observed half-life be as short as 10^5 years, one would conclude that the transition is second forbidden.

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* Formerly at Oak Ridge National Laboratory; now with Research Division, Atomic Energy Commission, Oak Ridge, Tennessee.

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On Elastic Constants of Nickel Crystals

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IN the "Letters to the Editor" column of this journal, Bozorth and his collaborators[1] reported their data on the elastic constants of nickel crystals, determined by the dynamic pulsing method, and stated that these constants had not been measured previously. I would like to remark that two reports on this subject have been published by Japanese physicists. Young's moduli for various crystallographic directions were measured with a static method of torsion by Honda and Shirakawa[2] in 1937, and with a dynamic method of magnetostrictive vibration by Yamamoto[3] in 1942. They determined elastic constants by combining their data on Young's moduli as a function of crystal direction with the measured value of the cubic compressibility of polycrystalline nickel obtained by Bridgman[4] and afterward corrected by Slater,[5] since it has been verified for most metals (though not yet for nickel) that the cubic compressibility is the same for a single crystal as for a polycrystal if the effect of grain-boundaries in the polycrystal is negligible.

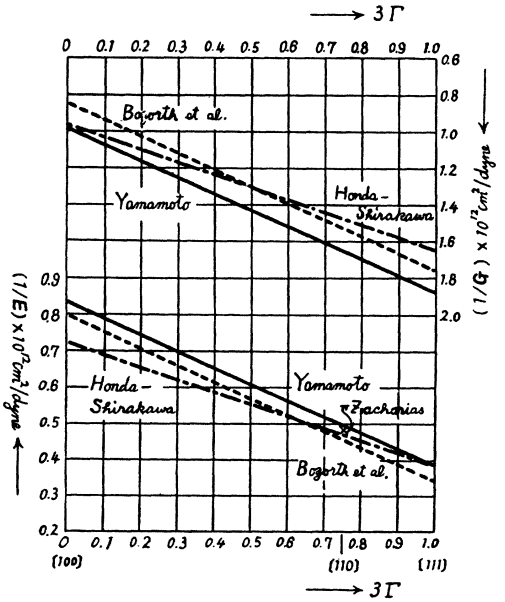

FIG. 1. Linear relations between the reciprocals of Young's and rigidity moduli, $1/E$ and $1/G$, and the orientation function, Γ, in nickel crystals.

TABLE I. Comparison among the three sets of data on the elasticity of nickel crystals.

Investigators	Elastic constant (10^{12} dynes/cm²)			Elastic anisotropy		Moduli for a polycrystal, computed with Voigt's theory (10^{12} dynes/cm²)	
	C_{11}	C_{12}	C_{44}	E_{111}/E_{100}	G_{100}/G_{111}	$\bar{E}$	$\bar{G}$
Honda-Shirakawa	2.52	1.51	1.04	1.90	1.72	2.16	0.82
Yamamoto	2.44	1.58	1.02	2.16	1.92	2.07	0.78
Bozorth *et al.*	2.50	1.60	1.185	2.35	2.09	2.32	0.89
						2.00[a]	0.74[a]

[a] Average of measured values for polycrystalline nickel.

Honda-Shirakawa's and Yamamoto's data are compared with those of Bozorth and others in Table I and Fig. 1. Table I contains the principal elastic constants, C_{ik}, elastic anisotropy expressed by ratios of Young's and rigidity moduli for [100] and [111] directions, E_{111}/E_{100} and G_{100}/G_{111}, and Young's and rigidity moduli for a pseudoisotropic polycrystal, $\bar{E}$ and $\bar{G}$, calculated by Voigt's[6] theory (under the assumption that strain components are uniform throughout every grain of a polycrystal). Averages of measured values of Young's and rigidity moduli for polycrystalline nickel are also added for comparison at the base of Table I. In Fig. 1 linear relations between both reciprocals of Young's and rigidity moduli, $1/E$ and $1/G$, and the orientation function $\Gamma=\gamma_1^2\gamma_2^2+\gamma_2^2\gamma_3^2+\gamma_3^2\gamma_1^2$ (γ_1, γ_2, and γ_3 are the direction cosines of a direction in reference to the crystal axes) are shown. Zacharias'[7] data on $1/E$ for the [100] direction, obtained with a dynamic method of piezoelectric excitation, is also plotted as a cross in Fig. 1.

No remarkable differences are seen among the three sets of data on elastic constants, but elastic anisotropy increases in the order of the data by Honda-Shirakawa, Yamamoto, and Bozorth *et al.* As to the values of Young's and rigidity moduli for a polycrystal, computed with the Voigt method of average, which usually gives values comparatively near to (but always slightly higher than) observed ones,[8] those computed from Yamamoto's data are nearest to, while those from Bozorth's data the farthest from observed values. Further, it is to be noted that the value of the cubic compressibility $\kappa=3/(C_{11}+2C_{12})$ computed from Bozorth's data, 0.526×10^{12} dynes/cm², is considerably lower than the measured value for a polycrystalline nickel (0.535×10^{12} dynes/cm²).

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The Zenith Angle Variation of the Latitude Effect of Cosmic Rays

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THE latitude effect of cosmic rays at sea level was measured with three different Geiger counter telescopes on a journey from Sydney (Australia) to Kure (Japan) and back.[1] Two telescopes subtended an angle of 26×33°, of which the first recorded the total radiation and the second the radiation filtered by 10 cm of lead. The third telescope consisting of two closely stacked trays

of Geiger counters subtended practically the whole hemisphere. The following uncorrected latitude effects were obtained; for the first and second, 20±1 percent, for the third telescope 13±1 percent.[1]

The first result exceeds the previous highest result of 15±1 percent obtained by Neher and Pickering,[2] while the third is of the same magnitude as ionization chamber measurements obtained at the same longitude.[3]

As the measurements under consideration were made simultaneously, longitude differences, atmospheric effects, and variations of primary cosmic-ray intensity are excluded. A quantitative calculation of the zenith angle sensitivity of several Geiger counter telescopes and of ionization chambers showed that after correction for seasonal and longitude effects all measurements except one,[4] which falls outside the range covered by the others, satisfy the relation: latitude effect averaged over all azimuths $=0.18\cos^2(1.2\zeta)$ in which ζ is the zenith angle. This is nearly the same zenith angle variation as that of the cosmic-ray intensity at latitudes above the knee. This coincidence appears to be fortuitous since the intensity variation is determined by absorption and decay only, whereas the variation of the latitude effect is mainly produced by deflection in the earth's magnetic field. Considering the uncertainty of the several effects[5] which affect the reduction to the geomagnetic latitude effect, no effort at such a correction is made.

It may be pointed out that the zenith angle variation found confirms the multiple production of mesons by the cosmic-ray primaries. If the whole energy of a primary particle were transferred to a single meson the latitude effect would disappear for a zenith angle at which the energy loss in the atmosphere becomes equal to the magnetic cut-off energy at the equator. The latitude effect would disappear first in the direction of the lowest cut-off energy, i.e., in the western direction. From Vallarta's[6] graphs this cut-off energy, which varies only slowly with zenith angle, is taken as 10 Bev for $\zeta>60°$. Thus, for $\cos\zeta=0.2$ or $\zeta=78.5°$ the latitude effect would disappear in the western direction, for $\zeta=84.5°$ in the north and south directions, and for $\zeta=88°$ in the eastern direction. The result of this calculation does not agree with the relationship which was deduced above from the experimental data; the latitude effect becomes 0.02 for $\zeta=60°$ and disappears practically for $\zeta=70°$.

Taking the latitude effect in the north and south directions as the same as the averaged effect, we may estimate the multiplicity in the energy range concerned. At $\zeta=70°$ the magnetic cut-off energy is 18 Bev and the energy loss 2 Bev/cos70°=6 Bev, i.e., about 18/6=3 mesons are produced on the average by each primary.

A detailed account of the calculation will appear in the *Australian Journal of Scientific Research.*

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The Internal Diamagnetic Field Correction in Measurements of the Proton Magnetic Moment

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IN recent high precision experiments[1,2] involving the proton magnetic moment, the internal diamagnetic field correction[3] to the measurements has become an important limitation to the accuracy of the results. This correction arises from the fact that the protons being measured are contained in a molecule, such as H_2, whose electrons to some extent magnetically shield the nucleus so that the magnetic field at the nucleus is not the same as the externally applied field. Approximations to this correction have been made either by using in the H_2 molecule the same correction as would be calculated for a single hydrogen atom[1] or by evaluating with Nordsieck wave functions in H_2 the contribution the electrons would make to the shielding if one could neglect the influence of the internuclear axis in preventing free diamagnetic motion of the electrons when the magnetic field is applied.[2] The latter approximation corresponds to neglecting the analog to the orbital moments' high frequency matrix elements in the theory of molecular diamagnetism.[4] These two methods of estimating the correction yield results which differ by almost a factor of two. An exact theoretical evaluation of the diamagnetic correction has been impossible because the term in the correction which is dependent on the orbital moments' high frequency matrix elements is numerically important and at the same time very difficult to evaluate since it depends on the wave function of the H_2 molecule in its various excited states.

The purpose of the present letter, however, is to point out that this difficult term is directly related to the spin-rotational interaction constant[5,6] of the molecule, which has been experimentally measured in certain cases, notably for H_2. This relationship can be seen by developing the theory for the internal diamagnetic field correction and comparing the results with the spin-rotational interaction theories of Foley and of Wick.[6] However, the results can be seen even more directly by adopting the point of view used once by Wick[7] in discussing rotational magnetic moments. From this point of view it is immediately seen that the internal diamagnetic field correction is a quantity entering directly into the theory of the spin-rotational magnetic interaction of diatomic molecule.

The result obtained from either of the above methods of analysis is that in a $^1\Sigma$-diatomic molecule the internal diamagnetic field H'(O) at the nucleus in the presence of an external field H is given by

$$\frac{H'(O)}{H}=-\frac{e^2}{3\,mc^2}\int\frac{|\psi|^2}{r}d\tau+\frac{1}{6}\alpha^2\frac{a_0a^2}{(\mu_0m/M)}\left\{\frac{2Z(\mu_0m/M)}{a^3}-\frac{\mu}{M}H_p\right\},$$

where a is the internuclear distance in the molecule, μ is the reduced mass of the molecule, μ_0 is the Bohr magneton, M is the proton mass, and H_p is the spin-rotational interaction constant.[5]

The first term in the above has been evaluated by Anderson[2] to be -3.24×10^{-5} while $\mu H_p/M$ has been determined in the experiments of Kellogg, Rabi, Ramsey, and Zacharias with the result that

$$H'(O)/H=[-3.2_4+0.53]\times10^{-5}=-2.7_1\times10^{-5}.$$

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Concerning W. P. Allis' Criticism of My Paper on Coulomb Interactions in a Plasma

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IN a note entitled "An error in a paper by Landau on Coulomb interactions in a plasma,"[1] Allis asserts that there is an error in my kinetic equation for the case of Coulomb interaction.[2] However this assertion is a result of a calculational error made by Allis himself. In expanding the collision integral in powers of Δ,