Groenewald did not introduce any mechanical rest mass, m_0, but set $e^2/2a$ equal to the observed mass of the electron.

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Identification of CO in the Solar Atmosphere*

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RECENTLY, a short section of the solar limb spectrum, extending approximately from λ23,100 to λ23,300, was traced with the high dispersion infrared spectrometer[1] attached to the Snow telescope at the Mount Wilson Observatory. It was noted that over 15 weak lines were conspicuously enhanced in intensity by about a factor of two as compared with their appearance in the spectrum of the center of the disk. Furthermore, the majority of the lines were regularly spaced in a fashion that left no doubt as to their molecular origin. It should be pointed out that enhancement toward the limb is common among solar molecular lines observed in the photographic region of the Fraunhofer spectrum,[2] but that no solar lines of molecular origin have hitherto been noted in the lead-sulfide region of the spectrum.

Investigation of the positions and spacing of the enhanced lines makes it certain that they are members of the positive branch of the 3−1 vibration-rotation band of CO centered at 4207.03 cm^{-1}. The strengthening of the lines toward the limb indicates that they are formed relatively high in the atmosphere where the temperature is about 5000°K. At this temperature the intensity maximum of the CO bands, although relatively flat, occurs at about $J=30$. The observed positions of the solar lines agree to within a few hundredths of a wave number with those calculated for the lines $J=25$ to $J=35$ from the molecular constants recently derived for CO by Rao.[3]

Additional confirmation of the presence of CO in the solar atmosphere has come from an examination of neighboring regions of the spectrum in the infrared atlas,[4] which reveals not only many additional lines of the 3−1 band, but also numerous lines arising from the 2−0 band at 4260.13 cm^{-1} and the 4−2 band at 4154.28 cm^{-1}. In every case, there is precise agreement between the observed and calculated line positions, and for all three bands the only lines observed are those with rotational quantum numbers in the neighborhood of $J=30$. All of the lines in the spectrum of the disk center are very weak; their central absorptions usually do not exceed 5 percent. Also, the line intensities do not appear to differ significantly from one band to the other, which is not surprising inasmuch as the Boltzmann factor is relatively small at solar temperatures.

It should be noted that CO is expected to be one of the most abundant molecules in the solar atmosphere, according to calculations by Russell.[5] Its failure to be observed previously is due only to the location of its electronic bands in the inaccessible ultraviolet.

In view of the presence of the overtone transitions 2−0, 3−1, and 4−2 at 2.3μ, it is to be expected that the corresponding fundamentals 1−0, 2−1, and 3−2 will be very strong. Migeotte has observed indeed the 1−0 band at 4.7μ in the solar spectrum both at Columbus, Ohio,[6] and from the Jungfraujoch.[7] He states, however, that the band originates in the earth's atmosphere and believes that the solar contribution to the band is negligible. He observes further that the band undergoes large and apparently random fluctuations in intensity, the line R_3 varying from 15–50 percent central absorption. Later, the 4.7μ band was observed by Shaw, Chapman, Howard, and Oxholm,[8] also at Columbus, but they found that the central absorption of R_3 was never less than 45 percent over a period of three or four months.

On the basis of observations made at the McMath-Hulbert and Mount Wilson Observatories, it can be stated that the telluric contribution to the 2−0 band, if present, is no greater than the contribution from the center of the solar disk. This result would imply that at least half of the contribution to the 1−0 band is also solar. If so, the 2−1 and 3−2 bands should appear with strength comparable to 1−0, at 2116.75 cm^{-1} and 2090.28 cm^{-1}, respectively. Inspection of the table of wavelengths and of the tracing of the 4.7μ region published by Shaw, *et al.*[8] suggests that some lines of the two difference bands may be present, but they are very much weaker than those of the 1−0 band at 2143.38 cm^{-1}. It would obviously be extremely important to compare tracings of the 4.7μ band made at various points on the solar disk, to determine the existence both of intensity variations and of Doppler shifts resulting from solar rotation.

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Far Infrared Transmission of Silicon and Germanium

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THE infrared transmission spectra of elementary silicon and germanium are of interest because of the remarkable electrical properties of these materials. The temperature-dependence of electrical resistance of germanium, for example, has been interpreted[1,2] as indicating a conduction-band gap resulting from impurity acceptors of approximately 0.01 ev. Study of the absorption of electromagnetic radiation of energies of this magnitude could thus furnish useful evidence for the solid-state theory of the properties of germanium,[3] and perhaps yield more accurate values of the band-gap energies than can be obtained from thermal and electrical measurements.

The infrared transmissions of optically polished samples of silicon and germanium of 2-mm thickness are given in Table I for

TABLE I. Infrared transmission for 2-mm samples of germanium and silicon (uncorrected for reflection losses).

cm^{-1}	T_{Ge}	T_{Si}	cm^{-1}	T_{Ge}	T_{Si}
260	0.12	0.36	540	0.31[a]	0.20
270	0.07	0.37	560	0.33	0.17
280	0.05	0.39	580	0.40	0.18
290	0.05	0.39	600	0.44	0.05
300	0.03	0.38	610	—	0.03[a]
320	0.03	0.37	620	0.47	0.05
340	0.01	0.37	640	0.45	0.27
360	0.01	0.37	660	0.47	0.30
380	0.11	0.37	680	0.47	0.32
400	0.24	0.36	700	0.48	0.36
420	0.15[a]	0.36	720	0.48	0.25
440	0.23	0.36	736	—	0.18[a]
460	0.27	0.37	740	0.47	0.18
480	0.37	0.28	760	0.47	0.19
500	0.34	0.25	780	0.47	0.22
516	—	0.14[a]	800	0.46	0.25
520	0.32	0.20			

[a] Indicates band minimum.

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

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