can apply to Eq. (3) below. The relations are

$$\alpha_1{}^1 = \alpha_1 + \gamma_p \alpha_2$$

Electron density measured;
one positive ion;
α_1 = electron-ion coefficient;
α_2 = ion-ion coefficient. $\qquad$ (1)

$$\alpha_2{}^1 = (\alpha_1 + \gamma_p \alpha_2)/\gamma_p$$

Negative ion density measured;
one positive ion;
α_2 = ion-ion coefficient;
α_1 = electron-ion coefficient. $\qquad$ (2)

$$\alpha_e = (\alpha_1 + \gamma_p \alpha_2)/(1 + \gamma_p)$$

Electron density measured;
negative carrier electrons;
positive ions of coefficients
α_1 and α_2 in equilibrium;
or
Positive ion densities measured;
one positive carrier;
α_1 = electron-ion coefficient;
α_2 = ion-ion coefficient. $\qquad$ (3)

The variations of coefficients with pressure are shown in the curves of Fig. 1. Curve A is Varnerin's observed curve in H_2. Curve B is Eq. (1) with γ_p proportional to p, while curve C is Varnerin's approximation of Eq. (1) with γ_p proportional to pressure squared. Curve D is that of Eq. (3) with γ_p proportional to pressure squared, and curve E is Eq. (2) with γ_p proportional to p^2. It is to be noted that curve D is a fair approximation to Varnerin's observation, possibly within experimental accuracy. It is possible that Eq. (1) might apply to Biondi and Brown's observations in O_2, the only gas where negative ion formation could occur, and even here the equilibrium process may be impossible.[7] It is thus clear that the assumption of two positive ions leads to a curve analogous to Varnerin's data.

Such a relation may with more complete observational data apply to Ne below 77°K and to N_2, since negative ions cannot form in these gases. More data are needed in O_2 to determine what the reaction is. Studies of ion mobilities by the Bristol[8] group indicate that just such dual positive carrier types are in equilibrium at one pressure as a result of labile cluster ion formation. It could further be expected that the coefficients α_1 and α_2 for molecular unclustered and clustered ions respectively would be dissociative coefficients. The coefficient α_1 would be smaller than α_2, since α_1 leads to an excited atom and an unexcited one from a molecule of high dissociative energy, while the larger cluster ion would readily dissipate its energy in the kinetic form. The ions in H_2 could be H_2^+ and H_4^+ or H_5^+. In any case irrespective of the exact interpretations above from the nature of the pressure variation curve and the nature of the carrier density measured, it is possible to account for present observations[9] in terms of relations (1), (2), or (3).

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[9] In this analysis the studies of Biondi and Brown (reference 1) and Varnerin (reference 5) alone have been discussed, since they present a strong case. The excellent studies of Holt and his associates (reference 3) are not considered, since their insufficient cooling-off periods and higher ion densities make interpretation at this time too difficult.

The Spin and Quadrupole Moment of Se[79]*

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THE nuclear spin of the radioactive nucleus Se[79] was determined as 7/2 by observing the quadrupole pattern of the $J = 2 \to 3$ transition in $O^{16}C^{12}Se^{79}$. Six hyperfine components were identified. Their frequencies are given in Table I and are compared with predicted frequencies for a spin of 7/2 and a quadrupole coupling constant (eqQ) of 754 Mc. Estimating the molecular field gradient $q (q = \partial^2 V / \partial z^2)$ for Se in OCSe by the method applied by Townes and Dailey[1] to OCS, one obtains the Se[79] quadrupole moment $Q = 1.2 \times 10^{-24}$ cm^2, with an error less than 50 percent.

Since the total amount of Se[79] available was only one microgram and the OCSe was diluted by foreign gases, the spectrum was observed with a high sensitivity recording Stark spectrometer. The weakest hyperfine lines were only slightly larger than the noise background. Frequency markers were introduced on the recording chart and by interpolation the positions of all lines were measured with reference to a line due to OCSe[78] in an excited vibrational state, $v_1 = 1$, which was of comparable intensity to the Se[79] lines and near the center of the quadrupole pattern. In turn, the OCSe[78] line was measured with respect to the ground state OCSe[78] and OCSe[80] lines. With the data of Geschwind, Minden, and Townes,[2] the frequency of the OCSe[78] excited state line was measured as $24{,}174.12 \pm 0.02$ Mc. The values for the hyperfine frequencies given in Table I are averages of some thirty traces.

The predicted frequencies of Table I assume only the spin and the value of eqQ. The rotational frequency of OCSe[79] without hyperfine structure was calculated as 24,179.13 Mc from measured frequencies[2] of OCSe[78] and OCS[80] and a value for the isotopic mass of Se[79] obtained from a formula of the Bohr-Wheeler type.

Quadrupole patterns caused by spins of 3/2, 5/2, 7/2, and 9/2 were calculated, and Fig. 1 compares the more intense lines for spins of 7/2 and 9/2 with the measured pattern. Spins of 3/2 and 5/2 gave no fit at all. It is seen that the positions and relative spacings unambiguously determine the spin of Se[79] as 7/2. Relative intensities agreed well with the predicted pattern, except that the $F = 9/2 \to 9/2$ transition occurring very near the zero position was not found. This is expected, since the Stark splitting for this line is only 1/20 of that for the other lines (or about 0.012 Mc in a field of 1200 volts/cm).

The Se[79] was produced by fission in uranium which had been subjected to a large neutron flux. A uranium slug was dissolved in concentrated hydrochloric acid, and the resulting gas was bubbled through water saturated with bromine. The acidity was adjusted to $2N$ with hydrochloric acid, and 0.23 mg of selenium carrier was added as the tetrabromide. Selenium was precipitated with SO_2. Contents of the vessel were pumped nearly to dryness, carefully rinsed with water, neutralized with ammonia, and pumped to dryness. Carbon monoxide was introduced into the vessel to a pressure of 1/2 atmos. The vessel was sealed and heated to 500°C for 15 min. The resulting OCSe was pumped into a trap cooled with liquid nitrogen and was collected.

TABLE I. Observed $O^{16}C^{12}Se^{79}$ lines compared with lines calculated for a quadrupole coupling constant of 754 Mc and a spin of 7/2. Calculated lines include second-order quadrupole effects.

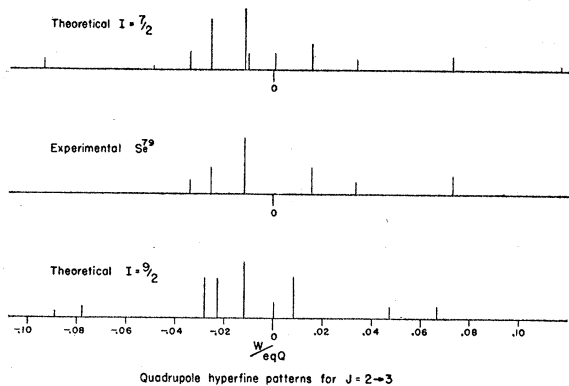| Transition	Calculated frequencies in Mc	Observed frequencies in Mc	Deviation in Mc
$F = 7/2 \to 7/2$	24,153.1	24,153.2	+0.1
$9/2 \to 11/2; 3/2 \to 1/2$	24,159.0	24,158.9	−0.1
$11/2 \to 13/2$	24,170.4	24,170.3	−0.1
$7/2 \to 9/2$	24,190.9	24,190.9	0
$3/2 \to 3/2$	24,204.8	24,204.8	0
$5/2 \to 7/2$	24,234.4	24,234.1	−0.3

Quadrupole hyperfine patterns for J = 2→3

FIG. 1. Comparison of the observed hyperfine structure of the $J = 2 \to 3$ transition of OCSe⁷⁹ with theoretical patterns.

Nuclear shell structure considerations[3] lead to an expected $g_{9/2}$ state for the $_{34}Se_{45}^{79}$ nucleus, although a $p_{1/2}$ state would not be improbable. The observed spin of 7/2 is a clear exception to the single particle strong spin-orbit coupling model. This spin has been predicted, however, by Goldhaber and Sunyar[4] for Se⁷⁹ and several other neighboring nuclei from a study of isomeric states. The other known exceptions of this type are $Na^{23}(I=3/2)$ and $Mn^{55}(I=5/2)$, which have been assumed to arise from $(d_{5/2})^3$ and $(f_{7/2})^3$ configurations, respectively. The Se⁷⁹ state probably involves a $(g_{9/2})^3$ configuration, in which two particles fail to pair off and give zero angular momentum, but give unit momentum instead. The positive quadrupole moment of Se⁷⁹ is consistent with such a state.

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Splitting of Bands in Solids

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THE natural explanation of the existence of metals with a partially filled band and insulators or intrinsic semiconductors with full or empty bands is one of the greatest early successes of the band theory of solids. However, metals of even valence required special consideration. Such materials would be insulators in a one-dimensional world, but become metals on account of a kind of overlapping or merging of bands which is only possible in more dimensions.

Recently Slater[1] devised a scheme by which the reverse can be achieved. Materials which would naively be expected to be metallic conductors may now be insulators or semiconductors (NiO or Au at low temperatures) by introducing suitable energy gaps into bands. This band splitting is a consequence of the assumption that the actual basic cell of the lattice may be an integral multiple of the naive basic cell, if certain refinements are considered, such as may arise from spin and possibly from a number of other causes. According to Slater's paper gaps may thus appear in principle almost anywhere in a band.

The purpose of the present note is to draw attention to the fact that the Slater gaps can only develop under certain conditions
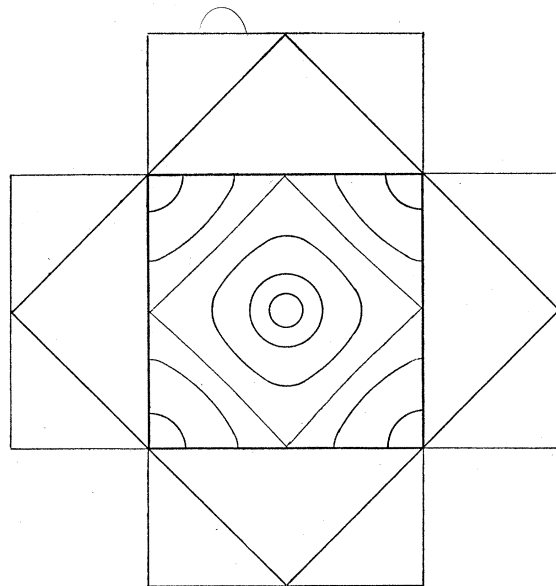

FIG. 1. The first three zones of the two-dimensional square lattice, with energy contours drawn in the first zone.

which greatly reduce their incidence. The potential in cases under consideration is assumed to consist of a major part, with the naive or unperturbed periods, and superimposed on this, a ripple or perturbation with larger periods. The resulting small gaps will almost certainly be mended by the same more dimensional mechanism, responsible for the merging of bands in metals of even valence. The condition that the gap persists is evidently that the new zone boundary, introduced by the perturbation, coincides very nearly with an equi-energy contour (in two dimensions) or surface (in three dimensions) of the unperturbed lattice in reciprocal space.

An example with the two-dimensional square lattice may illustrate this point. The reciprocal lattice is also square, and the zone boundaries are indicated in Fig. 1. The energy contours are like circles around the center of the first zone and around its corners. A square-like contour separates the center region from the corner regions of the first zone. The corner contours must meet the zone boundary at right angles, except the square-like contour, which has a double point where it meets the zone boundary and consequently may make any angle with the latter.

In Fig. 2 an added perturbation potential is assumed, with periods of twice the original lattice periods in both directions. This gives rise to a new zone pattern, similar to the one in Fig. 1 but at half scale. The original first zone thus contains roughly four perturbed zones, and naively new gaps may be expected, corresponding to $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$ filling of the original band. However, it is
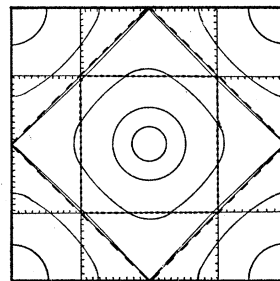

FIG. 2. New zone boundaries of the perturbed lattice within the first zone of the unperturbed lattice. The energy contours are the same as in Fig. 1.