the range 260–800 cm^{-1} (0.03–0.10 ev~40–12 microns). Infrared studies at higher frequencies have already been reported,[4-7] and show that while the spectrum of silicon has considerable structure in the region 800–5000 cm^{-1} (0.10–0.60 ev), germanium, in thin samples, has an approximately constant transmission of about 0.5 independent of thickness. The 0.5 loss is thus presumably the result almost entirely of reflection.

As Table I shows, germanium continues to transmit about 50 percent down to 600 cm^{-1}, and then exhibits a broad, very weak band at 540 cm^{-1} and a sharp, somewhat stronger band at 420 cm^{-1}. The major absorption occurs, however, in a broad band centered at 330 cm^{-1}. Although measurements on the low frequency side of this band extend only to about 250 cm^{-1}, it is already apparent that transmission is significantly higher than at 300 cm^{-1}. The observed increase at low frequency is reminiscent of the effect of instrumental scattered light. We believe it is genuine, however, since suitably thick crystals (>2 cm) of potassium iodide, a satisfactory substance for detection of high frequency scattered light at 250 cm^{-1}, show that instrumental scattered light is less than 5 percent in this region.

If the center of this band is taken as 330 cm^{-1}, the corresponding energy is 0.04 ev. This is a somewhat higher value for the energy gap than that suggested from the temperature-dependence studies[1,2] and may mean that other bands lie at still lower frequencies, or that the temperature-dependence studies require a more involved interpretation.

It has been reported[8] that appropriate heat treatment of germanium single crystals changes the temperature dependence of resistance to give an energy-gap value of 0.03 ev. In view of the closer concordance of this latter value with the energy of the transmission minimum at 330 cm^{-1}, it is conceivable that the sample on which the data of Table I were obtained had an energy-gap similar to that produced by heat treatment. However, it seems more likely that the band is analogous to the strong absorption in silicon at 610 cm^{-1}, since the other pairs of bands in the spectra have frequency ratios about equal to 610:330, *viz.*, 1120:540 and 736:420. This similarity of the spectra of silicon and germanium is understandable if the bands are ascribed to lattice vibrations for the lattice frequencies of the two substances should differ by a mass factor $(72/28)^{\frac{1}{2}}$ and a factor not much larger than unity, due to difference in lattice binding. This suggestion is compatible with the observation of Keesom and Pearlman[9] that the Debye θ curves as a function of temperature are identical for silicon and germanium apart from a scale factor of 1.8 on both θ and T axes.

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Phase Transition of $ND_4D_2PO_4$

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AMMONIUM dihydrogen phosphate, though isomorphous with KH_2PO_4, does not become ferroelectric. Instead, at 148°K it undergoes a transition which splits the crystal into many small fragments. Below this transition the dielectric constant is small and changes very little with decreasing temperature. It was generally believed that this transition was because of an interaction of the NH_4^+ ions on account of their deviation from a spherical symmetric configuration.[1,2] However, the magnitude of the anomaly of the specific heat occurring at this transition was much larger than those observed in other ammonia transitions, even though the crystal did not become ferroelectric.

In order to investigate this further, we replaced all the hydrogen by deuterium, making the following crystal; $ND_4D_2PO_4$. The crystals were of the same habit as the corresponding hydrogen salt. Their transition temperature, however, was shifted from 148°K to 242°K, i.e., 94° to higher temperatures.

This result enables us finally to decide whether there is an ammonia transition or not. Replacing H by D in an ammonia transition like that of NH_4Cl, for instance, changes the transition temperature only a few degrees, whereas the ferroelectric Curie point of KD_2PO_4 is about 90° higher than that of KH_2PO_4. The transition in the ammonium salt is therefore believed to be an order-disorder transition of the X_2PO_4 (X=H or D) groups, and the principal effect of the nonspherical symmetric ammonia ion is to prevent the occurrence of a spontaneous polarization, i.e., ferroelectricity.

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Charge-Symmetrical Interaction between Nucleons and Leptons

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LET us consider the direct interaction between the nucleons and the quantized wave field of leptons, as defined through the Hamiltonian

$$-g\{\psi_P^*\psi_N\cdot\psi_e^*\psi_\nu+\text{c.c.}+\tfrac{1}{2}(\psi_N^*\psi_N-\psi_P^*\psi_P)\cdot\tfrac{1}{2}(\psi_e^*\psi_e-\psi_e\psi_e^*)\}. \quad (1)$$

The terms in the first row correspond to the usual β-radioactivity. The terms in the second row are just those originally proposed by Oppenheimer and Schwinger[1] (except that we are using the scalar interaction, for simplicity). The expression (1) can be written in a remarkable form, if we accept the Majorana theory for the neutrino (in accordance with the double β-decay).

Thus we suppose $\psi_\nu^\dagger=\psi_\nu=w$ and decompose also $\psi_e=u+iv$ into its real and imaginary parts u and v. Further we put

$$\Psi=\begin{pmatrix}\psi_P\\ \psi_N\end{pmatrix} \quad \text{and} \quad \varphi=\begin{pmatrix}u\\ v\\ w\end{pmatrix}. \quad (2)$$

Then (1) can be written in the form

$$(g/2)\cdot(\Psi^*\boldsymbol{\tau}\Psi)\cdot(\varphi^*\boldsymbol{\xi}\varphi), \quad (1')$$

where $\boldsymbol{\tau}$ is the well-known operator of the isotopic spin of the nucleon and the components of $\boldsymbol{\xi}$ are the matrices

$$\xi_1=\begin{pmatrix}0&0&0\\0&0&i\\0&-i&0\end{pmatrix},\quad \xi_2=\begin{pmatrix}0&0&-i\\0&0&0\\i&0&0\end{pmatrix},\quad \xi_3=\begin{pmatrix}0&i&0\\-i&0&0\\0&0&0\end{pmatrix}. \quad (3)$$

These Hermitian matrices are just the irreducible representation (of rank 3) of the abstract operators satisfying the Duffin-Kemmer relations

$$\xi_i\xi_j\xi_k+\xi_k\xi_j\xi_i=\delta_{ij}\xi_k+\delta_{jk}\xi_i, \quad (4)$$

($i, j, k=1, 2, 3$). The matrices (3) satisfy further the relations $\xi_2\xi_1-\xi_1\xi_2=i\xi_3$, etc. The charge density of the lepton field can be expressed in the form

$$\rho=(e/2)(\psi_e^\dagger\psi_e-\psi_e\psi_e^\dagger)=e\varphi^\dagger\xi_3\varphi. \quad (5)$$