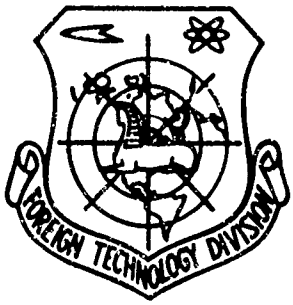
FTD-HT-23-1099-71

FOREIGN TECHNOLOGY DIVISION

TEMPERATURE DEPENDENCES OF THE VISCOSITY OF METALS

by

M. P. Bogdanovich
and B. A Baum



UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Foreign Technology Division Air Force Systems Command U. S. Air Force	2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED 2b. GROUP

3. REPORT TITLE

TEMPERATURE DEPENDENCES OF THE VISCOSITY OF METALS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Translation

5. AUTHOR(S) (First name, middle initial, last name)

Bogdanovich, M. P. and Baum, B. A.

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
1968	4	10

8a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d. DIA Task No. T69-04-9	9a. ORIGINATOR'S REPORT NUMBER(S) FTD-HT-23-1099-71 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	Foreign Technology Division Wright-Patterson AFB, Ohio

13. ABSTRACT

For pure metals three types of given dependences are observed: 1) the polytherm has its convex side facing the abscissa, which is probably explained by the weakening of bonds during the thermal expansion of a fluid; 2) the curve has its concave side to the abscissa, the activation energy increases with a rise in temperature, which can be caused by an increase in the coordination number, the integral bond energy increases, regardless of the possible weakening of a single bond, this can also take place in the case of intensive metallization of primarily covalent bonds; 3) the given linear dependence, the invariability of E with a rise in temperature is probably explained by the compensating effect of several factors.

DD FORM 1 NOV 65 1473

I

UNCLASSIFIED

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Liquid Metal Temperature Dependence Gallium Copper Iron Cobalt Nickel Lithium Silicon Zinc Cadmium						

EDITED TRANSLATION

TEMPERATURE DEPENDENCES OF THE VISCOSITY OF METALS

By: M. P. Bogdanovich, and B. A. Baum

English pages: 4

Source: Ural'skiy Politekhnicheskiy Institut. Trudy, (Ural Politechnical Institute, Transactions), No. 167, 1968, pp 96-98.

Translated by H. Peck

UR/0000-68-000-167

U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

* ye initially, after vowels, and after ъ, ь; e elsewhere. When written as ё in Russian, transliterate as yё or ё. The use of diacritical marks is preferred, but such marks may be omitted when expediency dictates.

FOLLOWING ARE THE CORRESPONDING RUSSIAN AND ENGLISH

DESIGNATIONS OF THE TRIGONOMETRIC FUNCTIONS

Russian	English
sin	sin
cos	cos
tg	tan
ctg	cot
sec	sec
cosec	csc
sh	sinh
ch	cosh
th	tanh
cth	coth
sch	sech
csch	csch
arc sin	$\sin^{-1}$
arc cos	$\cos^{-1}$
arc tg	$\tan^{-1}$
arc ctg	$\cot^{-1}$
arc sec	$\sec^{-1}$
arc cosec	$\csc^{-1}$
arc sh	$\sinh^{-1}$
arc ch	$\cosh^{-1}$
arc th	$\tanh^{-1}$
arc cth	$\coth^{-1}$
arc sch	sech^{-1}
arc csch	csch^{-1}
rot	curl
lg	log

TEMPERATURE DEPENDENCES OF THE VISCOSITY OF LIQUID METALS

M. P. Bogdanovich and B. A. Baum

The activation energy of viscous flow E with a temperature invariability of the flow units is defined by the expression [1].

$$E=\frac{R}{\lg e}\cdot\frac{d(\lg \nu)}{d\left(\frac{1}{T}\right)},$$

where ν is the coefficient of kinematic viscosity.

For pure metals three types of dependences of $\lg \nu$ on T^{-1} are observed:

1. The polytherm has its convex side facing the abscissa, which is probably explained by the weakening of bonds during the thermal expansion of a fluid.

2. The curve has its concave side to the abscissa. The activation energy increases with a rise in temperature, which can be caused by an increase in the coordination number. The integral bond energy increases, regardless of the possible weakening of a single bond. This can also take place in the case of intensive metallization of primarily covalent bonds.

3. The linear dependence of $\lg \nu$ on T^{-1}. The invariability of

E with a rise in temperature is probably explained by the compensating effect of several factors.

A combination of the above dependences is also possible.

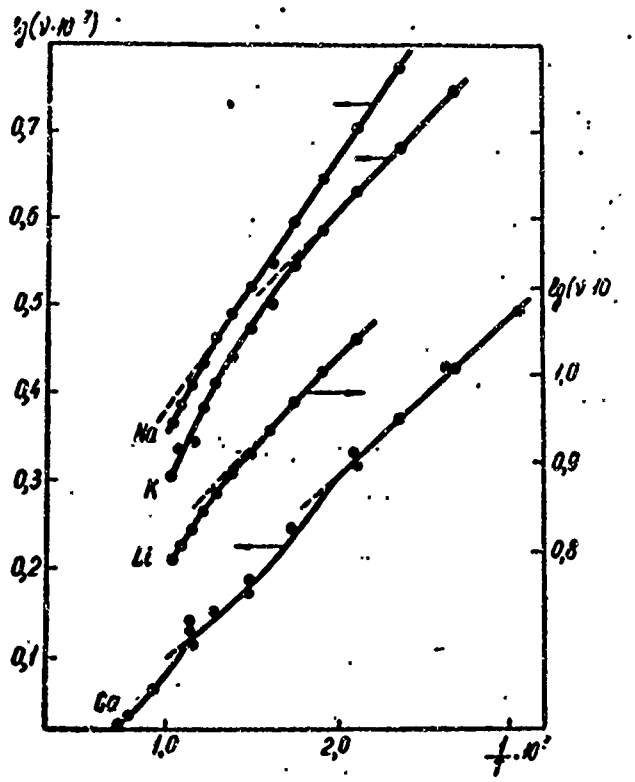
The first type is characteristic for Cu, Ag, and to a certain extent for Cr, Fe, Co, Ni (for example, [1, 2], and the second is characteristic for Li, Na, K, Si [1, 3], while the third is characteristic for Zn, Cd, Hg, Pb, Sn, Bi [3, 4].

For alkaline metals Li, Na, K (see the figure) the experimental shape of the temperature dependence of ν is explained by an increase in the coordination number, which is confirmed by the data of X-ray structural analysis [3, 5]. The heating of liquid silicon is obviously accompanied not only by an increase in the coordination number but also by the decay of complexes with permanent bonds and the metallization of the bonds that occurs in connection with this [1]. In this case the dimensions of the flow units are changed, and the value of E calculated from equation (1) does not reflect the true energy value of the interparticle interaction in the melt.

The constancy of E in such metals as Pb and Zn cannot be explained only by an increase in the coordination number, because in the liquid state it is also quite high at $T_{пл}$. We can assume that in these metals the magnitude of the charge of the ions participating in the viscous flow increases, the dimensions of the ions decrease, and their mobility increases. This concept is confirmed to a certain extent by data on the temperature coefficient of electrical resistance $\beta = d\rho/dT$. Thus, for Zn, Cd, Hg, In, Pb, Sn and Bi, β in the liquid state ($\beta_{ж}$) is less than in the solid state ($\beta_{тв}$) [6, 7]. At the same time, in Na, K, Cu, and Ag [8, 9] $\beta_{ж} > \beta_{тв}$.

It is interesting to note that the temperature dependence of the viscosity of liquid gallium [10] is of a more complex (mixed) nature (see the figure). Up to 230°C it is linear. This, as in the preceding case, can be explained by the metallization of the bonds and by a certain increase in the coordination number. At temperatures of 230 and 560°C there are observed bends corresponding to the transfer to

the second type of dependence. Since the existence of groupings with primarily covalent bonds [5] is not excluded in gallium, we can assume that they are most intensely destroyed here.



Dependence of lg ($\nu \cdot 10^7$ m^2/s) on 1/T for certain liquid metals.

BIBLIOGRAPHY

1. Б. А. Баум, П. В. Гельд, П. В. Кочеров. Изв. АН СССР, Металлы, 1967, № 1, 62.

2. А. А. Вертман, А. М. Самарин. Изв. АН СССР, ОТН, Металлургия и топливо, 1960, № 4, 95.

3. С. С. Кутателадзе, В. М. Боришанский, И. И. Новиков, О. С. Федынский. Жидкометаллические теплоносители. М., Атомиздат, 1958.

4. Е. Г. Швидковский. Некоторые вопросы вязкости расплавленных металлов. М., Гостеоретиздат, 1955.

5. В. К. Григорович. Периодический закон Менделеева и электронное строение металлов. М., изд-во «Наука», 1966.

6. Takeuty Sakae, Endo Hyrohysa. «J. Japan Inst Metals», 1962, 26, № 8, 498.

7. Р. П. Юрчак, Л. П. Филиппов. Теплофизика высоких температур, 1964, 2, № 5, 696.
8. А. Н. Соловьев. Ж. прикл. механики и техн. физики, 1963, № 1, 158.
9. Б. Е. Семячкин, А. Н. Соловьев. Ж. прикл. механики и техн. физики, 1964, № 2, 176.
10. K. E. Spells. «Proc. Phys. Soc.», 1936, 48, 299.