The Thermal Expansion of the Alkalis

At the New York meeting of the American Physical Society during February Bardeen[1] suggested the semi-empirical equation

$$W/V_0=A(V_0/V)+B(V_0/V)^{\frac{2}{3}}-C(V_0/V)^{\frac{1}{3}} \tag{1}$$

for the energies of the alkali metals. This equation is based upon a wave mechanical treatment of the alkalis by Frohlich.[2] Since this relation reproduces the relative change of volume with pressure in close agreement with Bridgman's[3] results, it seems reasonable to suppose that it represents the form of the potential energy curve in the neighborhood of the minimum with reasonable accuracy.

The combination of this idea with Debye's[4] idea that the thermal expansion of a solid is determined essentially by the anharmonic terms in the potential energy allows one to compute the thermal dilatation of the alkalis from Eq. (1). If one assumes that Debye's method applies to the energy expression (1), the thermal expansion formula thereby derived should be in fair agreement with the observed thermal expansion, since the thermal expansion depends on the form of the energy curve in the neighborhood of V_0. As is to be expected, this formula to a first approximation is Grüneisen's law[5]

$$\Delta V/V_0=KE \tag{2}$$

where $\Delta V/V_0$ is the thermal dilatation measured from 0°K and E is the corresponding increment to the thermal energy. The constant K is given by

$$K=\frac{9}{4V_0}\left[\frac{10A+4B-C}{(6A+3B-C)^2}\right]. \tag{3}$$

The advantage of this method for computing the thermal expansion from Eq. (3) rests in the fact that K is expressed directly in terms of the potential energy constants of the crystal lattice.

Dr. Bardeen[6] was kind enough to provide me with his values of A, B, C for the alkali metals. They give for K the values:

Element	Li	Na	K	Rb	Cs
10^6K	6.28	6.23	6.78	7.19	7.36

K is in $(\text{joule})^{-1}$.

In order to compare the results with experiment, one must have the values of both $\Delta V/V_0$ and E over a temperature range which is well below the melting point. (At higher temperatures second-order terms in Eq. (2) become more important.) The only substance for which these data appear to be available is sodium. The *International Critical Tables* yield a value of $\Delta V/V_0$ for the temperature range −191 to 16°C. Recent preliminary work of Quimby and Siegel[6] gives values of $\Delta V/V_0$ for the range 79 to 192°K and 192 to 273.1°K. A summary of the results for sodium follows:

Range °K	$10^3\Delta V/V_0$(obs.)	$10^3\Delta V/V_0$(calc.)
82.2–289.2	38.6	32.6
79 –192	19.3	17.1
192 –273.1	16.3	13.3

Dr. Bardeen reports that his values of A, B and C agree fairly well with the theoretical values of Frohlich. However, Frohlich's values of A, B and C yield thermal expansion values for sodium which disagree with experiment by a factor of three. Since the thermal expansion is thus seen to be a very sensitive function of A, B and C the above agreement appears to be fairly good.

I am grateful to Drs. Bardeen, Quimby and Siegel for the data they supplied.

LEWIS BALAMUTH

College of the City of New York,
New York, New York,
March 23, 1938.

---

[1] Bardeen, Bull. Am. Phys. Soc., Abstract No. 46, N. Y. Meeting (1938); Phys. Rev. **53**, 683 (1938).
[2] Frohlich, Proc. Roy. Soc. **A158**, 97 (1937).
[3] Bridgman, Proc. Am. Acad. (in press).
[4] Debye, *Atomtheorie des Festes Zustandes*, M. Born, second edition, Vol. 30, p. 667.
[5] *Handbuch der Physik*, Bd. X (1926), p. 41.
[6] Quimby and Siegel, to be published.

Heavy Beta-Rays?

Experiments by Schonland[1] and a recent paper by Chalmers[2] indicate that the scattering of beta-rays from metals is diffuse with a considerable fraction of the beta-rays being scattered through angles ranging from 90° to 180°. For ordinary electrons to produce the B band shown in a previous letter[3] they must, according to Zahn,[4] be produced by scattering within the selector. Compton[5] concurs in the possibility of this alternative explanation. The intensity which I obtain requires something like specular reflection rather than the diffuse scattering of Chalmers and Schonland for its explanation. As noted by Flammersfeld[6] the backward scattering from the base upon which the RaE is mounted affects considerably the $H\rho$ spectrum of the rays. In my experiments this backward scattering removes the possibility of showing that $p/(1-\beta^2)^{\frac{1}{2}}$ is a constant. Even though this may be the case as the beta-rays start out from the parent atoms the scattering from the base will on account of the attendant absorption give a range of values of p for each β. A table by O'Connor[7] shows a wide variation of values for the high energy end point and for the energy of the most prevalent rays but perhaps the most prevalent energy corresponds to $H\rho=2000$ and this for ordinary electrons gives $\beta=0.76$. If therefore the magnetic field is kept constant (340 gauss) and β_s first put at $0.76-0.16=0.60$ and then at $0.76+0.16=0.92$ the two pictures of the B band should on the internal reflection hypothesis be similar. Actually when $\beta_s=0.92$ the B band was pretty well removed. With our latest selector ($l=5$ cm, $w=0.044$ cm and made of aluminum), we have found high energy beta-rays with $p=0.12$ cm. This line appears when $H=340$ gauss, $V=3000$ volts but disappears when $H=340$ gauss, $V=4560$ volts. Are these then heavy electrons with p of about 8? The source was a mixture of RaD and RaE on a base of nickel. Distance from plates to film was 3.5 cm.

G. E. M. JAUNCEY

Washington University,
St. Louis, Missouri,
April 1, 1938.

---

[1] Schonland, Proc. Roy. Soc. **108**, 187 (1925).
[2] Chalmers, Phil. Mag. **25**, 322 (1938).
[3] Jauncey, Phys. Rev. **53**, 265 and 319 (1938).
[4] Zahn, Phys. Rev. **53**, 431 (1938).
[5] Compton, Phys. Rev. **53**, 431 (1938).
[6] Flammersfeld, Physik. Zeits. **23**, 973 (1937).
[7] O'Connor, Phys. Rev. **52**, 303 (1937).