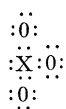


the electrons being shared as indicated by the formula



In the case of the oxides of arsenic and antimony, there are five electrons per As or Sb and six per O. To complete a four-pair tetrahedral valence shell around each atom requires that each As or Sb shares 3 electron pairs, at tetrahedron corners, with 3 oxygen atoms and each oxygen shares 2 pairs, at tetrahedron corners, with two As or Sb atoms,—precisely the arrangement determined from x-ray data.

It is plain that one can not only predict from this theory the number of electron pairs (per molecule or crystal unit) shared between electronegative atoms, but one can also predict that if an electronegative atom is adjacent to 2, 3, or 4 others, the arrangement will be that of 2, 3, or 4 corners of a (not necessarily regular) tetrahedron around its center.

Such predictions can be tested very readily by the results of x-ray analysis and in general they are found to be in agreement with experiment. Thus in iodine the negative atoms are in pairs; in crystals of Se and Te, each atom is adjacent to two others in a spiral chain; in P, As, Sb and Bi the atoms are in puckered layers, each adjacent to three others at three corners of a tetrahedron, while in the diamond, Si, Ge and gray Sn each atom is tetrahedrally surrounded by four others. Among compounds, several have been mentioned already; many others might be given.

As Lewis readily admits, there are exceptions to this tendency. Examples he gives are the molecules SF_6 and PCl_5 in which the central P and S atoms probably have 5 and 6 valence pairs, respectively. Other examples are afforded by such compounds as $CsICl_2$ and CsI_3 , in which the three halogen atoms form a colinear group. The number of valence electrons (counting 7 per halogen and 1 per Cs) in each X_3 ion is 22. The most reasonable distribution of these would seem to be one in which the central atom has 5 pairs and each of the others four.

Energies and Wave-Functions of the State $(1s)(2s)^3S$ in Helium-like Atoms

Eckart, in the Physical Review, September 1, 1930 (pp. 878 *et seq.*) pointed out that his modification of the Ritz method there pre-

In $CaCO_3$ and $NaNO_3$ both crystallographic and x-ray data indicate a 3-fold axis of symmetry through each C and N center and two-fold axes of symmetry through each C-O and N-O centerline. If the oxygen tetrahedra are oriented in agreement with this symmetry, each C or N kernel is surrounded by six pairs, joining it by double bonds to the neighboring oxygens.

The four pair valence shell is apparently stable if the valence shell is not made too large (as by the pull of surrounding electron atoms) in which case more pairs can be accommodated. The smaller the kernel charge—in general, the more electropositive the atom,—the more pairs can be accommodated in the valence shell but the less tightly each is held. Although in quartz (SiO_2), HgI_2 , ZnS , AgI and many other compounds relatively electropositive atoms are surrounded by four electronegative atoms at tetrahedron corners, suggesting electron sharing with tetrahedral valence shells around *all* the atomic kernels, in many others the electropositive atoms are surrounded by six or eight negative atoms. In some cases, (e.g. $NaCl$) the valence shells of the latter cannot be oriented so as to place the valence pairs on the centerlines between adjacent atoms; evidently in such polar crystals other considerations, such as the relative sizes of the atoms (or ions) are of the greatest importance in determining the type of arrangement. (Cf. Pauling, *J. Am. Chem. Soc.* **51**, 1010 (1929); Huggins, *J. Phys. Chem.*, in print.)

It should perhaps be pointed out that the point of view taken here is quite in agreement with recent developments in wave mechanics theory. (Cf. Bartlett, *Phys. Rev.* **36**, 1096 (1930) and papers by Bartlett and by Slater at the Cleveland Meeting of the American Physical Society.) The pairing of valence electrons, the sharing of such pairs between two atoms, and preferred orientations of electron orbits, once bones of contention between physicists and chemists, can now be agreed to by both.

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sented fails when applied to a state other than the lowest of a given series, e.g. $(1s)(2s)^3S$ of helium-like atoms, and suggested that a pro-

cedure might be worked out for applying the method to this case. This has been done by the author, using a comparison function designed to be orthogonal to the wave-function of the ground state.

The following comparison function is orthogonal to the exact wave-function ψ_1 of the ground state: $K(\phi_2 - \gamma_1\psi_1)$, where ϕ_2

culated ionization potential. The parameters ϵ and η correspond to Eckart's α and β for the state (1s)².

This comparison function gave the results summarized in the following table (α_0 and β_0 are the adjusted values of the parameters, $R_\infty h$ = unit of energy, W = energy, V_i = ionization potential):

	Z	α_0	β_0	W (calc.)	W (obs.)	V_i (calc.)	V_i (obs.)
He I	2	2.00	1.17	4.289	4.292	0.289	0.292
Li II	3	2.98	2.19	10.073	10.082	1.073	1.082
Be III	4	3.97	3.18	18.361	—	2.361	—
B IV	5	4.97	4.19	29.146	—	4.146	—

$= [u(\alpha_1)v(\beta_2) + u(\alpha_2)v(\beta_1)]/[2(1+b^2)]^{1/2}$, $b^2 = (2x)^2(x-1)^2/(x+\frac{1}{2})^8$, $x = \alpha/\beta$ (Eckart, Phys. Rev. **36**, 886), ψ_1 = exact wave-function of ground state, $\gamma_1 = \int \phi_2 \psi_1 d\tau$, $K = [1 - \gamma_1^2]^{1/2}$. Actually the use of a very accurate wave-function for ψ_1 (such as that of Hylleraas), was found to introduce too great complexities into the maximization. The function $\phi_2 = [u(\epsilon_1)u(\eta_2) + u(\eta_1)u(\epsilon_2)]/[2(1+c^2)]^{1/2}$, where $c^2 = 64(\epsilon\eta)^3/(\epsilon+\eta)^6$, was used for ψ_1 , (due to Eckart, Phys. Rev. **36**, 883). The validity of this approximation can be judged from the fact that a 10% change in γ_1^2 was found to produce only a 1% change in the cal-

One notices that α_0 is approximately equal to Z , ($Z - \alpha_0 \sim 0.02$); that $Z - \beta_0$ is essentially constant and ~ 0.82 ; and that $W(\text{calc.}) = (5/4)Z^2 + aZ + b$, where $a = -0.464$, $b = 0.216$.

Hylleraas (Zeits. f. Physik **65**, Heften 11 and 12, Nov. 14, 1930) has recently performed a calculation of this term for the special case of He I; his method, which results in a much more complicated wave-function, yields the value 0.290.

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A Theory of Collision Processes Involving No Radiation of Energy

The writers have developed a generalization of the Born collision method for dealing with collision processes. In the usual Born method the zero-order wave function for the colliding particle is a plane wave, undistorted by the presence of the stationary particle; which is so poor an approximation that the series for the cross section for many processes diverges; and in every case the first term is a bad approximation for small relative velocities. The writers use as a zero-order wave function one already distorted by an approximate mutual interaction field. The interaction energies effecting the transition have been expanded in a series which converges well for energies less than about 100 electron-volts. The cross sections for the various processes can be then computed and are valid for all except very large relative kinetic energies.

These cross sections, as a function of the size of the particles, of the nature of the transition

caused by the impact, of the mutual kinetic energy, and of the energy transferred from kinetic to energy of excitation, check quantitatively with such widely different experimental data as: Bleakney's¹ curves for ionization of Hg; Zemansky's² curves for transfer of excitation; Hanle's³ curves for excitation of various atoms; and Latyscheff and Leipunsky's⁴ curves for collisions of the second kind.

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¹ Bleakney, Phys. Rev. **35**, 139 (1930).

² Zemansky, Phys. Rev. **36**, 933 (1930).

³ Hanle, Zeits. f. Physik **54**, 848 (1929).

⁴ Latyscheff and Leipunsky, Zeits. f. Physik **65**, 111 (1930).