This work has been supported financially by the Swedish Atomic Energy Committee. The ready assistance of Mr. B. Nagel and Mr. S. G. Nilsson is gratefully acknowledged.

[1] L. Rosenfeld, *Nuclear Forces* (North Holland Publishing Company, Amsterdam, 1948), p. 180.
[2] R. E. Bell and L. G. Elliott, Phys. Rev. **74**, 1552 (1948).
[3] E. Melkonian, Phys. Rev. **76**, 1744 (1949).
[4] The values of a_t and a_s given in Table II are much more accurate, being closely connected with the eigenphases, which are stationary in the variational method used. See L. Hulthén, Kgl. Fysiograf. Sällsk. Lund Förhandlingar **14**, No. 21 (1944); Arkiv f. Mat. Astr. o. Fys. **35A**, No. 25 (1948). Smith, Barkas, Bishop, Bradner, and Gardner, Phys. Rev. **78**, 86 (1950).
[6] In addition to Eq. (2) we have the well-known relation
$$\sigma_0 = 3\pi a_t^2 + \pi a_s^2.$$
[7] L. Hulthén and S. Skavlem (unpublished manuscript, 1949).

The Hyperfine Structure of Ni^{61}

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INTERFERENCE spectrograms of nickel[1] enriched to 80 percent in Ni^{61} have been made with a liquid-nitrogen-cooled beryllium hollow cathode discharge tube filled with helium and argon. Fabry-Perot interferometers having 15, 25, 50, and 67 mm Invar separators were used with aluminum-coated quartz plates. No clear hyperfine structure splitting has been observed, but certain lines in the spectrum, especially those involving the $d^9s\ ^3D_3$ level, show definite broadening in excess of that caused by the Doppler effect.

The lines involving transitions to the $^3D_3$ level, in the region 3300 to 3600A, show a half-width of approximately 0.06 cm^{-1}. This is very nearly double the half-width of the sharpest lines from other transitions in the same region. The approximate half-width of these sharpest lines, 0.03 cm^{-1}, is very nearly equal to the limit of 0.025 cm^{-1} determined by Doppler broadening at liquid nitrogen temperatures. The resolution was insufficient to determine the spin, but the upper limit of the magnetic moment appears to be of the order of 0.25 nuclear magneton. Further study of this isotope by using liquid hydrogen cooling is contemplated.

[1] Produced by the Y-12 plant, Carbide and Carbon Chemicals Corporation, Oak Ridge, Tennessee, and obtained by allocation from the United States AEC.

On the Origin of the Sodium *D* Lines during Twilight

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PENNDORF[1] has recently proposed a new mechanism to explain the twilight luminescence of atmospheric sodium. This was done mainly in order to account for certain experimental results, found by Vegard and Kvifte,[2] which are hard to interpret on the usual theory. Unfortunately the new process itself raises great difficulties.

According to Bricard and Kastler[3] the intensity of the *D* line emission at twilight is about 1.5×10^{10} photons/cm^2 column/sec., or 10^4 photons/cm^3/sec. in a 15 km layer. To account for this Penndorf has suggested the following series of reactions, supposed to take place near 100 km height:

$$Na + N_2O = NaO + N_2, \quad (1)$$
$$NaO + Na_2 = Na(^2P) + Na_2O, \quad (2)$$
$$Na(^2P) = Na(^2S) + h\nu(\lambda = 5890A), \quad (3)$$
$$Na_2O + h\nu = Na_2 + O. \quad (4)$$

The rate of (2) must be $\alpha[NaO][Na_2] = 10^4$ reactions/cm^3/sec., in order to give the observed intensity of emission. The value of α is probably 10^{-10} cm^3/sec.

The four reactions quoted are to be considered together with (5) and (6):

$$Na_2 + h\nu = Na + Na, \quad (5)$$
$$Na + Na + X = Na_2 + X. \quad (6)$$

Equation (5) denotes the photo-dissociations of Na_2 by light of wave-length $\lambda = 3500A - \lambda = 2900A$. The rate of this reaction is $\delta[Na_2]$; here $\delta = (\pi e^2\lambda^2/mc^2)fI$, where f is the oscillator strength of the transitions leading to the dissociation, and $I(\sim4\times10^{20}$ photons/cm/cm^2/sec.) stands for the intensity of solar radiation in the spectral region concerned. Thus $\delta\sim3.6\times10^{-1}f$; even with f as small as 10^{-3}, $\delta > 10^{-4}$.

Three-body recombination (6) of Na atoms seems to be faster than radiative association; with a local particle density $[X] = 10^{14}$ its rate would be about $10^{-16}[Na]^2$. For equilibrium between (5) and (6)

$$\delta[Na_2] = 10^{-16}[Na]^2,$$

or

$$[Na_2] \leqslant 10^{-12}[Na]^2,$$

and by the conditions for reaction (2)

$$[NaO] \geqslant 10^4/\alpha \cdot 10^{-12} \cdot [Na]^2 = 10^{26}/[Na]^2.$$

Table I lists some possible values of [Na] and corresponding minimum values of [NaO].

TABLE I. Possible values of [Na], and corresponding minimum values of [NaO].

[Na]	$[NaO]_{min}$
10^4	10^{18}
10^5	10^{16}
10^6	10^{15}
2×10^6	2.5×10^{13}

By consideration of the Na^+:Na equilibrium in an ionized region it has been shown by the writer[4] that the greatest possible value of [Na] is 2×10^6 atoms/cm^3 at the heights concerned. Thus, in order to make Penndorf's process work, the concentration of NaO must be impossibly high (at least 25 percent).

Some of the values adopted in the calculation may be rather unfavorable to the new process, but it is clear that the ratio [NaO]:[Na] will always be very large. This again would be hard to explain, as NaO is probably dissociated not only by reaction (2), but also by sunlight, and by its reaction with atomic oxygen

$$NaO + O = Na + O_2.$$

[1] R. Penndorf, Phys. Rev. **78**, 66 (1950).
[2] L. Vegard and G. Kvifte, Geofys. Publ. Oslo, **16**, No. 7 (1945).
[3] J. Bricard and A. Kastler, Ann. de Geophys. **1**, 53 (1944).
[4] F. D. Kahn, Thesis, Oxford University (January, 1950).

Zero-Point Vibrations and Superconductivity

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A THEORY of superconductivity which depends on interaction of the valence electrons with the zero-point vibrations of the crystal lattice is proposed. This approach was stimulated by the recent finding of Reynolds, Serin, Wright, and Nesbitt[1] and of E. Maxwell[2] that the critical temperature, T_c, of mercury depends on the isotopic mass. The theory is a modification of one proposed some years ago by the writer.[3] It gives a natural explanation of the isotope effect and the energies and critical temperatures are of the correct order.

It is assumed that the vibrational modes of the superconducting state differ from those of the normal state in that the vibrations are such as to lower the energy of electrons in states near the