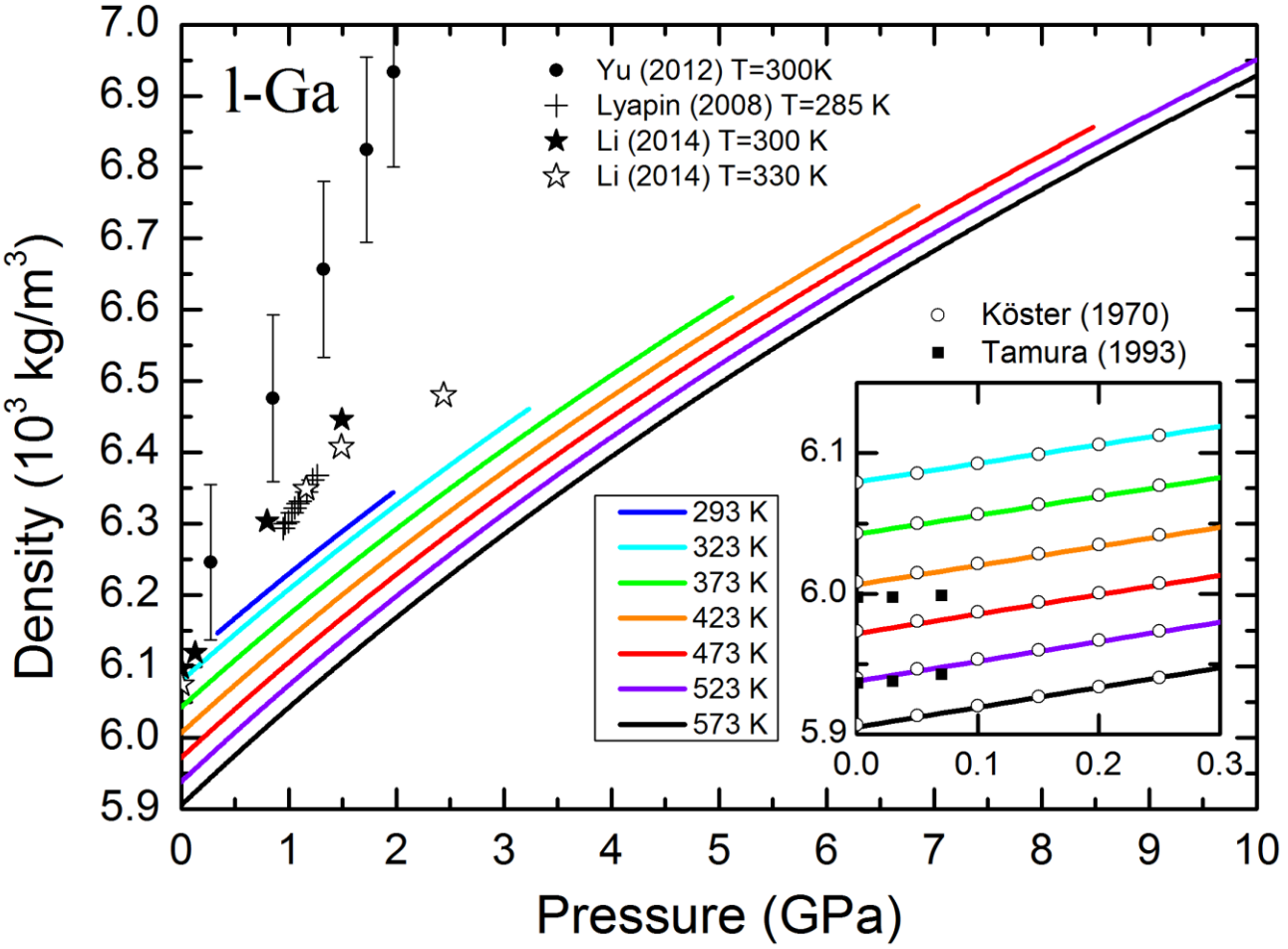
T=330 K



Study of liquid gallium as a function of pressure and temperature using synchrotron x-ray microtomography and x-ray diffraction Li, Renfeng and Li, Liangliang and Yu, Tony and Wang, Luhong and Chen, Jiaxuan and Wang, Yanbin and Cai, Zhonghou and Chen, Jiuhua and Rivers, Mark L. and Liu, Haozhe, Applied Physics Letters, **105**, 041906 (2014), DOI:http://dx.doi.org/10.1063/1.4891572

S.Ayrinhac (2015)

Technique : adiabatic sound velocity measurements + numerical procedure to calculate isothermal density



S Ayrinhac *et al, J. Phys.: Condens. Matter* **27** 275103 (2015)

Thermal expansion coefficient

↑ back to the table of contents

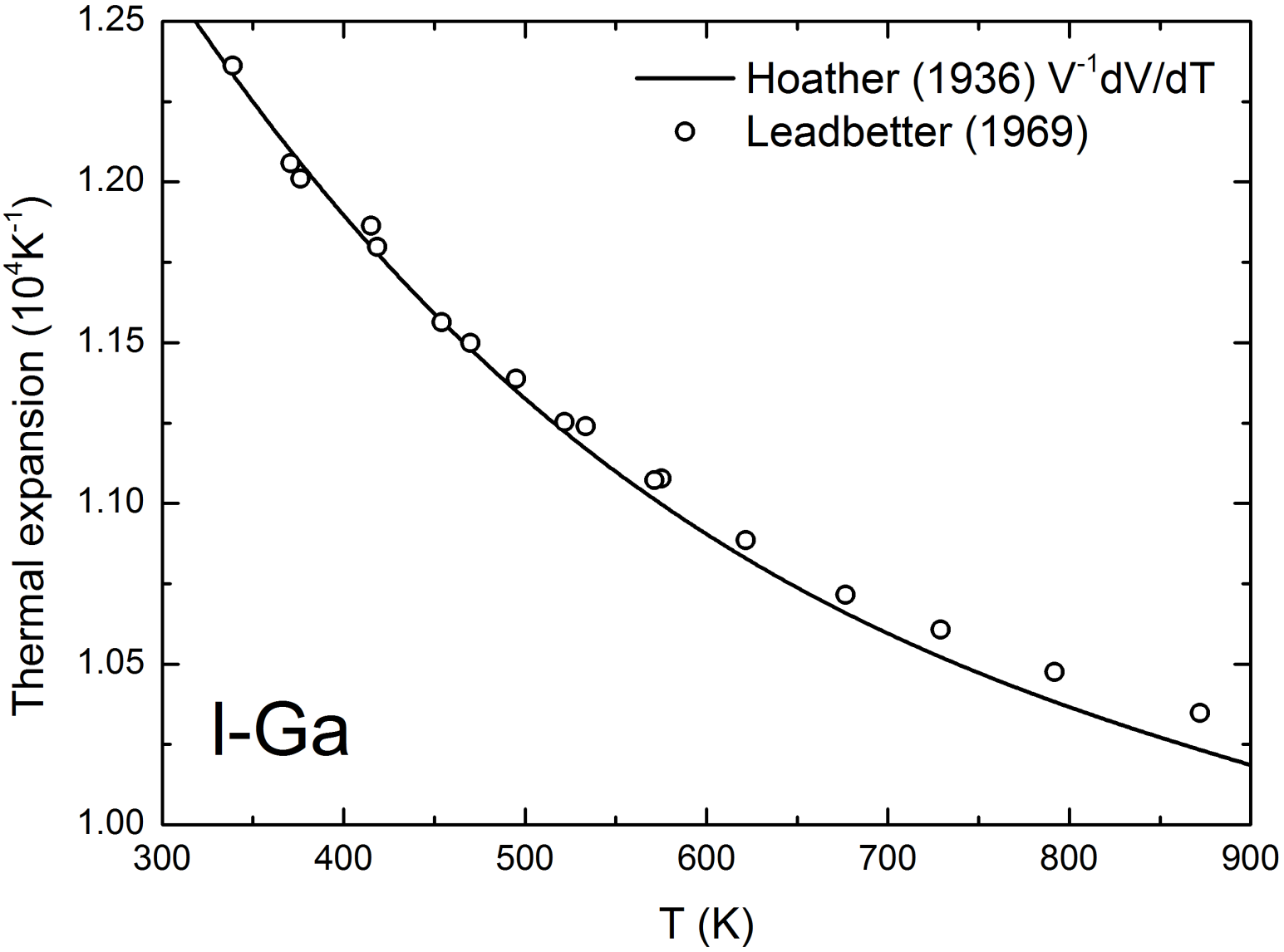
For isotropic materials the volumetric thermal expansion coefficient is three times the linear coefficient: $\alpha_V = 3\alpha_L$

Table 2. The thermal expansion coefficient β of liquid gallium

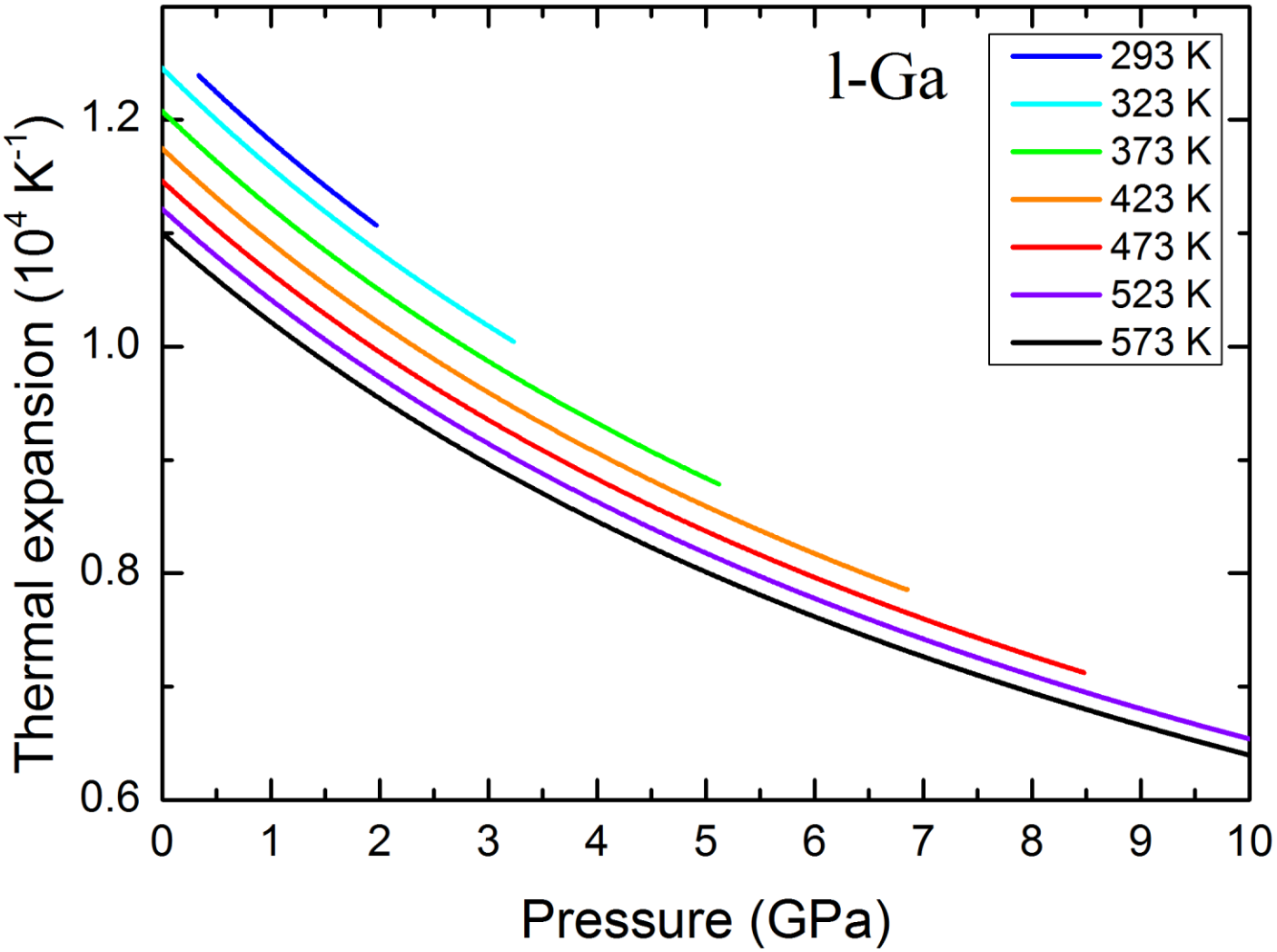
Experiment 1		Experiment 2	
t (°c)	$\beta \times 10^4$ (deg^{-1})	t (°c)	$\beta \times 10^4$ (deg^{-1})
65·8	1·2362	97·5	1·2058
103·0	1·2010	145·4	1·1798
141·9	1·1863	196·8	1·1499
180·8	1·1564	248·7	1·1253
222·0	1·1388	298·1	1·1072
260·4	1·1240	348·5	1·0885
302·0	1·1077	403·5	1·0716
		456·0	1·0607
		518·7	1·0476
		598·8	1·0348

Anharmonic effects in the thermodynamic properties of solids III. A liquid gallium immersion dilatometer for the range 50-700 °C: thermal expansivities of Hg, Ga, NaCl and KCl

A J Leadbetter and D M T Newsham *J. Phys. C: Solid State Phys.* **2** 210 (1969) doi:10.1088/0022-3719/2/2/303


Hoather (1936) V-1dV/dT
Leadbetter (1969)
I-Ga
Thermal expansion (10^4K^-1)
T (K)
1.25
1.20
1.15
1.10
1.05
1.00
300
400
500
600
700
800
900

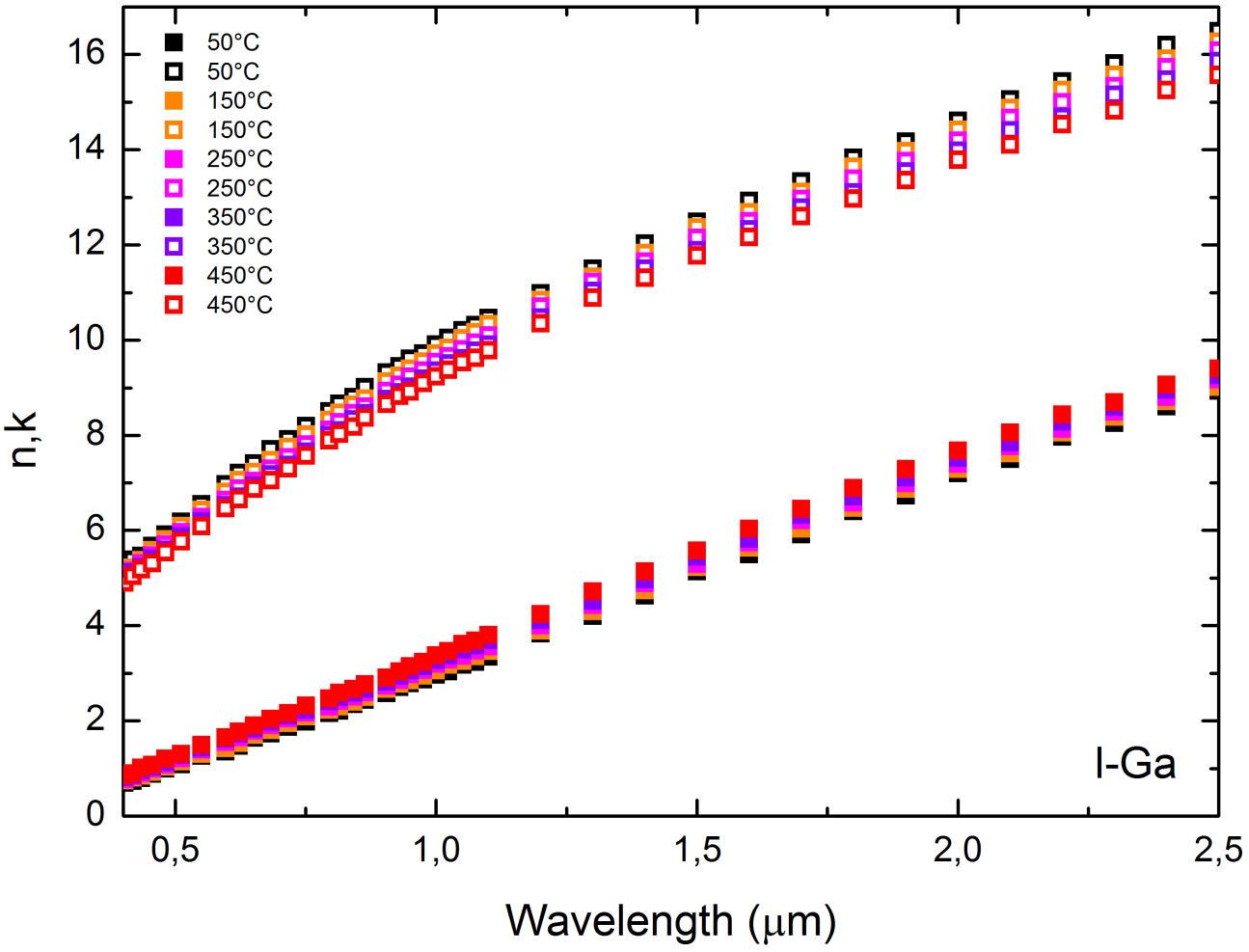
S.Ayrinhac *et al* (2015)



S Ayrinhac *et al, J. Phys.: Condens. Matter* **27** 275103 (2015)

Refractive index

back to the table of contents



Electronic characteristics and dispersion of optical constants of liquid gallium in the 0.4-2.5-μm spectral region
Teshev, R. Sh.; Shebzukhov, A. A. Optics and Spectroscopy, Volume 65, Issue 5, November 1988, pp.693-695

Electronic characteristics and dispersion of optical constants of liquid gallium in the 0.4-2.5-μm spectral region

Teshev, R. Sh.; Shebzukhov, A. A.

Optics and Spectroscopy,

65 (5) 693-695 (1988)

TABLE I. Optical constants of gallium in the liquid state.

λ, мкм	T (°C)									
	50		150		250		350		450	
	n	x	n	x	n	x	n	x	n	x
0.403	0.70	5.18	0.75	5.09	0.78	5.02	0.82	4.96	0.86	4.90
0.418	0.74	5.38	0.81	5.21	0.84	5.14	0.87	5.11	0.90	5.04
0.435	0.80	5.46	0.85	5.37	0.91	5.30	0.96	5.22	1.02	5.18
0.456	0.89	5.67	0.93	5.58	1.00	5.47	1.04	5.40	1.08	5.31
0.481	1.00	5.90	1.04	5.81	1.09	5.70	1.14	5.59	1.21	5.54
0.511	1.09	6.17	1.15	6.08	1.22	5.95	1.29	5.86	1.31	5.77
0.550	1.27	6.54	1.31	6.42	1.40	6.27	1.44	6.18	1.50	6.08
0.596	1.36	6.96	1.43	6.80	1.56	6.63	1.62	6.52	1.65	6.46
0.622	1.48	7.20	1.54	7.05	1.65	6.87	1.73	6.70	1.77	6.65
0.651	1.64	7.40	1.70	7.22	1.79	7.03	1.84	6.93	1.90	6.87
0.683	1.73	7.70	1.80	7.47	1.91	7.29	1.98	7.17	2.04	7.05
0.716	1.87	7.91	1.95	7.75	2.05	7.53	2.11	7.37	2.16	7.30
0.751	1.98	8.19	2.09	8.01	2.17	7.80	2.23	7.65	2.32	7.57
0.795	2.16	8.50	2.23	8.32	2.30	8.11	2.41	8.00	2.47	7.89
0.814	2.21	8.66	2.30	8.47	2.42	8.27	2.50	8.10	2.59	8.03
0.842	2.35	8.80	2.40	8.64	2.51	8.46	2.59	8.33	2.67	8.18
0.863	2.44	9.01	2.50	8.77	2.60	8.60	2.67	8.46	2.77	8.37
0.905	2.58	9.31	2.67	9.12	2.74	8.93	2.82	8.76	2.91	8.66
0.930	2.71	9.44	2.78	9.24	2.86	9.05	2.95	8.90	3.04	8.83
0.950	2.79	9.60	2.85	9.39	2.98	9.22	3.06	9.02	3.15	8.92
0.975	2.87	9.71	2.95	9.54	3.07	9.35	3.15	9.18	3.24	9.09
1.000	2.97	9.90	3.06	9.71	3.20	9.53	3.28	9.35	3.38	9.23
1.023	3.04	10.04	3.18	9.83	3.29	9.65	3.38	9.50	3.47	9.37
1.050	3.18	10.20	3.26	10.03	3.37	9.80	3.50	9.61	3.62	9.53
1.075	3.24	10.31	3.36	10.16	3.48	9.94	3.59	9.77	3.69	9.62
1.100	3.35	10.46	3.47	10.33	3.57	10.09	3.70	9.90	3.80	9.78
1.200	3.83	10.98	3.89	10.84	4.00	10.70	4.11	10.47	4.24	10.35
1.300	4.20	11.49	4.30	11.32	4.43	11.21	4.52	11.03	4.72	10.89
1.400	4.63	12.02	4.74	11.82	4.89	11.64	4.97	11.49	5.14	11.30
1.500	5.14	12.48	5.23	12.36	5.30	12.14	5.45	11.88	5.58	11.77
1.600	5.50	12.92	5.64	12.68	5.75	12.49	5.83	12.32	6.03	12.16
1.700	5.91	13.32	6.03	13.11	6.21	12.96	6.32	12.78	6.45	12.60
1.800	6.40	13.82	6.47	13.63	6.58	13.38	6.71	13.10	6.89	12.97
1.900	6.73	14.16	6.87	13.96	6.99	13.75	7.11	13.53	7.29	13.35
2.000	7.20	14.60	7.29	14.41	7.40	14.18	7.52	13.97	7.68	13.78
2.100	7.50	15.05	7.62	14.87	7.77	14.66	7.85	14.40	8.06	14.10
2.200	7.97	15.42	8.06	15.25	8.14	14.99	8.29	14.68	8.44	14.53
2.300	8.26	15.80	8.39	15.56	8.50	15.33	8.60	15.15	8.70	14.82
2.400	8.61	16.19	8.72	15.90	8.81	15.72	8.96	15.46	9.06	15.25
2.500	8.94	16.48	9.02	16.26	9.17	16.07	9.26	15.85	9.40	15.56

λ (μm)	n (50°C)	k (50°C)
0.403	0.7	5.18
0.418	0.74	5.38
0.435	0.8	5.46
0.456	0.89	5.67
0.481	1	5.9
0.511	1.09	6.17
0.55	1.27	6.54
0.596	1.36	6.96
0.622	1.48	7.2
0.651	1.64	7.4
0.683	1.73	7.7
0.716	1.87	7.91
0.751	1.98	8.19
0.795	2.16	8.5
0.814	2.21	8.66
0.842	2.35	8.8
0.863	2.44	9.01
0.905	2.58	9.31
0.93	2.71	9.44
0.95	2.79	9.6
0.975	2.87	9.71
1	2.97	9.9
1.023	3.04	10.04
1.05	3.18	10.2
1.075	3.24	10.31
1.1	3.35	10.46
1.2	3.83	10.98
1.3	4.2	11.49
1.4	4.63	12.02
1.5	5.14	12.48
1.6	5.5	12.92
1.7	5.91	13.32
1.8	6.4	13.82
1.9	6.73	14.16
2	7.2	14.6
2.1	7.5	15.05
2.2	7.97	15.42
2.3	8.26	15.8
2.4	8.61	16.19
2.5	8.94	16.48

Electronic characteristics and dispersion of optical constants of liquid gallium in the 0.4-2.5-μm spectral region
Teshev, R. Sh.; Shebzukhov, A. A.
Optics and Spectroscopy,
65 (5) 693-695 (1988)

n(800 nm, 50°C)=2.17
k(800 nm, 50°C)=8.54

Optical investigation of the solid-liquid transition in gallium
R. Kofman, P. Cheyssac and R. Garrigos, Journal of Physics F: Metal Physics, 9 (12) 2345 (1979)

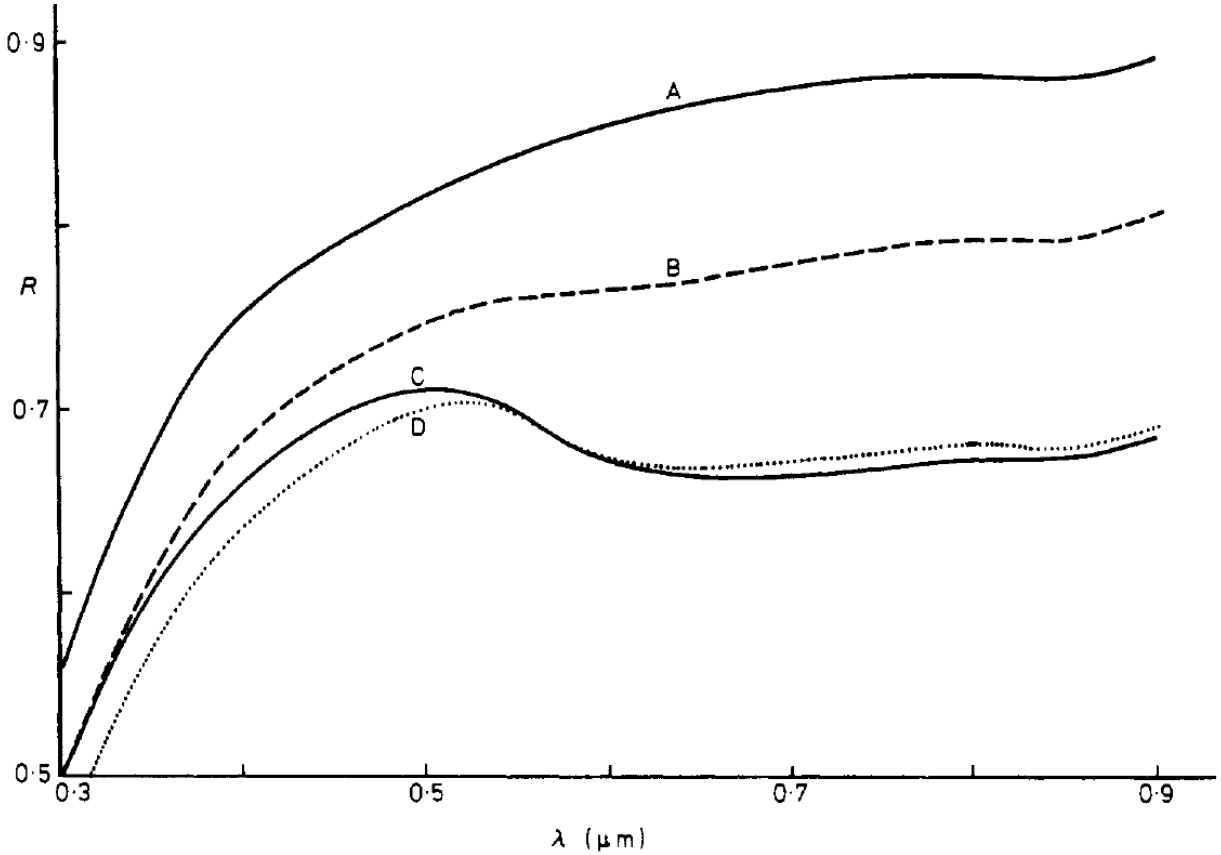


Figure 2. Plots of $R(\lambda)$ for different temperatures T(°C): A, 50; B, 29; C, 0 (all for increasing T); and D, −19 (for decreasing T).

Optical properties of Ga monocrystal in the 0.3-5-eV range
R. Kofman, P. Cheyssac, and J. Richard
Phys. Rev. B, **16**, 12 (1977)

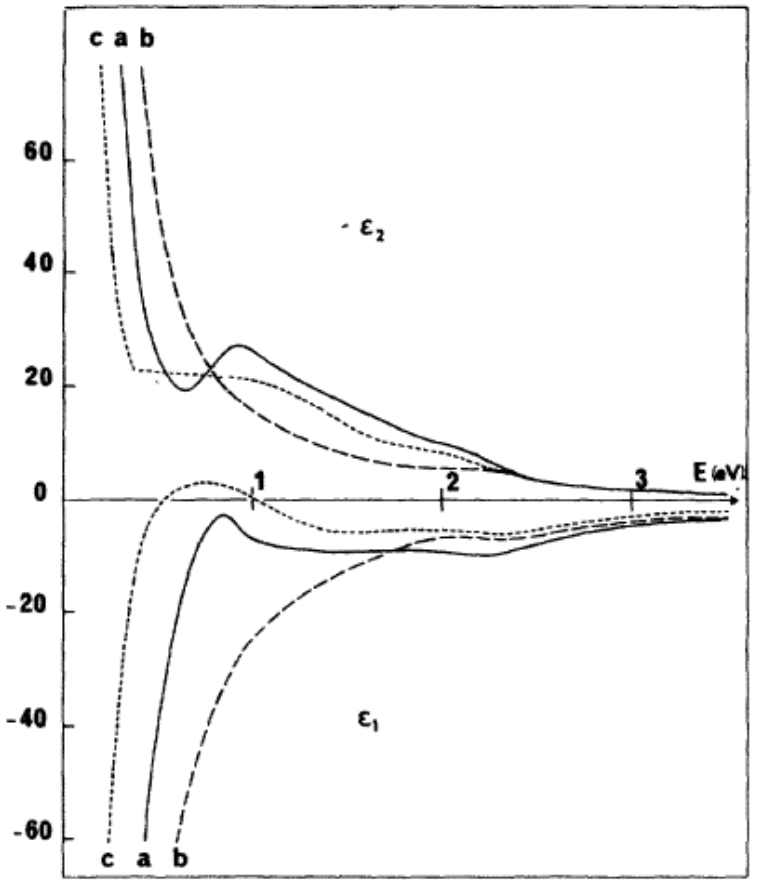
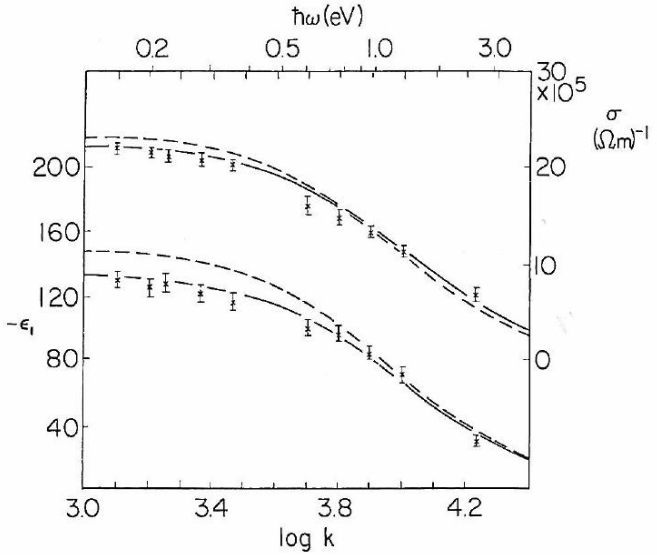
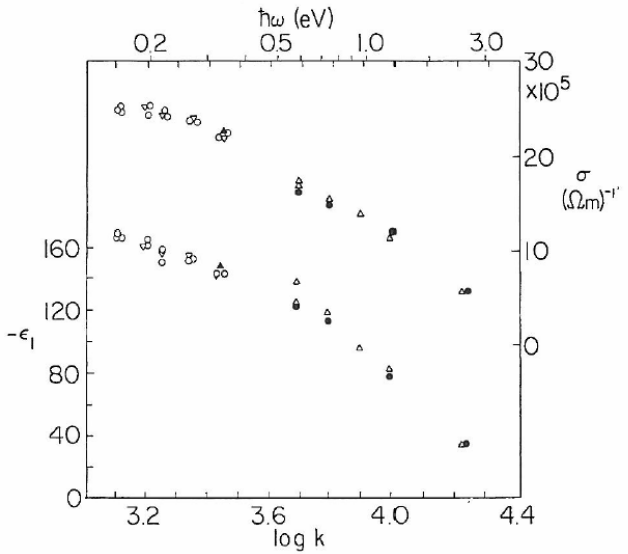


FIG. 10. Real ϵ_1 and imaginary ϵ_2 part of the dielectric constants along the three axes.

Comins, N. R.
The optical properties of liquid metals.
Philosophical Magazine
25 (4), 817-831 (1972)



The optical constants of liquid gallium (860°C) : × (present work).



The experimental results for σ and ϵ_1 for liquid gallium (600°C) showing values from five different specimens.

Optical properties

Shulz (1957), reflectance
Lenham (1963), 0.4-0.8 um, α-Ga
Lelyuk (1964), ellipsometry
Bor (1967), 0.4-0.65 um, nk, n^2-k^2
Rapp (1971)
Comins (1972), sigma, -epsilon1
Hunderi (1974), thin films
Ferraton (1976)
Kofman (1977), 0.25-4.1 um, R, Ga monocrystal
Jezequel (1977), 0.083-0.62 um, annealed thin films
Kofman (1979), 0.3-0.9um, sol-liq transition, thin film 0.1 um
Teshev (1988), 0.4-2.5 um
Regan (1997), thin film ~5 A

Electrical resistivity

back to the table of contents

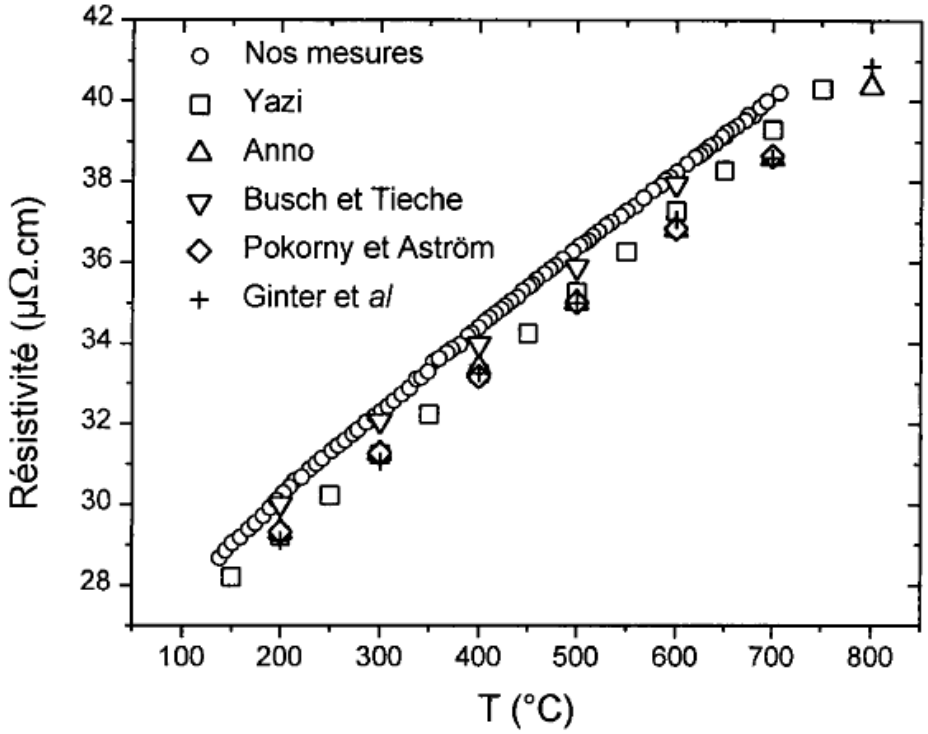


figure 3.3 :Résistivité électrique du gallium liquide en fonction de la température

Lamia Ben Hassine thesis (2000)