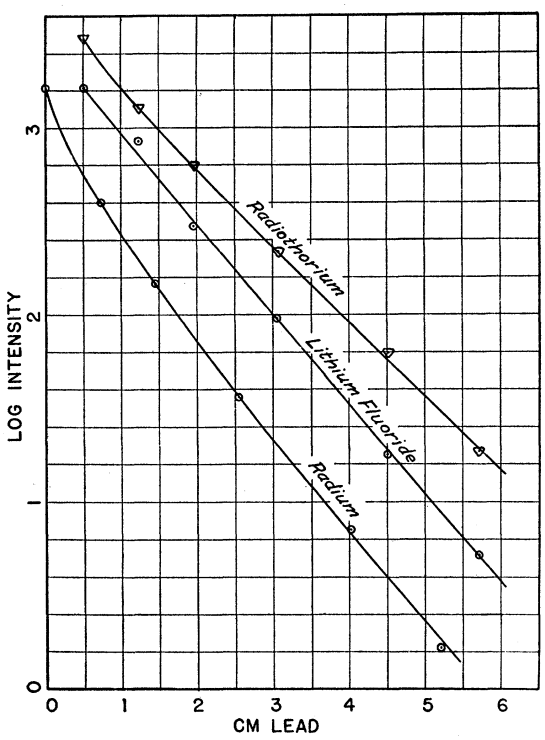

FIG. 1. Absorption of rays in lead.

To investigate the problem more closely, we have made provision for varying the amount of lead between the target and the ionization chamber. Measurements with much reduced lead filtration produced a large increase in the ionization which enabled us to make absorption measurements. The presence of strong γ-radiation was indicated by the observation that the absorption, per electron, was nearly the same for lead as for paraffin. The experimental arrangement was not suitable for an absolute determination of absorption coefficients as it was necessary to use a rather large solid angle. For this reason the absorption was compared directly with the absorption of γ-rays from radium and thorium sources placed in the exact position of the target.

The results of such a series of measurements at 600 kv with a lithium fluoride target and lead absorbers are shown in Fig. 1, from which we conclude that the γ-rays from lithium fluoride have about the same quantum energy as γ-rays from radium filtered through about 2 cm of lead. The plot is a straight line, within the accuracy of our measurements, indicating that the radiation is monochromatic, or at least nearly so. There is no evidence of a component of much harder radiation and, if such a component is present, it must be of very much smaller intensity. It is tempting to associate this γ-radiation with the short range α-particles, as the quantum energy corresponds approximately to the energy difference between two 1.15 cm particles and two 0.65 cm particles, namely, about 1.5×10^6 e.v.

It may be of interest to note that the intensity of γ-radiation at 600 kv and 20 microamperes ion current is about equal to that from 0.1 milligram of radium. The number of quanta is therefore not very different from the number of α-particles in the 1.15 cm group, thus giving support to the above suggestion.

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The Nature of the "Forbidden" Lines in the Pb I Spectrum

In a recent letter to the *Physical Review*,[1] one of us has reported the appearance of some Pb I lines which are forbidden for the normal dipole radiation. These lines were obtained in the spectrum of high frequency electric discharges in mixtures of lead vapor with inert gases.

The strongest of these lines λ4618.0A, corresponding to the transition from $6p^2\,{}^1S_0$ to $6p^2\,{}^3P_1$ energy level, cannot be explained by quadrupole radiation as violating the $0\rightarrow1$ interdiction for the change of the resultant angular momentum quantum number J. The appearance of this line was therefore attributed to the electrically perturbed dipole radiation although the absence of sufficiently strong external or intermolecular electric fields hardly supports this view. Hence the remaining "forbidden" lines λ4659.4 ($6p^2\,{}^3P_0-6p^2\,{}^1D_2$), λ5312.7 ($6p^2\,{}^3P_2-6p^2\,{}^1S_0$) and λ7330 ($6p^2\,{}^3P_1-6p^2\,{}^1D_2$) which are allowed for the quadrupole radiation could also be interpreted as the electrically perturbed dipole radiation.

The emission of the line λ4618.0 can be explained however by the *magnetic dipole radiation* thus avoiding the hypothesis of strong electric fields under the described experimental conditions. A detailed examination, which will be published shortly, has shown that there exists a finite probability of the transitions from the energy state ${}^1S_0$ to that ${}^3P_1$ for the magnetic dipole radiation. Brinkman's[2] selection rules for the change of the quantum numbers L and S in the magnetic dipole radiation ($\Delta L=0$ and $\Delta S=0$) cannot be applied here since they are strictly valid only for extreme Russell-Saunders coupling for which electric dipole and quadrupole intercombination lines are also forbidden. A deviation from Russell-Saunders coupling in the case of the energy states of the neutral lead atom belonging to the electron configuration $6s^2\,6p^2$ is indicated by the wide relative separation of the ${}^3P$ levels.

[1] H. Niewodniczański, Phys. Rev. **44**, 854 (1933).

[2] H. C. Brinkman, Dissertation, Utrecht (1932), also quoted by A. Rubinowicz and J. Blaton, Ergebnisse der exakten Naturwiss. **11**, 190 (1932).

The probabilities of the analogous transitions from $^1S_0$ to $^3P_1$ energy state in C I, N II and O III were calculated by Stevenson[3] who found finite values for these probabilities. However, Stevenson does not separate the multipole radiation into the quadrupole and magnetic dipole radiation and interprets accordingly the radiation corresponding to the transitions between the energy states $^1S_0$ and $^3P_1$ as quadrupole radiation in contradiction to the $J_1+J_2\geq 2$ selection rule for this radiation.

Assuming the line λ4618.0 to be due to the pure magnetic dipole radiation, the lines λ4659.4 ($^3P_0-{}^1D_2$) and λ5312.7 ($^3P_2-{}^1S_0$) can be explained as pure quadrupole lines and the line λ7330 ($^3P_1-{}^1D_2$) as due to the mixed magnetic dipole and quadrupole radiation.

We hope to confirm the above explanation of the forbidden Pb I lines by the Zeeman effect.

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[3] A. F. Stevenson, Proc. Roy. Soc. **A137**, 298 (1932).

Concerning the Thermoelectric Effects of the Alkalis

In an extensive article,[1] I have presented an elementary treatment of the electron theory of metals in a simpler and more complete manner than I had given in my paper of 1928[2] and H. Bethe has followed this with a basic wave-mechanical formulation of the theory. In this note I should like to extend one phase of this treatment.

From my elementary theory the Thomson coefficient μ defined by $U=-\mu J\,(dT/dx)$ (U=rate of heating, J=current density), is given by

$$\mu=-\frac{\pi^2}{3}\frac{k^2}{|e|}\frac{\Lambda T}{\zeta};\qquad \Lambda=1+\tfrac{1}{2}\frac{d\log l}{d\log v} \tag{1}$$

with the simplifying assumptions that Λ and ζ are independent of T. $|e|$ is the absolute value of the charge on an electron, ζ the internal potential per electron in the Gibbs sense which I formerly denoted by W_i, l the free path, and in the expression for Λ the derivative is to be taken for the limiting velocity ($v=\bar{v}$) of the Fermi distribution. Originally I had chosen silver as an example and placed $\Lambda=1$ as a reasonable approximation. Now μ is *positive* for Cu, Ag and Au (also for Hg) and hence Eq. (1) seemed to predict the *wrong sign*. However, the alkalis rather than the noble metals are the true representatives of metals with "free" electrons. Their ionization potentials (with the exception of Li) are particularly small, their mono-valence most pronounced and the closed shell of eight electrons inside the valence electron (again excepting Li) is most clearly defined (better than the shell of eighteen electrons inside the valence electron of the noble metals).

At the time of the preparation of my *Handbuch* article measurements of the Thomson coefficients of the alkalis were not known to me. However, even at that time I could conclude from older measurements of the thermoelectric force by Bernini, et al., that, because of thermodynamic relations, the Thomson coefficient of Na and K must be negative and hence the sign required by Eq. (1) actually occurred for Na and K. In a note I postulated that reliable measurements on Rb and Cs would agree with formula (1) and expected that the comparison for Li would be less satisfactory than for the remaining alkalis.

Meanwhile my attention has been called to an article by C. C. Bidwell.[3] Here measurements of the thermoelectric force are given ($\Theta_1=d\Theta/dT$ if Θ denotes the thermoelectric difference of potential) for the complete series of the alkalis. They show a good *linear falling off* of Θ_1, above the melting point, if all the measurements are referred to lead as the second metal. Li is an exception and shows a *linear rise* above the melting point. Since the thermodynamic relation

$$\mu=Td\Theta_1/dT \tag{2}$$

must hold if μ is taken zero for lead, the linear decrease of Θ_1 denotes *proportionality of μ with T* and a *negative sign* as is required by Eq. (1). It is also understandable that these relations are best satisfied in the *molten state*. For the elementary theory does not take the crystal lattice into account but replaces its action schematically by a free path l, which is independent of all regularity in space. In the *solid state* Bidwell finds an α- and a β-modification. The β-modification joins at the melting point and also shows a passable linear decline of Θ_1 with T, while in the neighborhood of the melting point μ rises rather suddenly. The transition point between α and β lies at lower temperatures (−100°C for K, etc.). In the α-phase Θ_1 rises with T; for such low temperatures, however, our elementary theory is certainly not valid.

For the molten state our formula (1) yields the *correct order and order of magnitude* of the Thomson coefficients. Table I shows this, the numbers denoting microvolts per degree. The experimental data are the values given by Bidwell in his Table III under "liquid" (denoted there by d^2E/dt^2); the theoretical values are calculated from Eq. (1):

Table I.

μ/T	Li	Na	K	Rb	Cs
Exp.	+0.40	−0.0282	−0.0275	−0.069	−0.062
Theor.	−0.016	−0.023	−0.036	−0.041	−0.048

Li is an exception; the remaining alkalis check surprisingly well. With respect to the order we prefer to give more credence to the theoretical numbers than to the experi-

[1] A. Sommerfeld, Handb. d. Physik **24**, 2 (in press), Springer.

[2] A. Sommerfeld, Zeits. f. Physik **47**, 1–32, 43–60 (1928).

[3] C. C. Bidwell, Phys. Rev. **23**, 357 (1924).