ments of the bomb. Evidence of other lines is present but confused by near coincidence with lines arising from the beryllium. For this reason, they are not included in Table I.

As a result of stimulating conversations with our colleague, W. H. Zachariasen, we propose the following simple model to explain this rather unusual transformation. Cerium, which is the first atom in the periodic table to permit the existence of a $4f$ electron in the free gaseous state, when condensed exhibits the tendency to become perverted from a trivalent to a quadrivalent state. For instance, CeO_2 is the stable oxide. Apparently, the application of 12,000 atmospheres of pressure is sufficient to evoke this transformation and the $4f$ electron is literally squeezed into a $5d$ state. No other model appears capable of explaining the enormous contraction from one closely packed structure to an identical closely packed structure. Quantitatively, this model appears to be supported by the lattice constants observed. Thus, according to W. H. Zachariasen,[9] the ionic radii of trivalent and quadrivalent cerium with a coordination number of 12 should be 1.85 ± 0.01A and 1.71 ± 0.02A, respectively; the lattice constants observed correspond to ionic radii of 1.82A and 1.71 ± 0.02A to which a small correction of about 1.5 percent should be applied for normal compressibility by comparison with the data on lanthanum and praseodymium. If we assume that the phase observed by Trombe and Foex[6] is also a collapsed face-centered structure, the Clapyron equation permits us to make a rough estimate of the energy level separation between the $4f$ and $5d$ states. Such an estimate yields a value of approximately 0.04 ev. In addition, such a change in the electronic configuration of cerium would explain qualitatively the slight decrease in the change of the paramagnetic susceptibility with temperature.[10] Quantitative agreement is not to be expected since the low temperature transformation probably does not go to completion.

The hypothesis proposed above also explains why the transformation, unique to cerium, is absent in lanthanum and praseodymium. In the former, the $5d$ state is known to be the more stable, while in the latter, the $4f$ state is probably sufficiently stable to resist perturbation by pressure in the experimentally available range.

Several related observations deserve mention herein. Below the transformation pressure, the cerium was often partially converted to an alternative form (tentatively identified as a close-packed hexagonal form) which occasionally persisted even at the highest pressures. In view of the lack of reproducibility in the formation of this phase, we believe it to be a metastable form created by the action of unavoidable but variable friction transmitted by the binding cement. Upon sudden release of the high pressure, this form (unmistakably identifiable as close-packed hexagonal) invariably was present and gradually transformed over a period of days to the original face-centered cubic modification. After several weeks the cerium oxidizes and only CeO_2 lines are observed in the diffraction pattern.

In agreement with Bridgman,[4] we observe that below the transformation pressure the compressibility of Ce progressively increases with increasing pressure, accounting for an appreciable fraction (over $\frac{1}{3}$) of the over-all volume change. We believe that this progressive increase in compressibility, terminating in a decisive collapse, is responsible for an increase in amplitude of thermal vibration in the lattice and accordingly explains the anomalous increase of resistance with pressure in Ce, previously reported by Bridgman.[3]

Attempts to produce the transformation in rather impure Ce (containing at least 0.2 percent Fe) existing in the hexagonal modification at atmospheric pressure were unsuccessful.

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The Frequency ν_2 in the Infra-Red Spectrum of CH_4

JOHN S. BURGESS
Mendenhall Laboratory of Physics, The Ohio State University, Columbus, Ohio
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THE infra-red spectrum of methane has been investigated at length by Cooley[1] and Nielsen and Nielsen,[2] and the complex structure of the band ν_4 has been admirably analyzed by Jahn[3] and Childs and Jahn[4] in a series of papers. They accounted for the rotational structure of ν_4 on the basis that there exists a resonance Coriolis interaction between the frequency ν_4 and the optically inactive frequency, ν_2. This analysis has been verified by Shaffer, Nielsen, and Thomas[5] who have presented a theory of the rotation-vibration problem of the tetrahedrally symmetric XY_4 type of molecule complete to second order of approximation.

The Coriolis interaction affects the vibrations somewhat in the following manner. If ν_4 is larger than ν_2, the effective moments of inertia in these states will be, respectively, larger and smaller than the moment of inertia in the normal vibrational state. This should give rise to convergence of the rotational lines in ν_4 toward higher frequencies, and in the frequency ν_2, if it were active, toward lesser frequencies. If, on the other hand, ν_4 is smaller than ν_2, a situation just the reverse of the above should prevail.

The Coriolis perturbation will cause a mixing of the wave functions of the two states so that, if the two frequencies are near enough alike, it should be possible to observe ν_2. This is indeed the case in the molecules SiH_4 and GeH_4 where the two frequencies are separated by 65 cm^{-1} and 114 cm^{-1}, respectively. Tindal, Straley, and Nielsen[6] have reported on the activity of the band ν_2, induced by this Coriolis interaction, for these two molecules. The frequency ν_2 has never been observed in the spectrum of CH_4 principally because it overlaps almost exactly the region of the strong water vapor band. An indication of its existence is nevertheless suggested by the data of Coblentz.[7]

This region has been explored with our vacuum infra-red grating spectrometer, and the band ν_2 has now been observed. The band center has been determined to lie at about 1533.6 cm^{-1} while ν_4 lies at 1305.9 cm^{-1}. The Q branches of these two bands do fold away from each other as is to be expected from the theory outlined above, and the ν_2 band is considerably weaker in intensity.

Complete details of these measurements will be published at a later date.

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Note on Measurements of Ambipolar Diffusion in Helium*

MANFRED A. BIONDI AND SANBORN C. BROWN
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts
June 3, 1949

THE discussion presented in the last paragraph of the article "Measurements of ambipolar diffusion in helium" [1] is in error. The mobility of He^{++} should be $\sqrt{2}$ times the mobility of He^{+} if charge transfer is neglected, and thus would not explain the difference between our measurements and those of Tyndall and Powell. Meyerott[2] has suggested that the theoretical mobility of

He_2^+ agrees with Tyndall and Powell's measured value of 21.4 (cm/sec.) per (volt/cm). The mobility of He^+ in He, neglecting charge transfer, may be determined by the extrapolation of the curve given in Fig. 8 (reference 1) as $\mu_+=26$ (cm/sec.) per (volt/cm). The mobility of He_2^+ should be $\frac{1}{2}\sqrt{3}$ times this value of 22.5 (cm/sec.) per (volt/cm). The agreement between this predicted value and Tyndall and Powell's measured value suggests that they may have measured the mobility of He_2^+. It appears, in any case, that the measurements made by Tyndall and Powell and in our experiment are for two different ions, but the exact identity of the ions in each experiment is not known. Mass spectrographic analysis of our ions is planned.

* This work has been supported in part by the Signal Corps, the Air Materiel Command, and ONR.

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Comment on the Nuclear Capture of Negative Mesons

J. BARNOTHY
Barat College, Lake Forest, Illinois
June 7, 1949

A NUMBER of different authors have observed that when negative mesons are stopped in an element with high atomic number the negative mesons do not undergo the normal decay process and it was therefore assumed that they are captured by the nuclei. This interpretation, however, encounters some difficulties because it does not explain the failure to detect stars at the end of such meson tracks.[1] I would like to suggest an explanation to account for the fact that no decay electrons were observed if lead was used as stopping material.

If—and this is rather plausible—the negative meson is captured on a K-shell, then almost the double of the K-shell energy of the meson is needed to liberate the decay electron from the atomic binding. Hence, the decay electron of a meson disintegrating in lead will lose 38.6 Mev of its energy merely in order to be able to get out from the atom. This energy loss is rather considerable, since 54 Mev represents the upper limit of the energy of the decay electrons. It seems rather reasonable to assume that no decay will occur whenever the electron does not obtain an energy sufficient for leaving the K-shell and hence these latter cases might bear the aspect of a nuclear capture leading to no stars at the end of the meson track.

For example, in Retallack's[2] experimental arrangement, where lead plates were placed in the cloud chamber, he observed a total of 27 negative meson tracks stopped in lead. Computing with the same 31 percent probability, experimentally found for positive mesons which can get out of the lead plate and produce a track in the cloud chamber, we would have to expect 8 decay electron tracks, whereas only one was observed. If, however, 38.6 Mev are needed in order that a decay electron should be able to leave the lead atom, and, moreover, we assume a continuous spectrum of the decay electrons between 5 Mev and 55 Mev with a most probable electron energy of about 40 Mev, then we immediately see that out of the 27 negative mesons merely 9 electrons could get out of the lead atom. Moreover, these 9 electrons will have energies between 0 and 15 Mev, hence it is most probable that only about one of them can emerge from the lead plate and produce a track in the cloud chamber.

In order to test the validity of the above given interpretation, it would be of interest to perform cloud-chamber measurements by using as stopping material, for instance, barium, in which case the energy loss of the electron within the atom would amount to 18 Mev, hence we would have to expect a shifting in the energy spectrum of the electrons by 18 Mev toward lower energies.

Our interpretation of the failure to detect decay electron tracks from lead does not, however, explain the apparent shortening of the lifetime of negative mesons in lighter materials (NaF; Al: S) because even for iron the decay electron needs only 3.9 Mev to be released from the meson K-shell, hence this energy loss is quite negligible as compared with the average initial energy of the electron. It remains an open question whether we are confronted, in the apparent lifetime shortening of the negative mesons, with a nuclear capture[3] or with a true decrease of the lifetime occurring in the K-shell.[4] Anyhow, the missing decay electron tracks from lead can no longer be considered as a proof in favor of the nuclear capture conception.

The author would like to point out that similar experiments performed with cloud chambers and by using as stopping materials substances with atomic numbers ranging between sulfur and iron will probably decide between the above-mentioned two alternatives. Because in these materials a quite considerable shortening of the lifetime is to be expected, whereas the energy needed for the electron to leave the K-shell of the meson is still quite negligible.

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Spontaneous Decay Rate of Heavy Mesons

L. I. SCHIFF
Stanford University, Stanford, California
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THE assumption of a direct coupling between heavy (π) and light (μ) mesons that leads to the observed rate of $\pi-\mu$-decay, also explains the observed rate of capture of negative μ-mesons by nuclei as a second-order process.[1] Alternatively, it has been proposed[2] that μ-mesons are directly coupled to nucleons. This latter assumption leads to $\pi-\mu$-decay as a second-order process even if no direct $\pi-\mu$-coupling is postulated.[3] If, in addition, a direct coupling between electrons (e) and nucleons is assumed,[2] $\pi-e$ decay also appears as a second-order process. A comparison of the rates of $\pi-\mu$- and $\pi-e$-decay with observation can therefore be expected to throw some light on the validity of the assumption of direct couplings of μ-mesons and electrons with nucleons.

It is assumed in this note that π-mesons are scalar particles μ-mesons, electrons, neutrinos (ν), neutrons (N), and protons (P) are all Dirac particles, and that all couplings are of the scalar type that involve the Dirac β-operator. The interaction term in the Hamiltonian then has the form

$$H'=G\int\psi_\pi(\psi_P^*\beta\psi_N)d\tau+g_\mu\int(\psi_\nu^*\beta\psi_\mu)(\psi_P^*\beta\psi_N)d\tau+g_e\int(\psi_\nu^*\beta\psi_e)(\psi_P^*\beta\psi_N)d\tau+\text{c.c.} \quad (1)$$

The strength of nuclear forces gives G the approximate value $(4\pi\hbar c^3/3)^{\frac{1}{2}}$. The interaction (1) leads to a reciprocal mean life for decay of a π-meson at rest

$$\frac{1}{\tau_\pi}=\frac{G^2g^2p^2}{2\pi^5m\hbar^8c^5}\left|\int_0^\infty\frac{P^4dP}{(P^2+M^2c^2)^{\frac{1}{2}}}\right|^2. \quad (2)$$

In (2), m is the mass of the π-meson, p is the momentum of the emitted neutrino, M is the mass of the nucleon, and the integration is carried over all intermediate nucleon momenta P. The formula gives $1/\tau_{\pi\mu}$ or $1/\tau_{\pi e}$ according as g is given the value g_μ or g_e. A term $\pm mc$ has been neglected in the energy denominator in comparison with $(P^2+M^2c^2)^{\frac{1}{2}}$.

The divergence of the integral in (2) places any quantitative conclusions drawn from this formula on doubtful ground. Since, however, this integral is the same for the rates of both $\pi-\mu$- and $\pi-e$-decay, it cancels out of their ratio, to give

$$\tau_{\pi\mu}/\tau_{\pi e}=(g_e^2p_e^2/g_\mu^2p_\mu^2); \quad (3)$$

p_μ and p_e are the momenta of the neutrinos emitted in the two modes of decay. If we assume, as suggested by Tiomno and