

possible. This I have recently succeeded in doing, in the case of carbon disulphide, with an accuracy apparently not far short of that attained in visual measurements.

The apparatus consists of a spectro-bolometer with very sensitive galvanometer, operated in connection with a Kerr cell. This has plates 5×37 cm and 1.3 cm apart. Light from a special tungsten strip filament lamp is concentrated in a narrow conical beam to an image in the center of the cell, from which it diverges to be focussed later on the slit of the spectrometer. A large aperture double-image prism (only one of the images is utilized) polarizes the entering light in the 45° azimuth and a similar prism crossed at 90° serves as "analyzer." The electrostatic stress converts the plane polarized light into elliptical and the minor axis of the ellipse is proportional to the square root of the resultant galvanometer deflection. The phase difference is readily computed upon comparing the deflection with

that produced by a known rotation of the polarizing prism. A high speed Wehrsen "Mercedes" static machine has so far served as a very satisfactory source of high potential.

The spectral range which can be explored in this way seems to be from about 0.5μ to 2μ or beyond, thus extending the previous wavelength range for this work some four-fold. Carbon disulphide, over this range, shows a dispersion of the Kerr double refraction in better agreement with the Havelock formula $B = C(n^2 - 1)^2 / \lambda n$ than might reasonably be expected. There are some discrepancies, however, to be investigated more carefully later—and explained if possible. The method is to be further developed and extended to such other materials as have sufficient infrared transparency.

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April 7, 1931.

Quantum Mechanics and the Chemical Bond

Three years ago I announced in a short note¹ the discovery of some new results regarding the chemical bond. It was pointed out that under certain conditions the formation of chemical bonds by an atom can destroy the distinction between s and p eigenfunctions, and a criterion determining whether this change in quantization of the single-electron eigenfunctions will or will not take place was given. It was also announced that this change in quantization permits the formation of four equivalent tetrahedral bonds by carbon.

Since then a number of further results bearing on the nature of the chemical bond have been obtained; it is the purpose of this letter to call the attention of physicists to a paper in the April, 1931, issue of the Journal of the American Chemical Society in which they are given in detail. It was first shown from the quantum mechanics that the main resonance integrals for an electron-pair bond between two atoms involve only one single-electron eigenfunction on each atom. In consequence many properties of electron-pair bonds can be derived from a consideration of single-electron eigenfunctions alone. Thus it is shown that if $s-p$ quantization is not changed, the bonds formed by the p eigenfunctions will tend to be at right angles to one another. A very simple but powerful approximate *quantitative* treatment of bond strengths is given. With its aid

it is shown that when $s-p$ quantization is broken through bond formation, the best bond eigenfunctions which can be formed from a combination of s and p eigenfunctions alone are tetrahedral eigenfunctions, so that the two, three, or four bonds formed will tend to make angles of $109^\circ 28'$ with one another. This explains the tetrahedral angles found experimentally not only for quadrivalent carbon, nitrogen, silicon, etc., but also for trivalent nitrogen, oxygen, etc. The tetrahedral eigenfunctions also allow free rotation about single bonds, but not about double bonds.

When d eigenfunctions as well as s and p are available for bond-eigenfunction formation a number of bond configurations are possible. One d eigenfunction with s and p permits the construction of only four strong bonds, and these are directed towards the corners of a square. Such a configuration has been shown to exist for bivalent palladium and platinum, and this theory predicts it also for bivalent nickel in $K_2Ni(CN)_4$ and for trivalent gold. Two d eigenfunctions give six strong bonds directed towards the corners of an octahedron; this configuration is found in many complexes.

¹ Linus Pauling, Proc. Nat. Acad. Sci. **14**, 359 (1928).

It is also shown that in complex ions the orbital magnetic moments of electrons are extinguished through the interaction with surrounding atoms, so that the magnetic moment is due to the spin moments of unpaired electrons alone. Together with the results obtained regarding bond eigenfunctions, this leads to a complete theory of the magnetic moments of polyatomic molecules and complex ions. With its aid magnetic data have been shown to provide verification of many predictions regarding bond eigenfunctions; and in a number of doubtful cases magnetic data provide a basis for definite decision as to the type of bonds in a given complex.

These results have also permitted the formulation of a set of principles determining the structure of crystals containing electron-pair bonds, to be published in the *Zeitschrift für Kristallographie*.

Three of these results have been independ-

ently obtained by Slater and announced in a preliminary communication.² He points out the possibility of the formation of four equivalent tetrahedral bonds by a carbon atom (as I did in 1928), without giving the tetrahedral eigenfunctions and without recognizing that tetrahedral eigenfunctions are also important even when fewer than four bonds are formed; and mentions that this leads to restricted rotation about a double bond. Having apparently assumed the importance of one single-electron eigenfunction to bond formation, he also shows that *p* eigenfunctions should lead to 90° bond angles.

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April 7, 1931.

² J. C. Slater, *Phys. Rev.* **37**, 481 (1931).

Time Lag in Changes of Electrical Properties of Rubber with Temperature and Pressure

An abstract of a paper by the author entitled "Time Lag in Changes of Electrical Properties of Rubber with Temperature and Pressure" appeared in the *Physical Review*, Vol. 35, page 1429, June 1, 1930. Data were presented which apparently showed that two or more hours might be required for the dielectric constant, power factor, and resistivity to become constant after the temperature had been changed. In attempting to check these results, an error in experimental technique was

discovered. Measurements with improved apparatus show that the dielectric constants and power factor follow the temperature changes with little if any time lag. No additional measurements on rubber under pressure have as yet been made.

ARNOLD H. SCOTT

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April 6, 1931.

The Uncertainty Principle

Kennard has connected the uncertainty principle with radioactive disintegration by showing (*Phys. Zeits.* **30**, 495-497) how to derive Gamow's formula for radioactive disintegration from known quantum principles plus the uncertainty principle of Heisenberg without the additional postulate assumed by Gamow that a particle of energy W can pass through a potential wall of height $V > W$.

Here we have the pure chance phenomena of radioactive disintegration, independent of the disturbance produced by the act of measurement, and performed for us by nature at a rate that has remained constant since the solidification of the earth's crust, linked with the probability phenomena of the new quantum mechanics, the indeterminateness of which is assumed to be caused by an uncon-

trollable perturbation introduced of necessity in the process of measurement.

Is it not better to leave the indeterminateness in nature where we find it, rather than to attribute it to the inevitable perturbation introduced when making an observation, although we do not know how this perturbation introduces the indeterminacy?

If we can believe that the general laws of quantum mechanics are fundamental laws of nature, the various possibilities of natural behavior should be inherent in these laws, whether they be of a physical, chemical or biological character. I shall not expatiate here on the considerable progress that has already been made by the application of the quantum laws to chemistry, by the work of Heitler, London, and Slater. The generality