Full Paper _____ *Thematic Section:* Physicochemical Research.
Reference Object Identifier – ROI: jbc-01/17-52-10-140 *Subsection:* Metallurgy and Materials Science.
The Digital Object Identifier – DOI: 10.37952/ROI-jbc-01/17-52-10-140
Submitted on October 16, 2017.

Viscosity of liquid gallium

© **Vladimir V. Filippov*** and **Anastasia A. Belozerova**[+]
Institute of Metallurgy *UB RAS. Amundsena St., 101. Ekaterinburg, 620016. Sverdlovsk region. Russia.*
Phone: +7 (8343) 267-96-54. E-mail: aa_belozerova@mail.ru

*Supervising author; [+]Corresponding author
Keywords: viscosity, gallium, oscillating cup method, Arrhenius equation, liquid metal coolant.

Abstract

The low melting point of gallium makes it possible to widely use it as a coolant in cooling systems of nuclear reactors and high-power electronic components, as well as in metallic composite products. Information about the viscosity is very important for the optimal design and operation of devices used for the transport and pumping of liquid metals. However, the discrepancies in the results presented in the literature and the very limited temperature range of the studies require new precise measurements to obtain reliable data on the viscosity of liquid gallium over a wide temperature range. In the present paper, the viscosity of liquid gallium was determined by an oscillating cup from the room temperature to 1200 K. The error of the viscosity measurements did not exceed 2.5%. This method is the most reliable and widely used for measuring the viscosity of metallic melts at high temperatures. To obtain reliable experimental data on the viscosity of gallium, we studied the effect of the meniscus and the possibility of forming an oxide film on the surface of liquid gallium. It is established that the viscosity of liquid gallium over the entire temperature range is well described by the Arrhenius equation. The activation energy of the viscous flow of liquid gallium, determined from this equation, is 3813.2±28.7 J/mol. The obtained experimental results on the viscosity of liquid gallium are compared with the data available in the literature. The results of the comparison show that the results of our measurements are in good agreement with the most reliable literature data.

References

[1] V.Ya. Prokhorenko, V.V. Roshchupkin, M.A. Pokrasin, S.V. Prokhorenko, V.V. Kotov. Liquid Gallium: Potential Uses as a Heat-Transfer Agent. *High Temperature*. **2000**. Vol.38. No.6. P.954-968. DOI:10.1023/A:1004157827093

[2] A. Miner, U. Ghoshal. Cooling of high-power-density microdevices using liquid metal coolants. *Applied Physics Letters*. **2004**. Vol.85. No.3. P.506-508. DOI:10.1063/1.1772862

[3] A.B. Shubin, E.V. Ignatieva, and I.E. Ignatiev. Producing of the metallic compositions from the mixes of copper-containing powders and gallium melts: determination of optimum vibration treatment parameters. *Butlerov Communications*. **2016**. Vol.45. No.3. P.116-120. DOI: 10.37952/ROI-jbc-01/16-45-3-116

[4] A.B. Shubin, and V.A. Bykov. Diffusive-hardening alloys based on copper and gallium: calorimetry and structure investigation. *Butlerov Communications*. **2016**. Vol.47. No.7. P.57-61. DOI: 10.37952/ROI-jbc-01/16-47-7-57

[5] A.B. Shubin, and L.F. Yamshchikov. Physico-chemical properties of metallic composite materials based on gallium. *Butlerov Communications*. **2017**. Vol.50. No.4. P.141-145. DOI: 10.37952/ROI-jbc-01/17-50-4-141

[6] K.E. Spells. The determination of the viscosity of liquid gallium over an extended range of temperature. *Proc. Phys. Soc*. **1935**. Vol.48. P.299-311. DOI:10.1088/0959-5309/48/2/308

[7] S.P. Yatsenko, V.I. Kononenko, V.N. Danilin, E.P. Druzhinina. Properties of gallium in aqueous solutions and alloys in Proc. Inst. Chem. No. 12. *Sverdlovsk: Ural Branch of Academy of Sciences USSR.* **1966**. 137p. (russian)

[8] T. Iida, Z. Morita, S. Takeuchi. Viscosity Measurements of Pure Liquid Metals by Capillary Method. *J. Jpn. Inst. Met*. **1975**. Vol.39. P.1169-1175.

[9] W. Menz and F. Sauerwald. Viscosity measurements XVII. The new double capillary viscosimeter and a critical survey of new measurements of η-values for pure metals. *Acta Metall*. **1966**. Vol.14. P.1617-1923.

[10] V.N. Genrikh, A.B. Kaplun, A.N. Soloviev. Investigation of the viscosity of liquids by the vibrational method. In Proc. "Investigation of the thermophysical properties of substances". *Novosibirsk: Nauka*. **1967**. P.112-136. (russian)
[11] A.N. Kuznetsov. Experimental Investigations of the Viscosity of Liquid Gallium, Indium and Tin. In Proc. "Physicochemical Studies of Liquid Metals and Alloys". *Sverdlovsk: Ural Branch of Academy of Sciences USSR*. **1974**. P.74-79. (russian)
[12] I.A. Tikhomirov, A.A. Orlov, D.G. Vidyaev. Investigations of the viscosity of the gallium-lithium system. *Proc. Tomsk Polytechnic University*. **2003**. Vol.306. No.4. P.77-80. (russian)
[13] H.V. Tippelskirch. Viscosities of Cesium Vapor to 1620 K and of Liquid Gallium to 1800 K. *Ber. Bunsenges. Phys. Chem*. **1976**. Vol.80. P.726-729.
[14] V.F. Kiselev, L.F. Kozin, R.Sh. Nigmetova. Viscosity and electrical resistivity of the mercury-gallium system. *Zh. Fiz. Khim*. **1979**. Vol.53. P.400-402. (russian)
[15] V.V. Filippov, S.A. Uporov, V.A. Bykov, K.Y. Shunyaev, B.R. Gelchinsky. An automated setup for measuring the viscosity of metal melts. *Instruments and Experimental Techniques*. **2016**. Vol.59. No.2. P.305-311. DOI:10.1134/S0020441216010036
[16] E.G. Shvidkovskiy. Some questions of the viscosity of molten metals. *Moscow: Gostekhizdat*. **1955**. 206p. (russian)
[17] M.J. Assael et al. Reference Data for the Density and Viscosity of Liquid Cadmium, Cobalt, Gallium, Indium, Mercury, Silicon, Thallium, and Zinc. *J. Phys. Chem. Ref. Data*. **2012**. Vol.41. 033101-1–033101-16. DOI:10.1063/1.4729873
[18] W. Brockner, K. Tørklep, H.A. Øye. Viscosity of Aluminium Chloride and Acidic Sodium Chloroaluminate Melts. *Ber. Bunsenges. Phys. Chem*. **1979**. Vol.83. P.1-11. DOI:10.1002/bbpc.19790830102
[19] T. Ito, N. Kojima, A. Nagashima. Redetermination of the Viscosity of Molten NaCl at Elevated Temperatures. *Int. J. Thermophys*. **1989**. Vol.10. P.819-831. DOI:10.1007/BF00514478
[20] Y. Sato, K. Sugisawa, D. Aoki, T. Yamamura. Viscosities of Fe–Ni, Fe–Co and Ni–Co binary melts. *Meas. Sci. Technol*. **2005**. Vol.16. P.363-371. DOI:10.1088/0957-0233/16/2/006
[21] K. Tørklep and H. A. Øye. Some Comments on the Viscosity of NaCl and Determination of Viscosity in General. *Ber. Bunsenges. Phys. Chem*. **1981**. Vol.85. P.814-815. DOI:10.1002/bbpc.19810850816
[22] P.P. Arsent'ev, V.V. Yakovlev, M.G. Krasheninnikov, L.A. Pronin, E.S. Filippov. Physicochemical Methods for Studying Metallurgical Processes. *Moscow: Metallurgiya*. **1988**. 511p. (russian)