

calculated from Eq. (1). The expected linear dependence is indeed observed in both cases and the agreement is considered close enough to constitute a satisfactory confirmation of the practical utility of Bell's approximation.

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W. G. PETTUS

The Babcock and Wilcox Company
 Lynchburg, Virginia
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The Surface Tensions of Liquid Metals at Their Melting Points*

Various attempts have been made to correlate surface tensions of liquid metals with other physical properties of the elements (1). Taylor used a number of such correlations as a basis for estimating values of unknown surface tensions of twenty-seven metals at their melting points (1). Taylor did not, however, correlate these estimated values with common parameters of the metals. Hildebrand and Scott (2) had found that for organic liquids, a linear relation existed between $\log(\gamma/V^{1/3})$ and $\log S$, where γ is the surface tension, V the molar volume, and S the energy of vaporization per unit volume. Hildebrand and Scott (2) and Bondi (3) attempted to apply this surface tension equation to liquid metals, and Bondi had some apparent success. However, these investigators used arbitrary temperatures and relatively small sample sizes in their attempted correlations. Since it was felt that a more significant test

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TABLE I
 SOURCES OF SURFACE TENSION DATA

Element	Method of measurement	References	Element	Method of measurement	References	Element	Method of measurement	References
Ag*	a, b	8, 14	Ga*	d	4	Pb	a, b	10, 14
Al*	b	4	Ge	e	13	Pd	c	1
Au*	b	14	Hf	f	7	Rb	c	1
Ba	c	1	Hg*	b	4	Re	c	1
Be	c	1, 12	In	g	10	Sn	a, b, g	9, 10, 14
Bi	b	5, 14	Ir	c	1	Sr	c	1
Ca	c	1	K	b	4	Ta	c	1
Cb	c	1	Li	c	1	Ti	a	11
Cd*	b	4, 14	Mg	b	4	Tl*	a	14
Co*	a	9	Mn	c	1	U	c	1
Cr	c	1	Mo	c	1	V	a	11
Cs	c	1	Na	b	6	W	c	1
Cu*	a	9	Ni*	a	9	Zn	b	4
Fe*	a	9	Os	c	1	Zr	f	7

- * Surface tension extrapolated to the melting point.
- a Sessile drop
- b Maximum bubble pressure
- c Estimated values
- d Pendant drop
- e Analysis of solid state curvature
- f Drop-weight
- g Capillary

should be made, the present investigation was carried out to determine whether or not the Hildebrand and Scott equation or a modification of it could be applied to a large number of liquid metals at their melting points. This study was made difficult in that (a) the accuracy of some of the

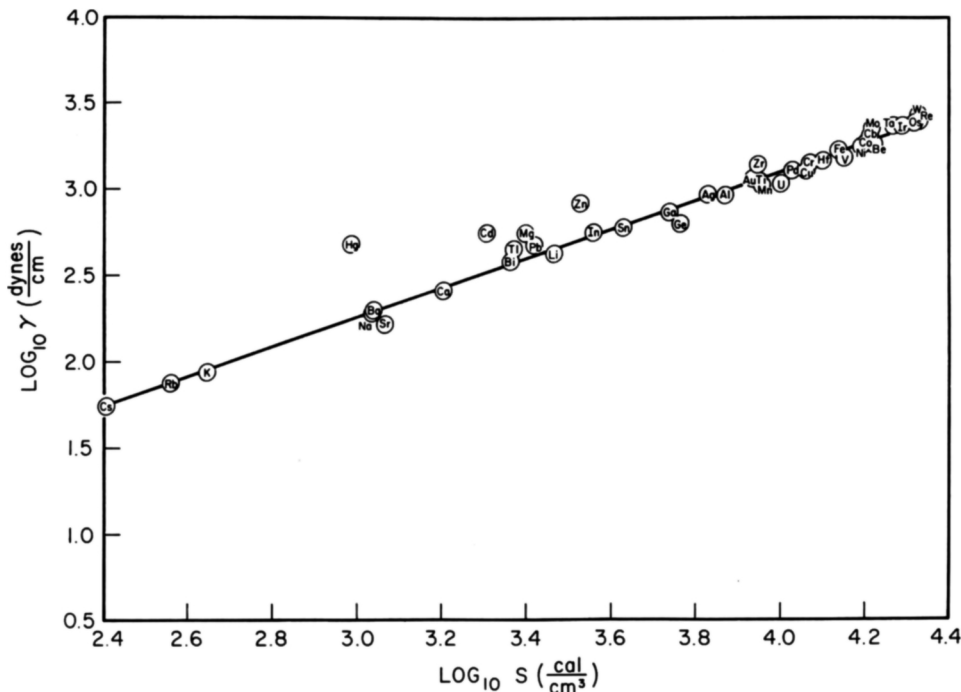


FIG. 1. Log surface tension—log energy of vaporization per unit volume plot for liquid metals at their melting points

experimentally determined surface tension values is open to question because of the difficulties encountered in measuring surface tensions of liquid metals, and (b) for many metals, estimated surface tensions reported in the literature were used because of the absence of experimental values. Nevertheless, the energy of vaporization per unit volume has emerged as bearing an important relationship to the magnitude of surface tensions of liquid metals.

Data for $S(\varrho)$ and γ were obtained from the literature, and Table I gives references to the sources of the surface tension data used. Taylor's estimated values (1) were used in most cases where experimental data were not available. In some cases surface tensions at the melting point were obtained by extrapolation on surface tension-temperature plots. Figure 1 is a plot of $\log \gamma$ against $\log S$. This plot could not be improved by using, as Hildebrand and Scott did, $\log(\gamma/V^{1/3})$ for the ordinate. The data show that with but few exceptions the plotted points, which include estimated as well as experimentally determined surface tensions, fall on a straight line with relatively little scatter. It is interesting to note that the elements magnesium, zinc, cadmium, and mercury, whose plotted points show the largest deviations are metals that have small liquid ranges.

The results of this investigation indicate that surface tension and energy of vaporization per unit volume are dependent on the same basic property.

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SIMON W. STRAUSS

U. S. Naval Research Laboratory
Physical Metallurgy Branch
Metallurgy Division
Washington, D. C.

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Generalized Resonance Integral Representation*

Atomic Energy Commission, and the Babcock and Wilcox Company, Lynchburg, Virginia.

Chernick and Vernon (1) and Dresner (2) have pointed out that for thorium-232 and uranium-238 selective use of Narrow Resonance and the Narrow Resonance Infinite Absorber approximations can give good representations of neutron spectrum effects in the resonances.

For homogeneous mixtures of resonance absorber and scatterer the formulas for these two approximations are as given in Eqs. (1) and (2), for the N.R. and N.R.I.A. approximations, respectively.

$$R = \int \frac{dE}{E} \sigma^A(E) / \{1 + [\sigma^A(E) + \sigma^S(E)]/\sigma^P\} \quad (1)$$

$$R = \int \frac{dE}{E} \sigma^A(E) / \{1 + [\sigma^A(E) + \sigma^S(E)]/[\sigma^P - \sigma_{\text{abs}}^P]\} \quad (2)$$

$\sigma^A(E)$ and $\sigma^S(E)$ are the microscopic resonance absorption and scattering cross sections of the absorber nuclei; σ^P is the potential scattering per absorber atom of the medium; σ_{abs}^P is the potential scattering per atom of the absorber.

For lumped absorbers Chernick and Vernon simplified the spatial distribution problem through use of lump collision probabilities calculated from Wigner's rational approximation. Algebraic manipulation of Chernick and Vernon's results gives, for lumped absorbers, Eq. (3) for the N.R. approximation and Eq. (4) for the N.R.I.A. approximation.

$$R = \int \frac{dE}{E} \sigma^A(E) / \{1 + [\sigma^A(E) + \sigma^S(E)]/[\sigma^P + S/4NV]\} \quad (3)$$

$$R = \int \frac{dE}{E} \sigma^A(E) / \left\{ \frac{1 + [\sigma^A(E) + \sigma^S(E)]}{[\sigma^P + S/4NV - \sigma_{\text{abs}}^P]} \right\} \quad (4)$$

S/V is the surface-to-volume ratio of the lump; N is the number density of absorber atoms within the lump; σ^P in this case is the potential scattering within the lump per absorber atom within the lump.

Aside from dependence on quantities determined purely by the species of the absorber (i.e., whether it is U^{238} or Th^{232} , etc.) the resonance integral is a function solely of the quantity

$$(\sigma^P + S/4NV)$$

For lattices, Rothenstein (3) has shown that the shadowing effect of lumps on each other can be represented to first order by a reduction of the surface S to an effective surface S^{eff} through the Dancoff correction (4)

$$S^{\text{eff}} = S(1 - C) \quad (5)$$

Consequently it is proposed that for each species of resonance absorber a single relationship of the form

$$R = f(\sigma^P + S^{\text{eff}}/4NV) \quad (6)$$

should accommodate all cases—homogeneous mixtures, single lumps and lattices of metal, oxide, carbide, etc. This is tested in the accompanying plots of R vs $(\sigma^P + S^{\text{eff}}/4NV)$.

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