air column of the horn, reacting on the telephone plate, forces the electric oscillation to remain at the horn frequency a', with different amplitudes passing a maximum when the electric oscillation is also at a'; i.e., in resonance. Hence the difference of figures 1 and 3, since, in the latter, no reacting mechanism is available. The continuous noise in figure 1 throughout all frequencies must thus be regarded as a case of forced vibration of the L circuit with synchronism at a' while the horn is in turn governed by the spring break. At the same pitch the nodal intensity of the free system (siren, s_s) increases much faster than the nodal intensity of the forced system (electric oscillation, s_0), as shown by the graph in figure 5, where the horizontal scale s_0 is increased four times.

Finally the decreasing nodal intensity (s) toward the mouth of the horn is enhanced by its increasing sectional area. This somewhat obscures the linear relation of the fringe displacement, s, to the corresponding nodal pressure, as I shall indicate in a subsequent paper in which large cylindrical pipes are tested, for s measures the potential energy of the stationary wave at the pinhole point of the probe.

THE FINE STRUCTURE OF THE HELIUM ARC SPECTRUM

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Ever since its discovery the spectrum of helium has been thought to consist of singlets and doublets. Recently, however, spectroscopic theory has indicated that it should consist of singlets and triplets since helium is a two-electron system. Various attempts have been made to resolve the doublets into triplets,[1] but up to the present there have been no conclusive results. Within the last few months interest has been revived in these lines by the theoretical work of Heisenberg,[2] which predicts a triplet structure with unusual separation ratios. It is now possible to show that the helium lines really have a structure similar to that predicted by Heisenberg.

The resolution of these lines has been made possible by the use of the compound Fabry-Perot interferometer[3] for the diffuse series line 5876, and the use of gold films on the simple interferometer for the sharp series line 7065. It is also necessary to cool the discharge tube in liquid air and to use a low current density. The use of the gold films was suggested by Dr. Babcock and produces a large increase in efficiency in the red.

The wave-lengths of the three components of these lines are given in table 1. They were determined with reference to the singlet lines 6678.149 and 5015.675 as standards, and are probably correct within 0.003 Å. The centers of gravity are very near the values determined by Merrill.[4] The apparent doublet separations of 4713, 4471 and 3888 were also measured and are given in the same table. For these lines the wave-lengths of the weak components were determined by using the measured separations in connection with Merrill's values for the strong components.

TABLE 1

INTENSITY	DESIGNATION	WAVE-LENGTH IN I. A.	$\Delta\nu$
1	$2^3P_0 - 3^3S_1$	7065.707	
			0.992
3	$2^3P_1 - 3^3S_1$	7065.212	
			0.071
5	$2^3P_2 - 3^3S_1$	7065.177	
1	$2^3P_0 - 3^3D_1$	5875.963	
			0.928
3	$2^3P_0 - 3^3D_{12}$	5875.643	
			0.120
5	$2^3P_2 - 3^3D_{123}$	5875.601	
1	$2^3P_0 - 4^3S_1$	4713.373	
			1.038
8	$2^3P_{12} - 4^3S_1$	4713.143*	
1	$2^3P_0 - 4^3D_1$	4471.681	
			1.021
8	$2^3P_{12} - 4^3D_{123}$	4471.477*	
8	$2^3S_0 - 3^3P_{12}$	3888.646*	
			0.286
1	$2^3S_0 - 3^3P_0$	3888.603	

* Merrill's values.

The intensities in the triplets were estimated visually. One of the strong lines was clearly stronger than the other, while these two together are known to have eight times the intensity of the weakest component as shown by D. Burger.[5] Accordingly they were judged to have close to the theoretical values of 5:3:1. The separation of 4713 is very close to the corresponding separation in 7065, while the separation of 4471 shows clearly the effect of the decrease of the 4*D* term over the 3*D*. The separation of 3888 is very close to that given by the work of McCurdy.[6]

The fact that two components are so close together in the strong line makes it difficult to distinguish their resolution from a reversal. There are several reasons for believing that we have here a case of true resolution. In the first place the components are not of equal intensity. The phenomenon of unsymmetrical reversal has been recorded frequently, but usually under circumstances which make it probable that more than a single line was present. Furthermore, the discharge tube used as a source was such that reversal was not likely. It was bent in the form of a U and inserted in a liquid air flask, so that the discharge was always surrounded by liquid air, while the tube through which the discharge was observed extended up out of the liquid air and was thus at a higher temperature. Most conclusive, perhaps, is the fact that the definition improved with a decrease in current and a decrease in temperature as the tube became cooled with liquid air. In fact, without the liquid air, the structure almost disappeared and reversal appeared in 6678. This reversal had disappeared entirely when the plates were taken. The current density used was 0.09 amp. per sq. cm.

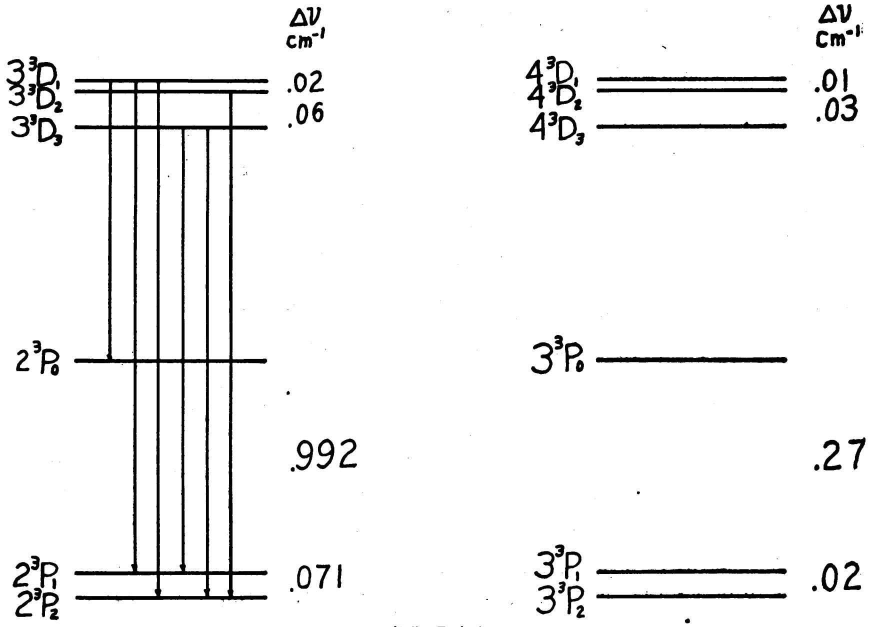

FIGURE 1

Fine structure of energy levels in Helium.

Figure 1 gives the scheme of energy levels which will produce the observed lines. The *P* levels are entirely inverted, while the *D* levels are partly so. The theory of Heisenberg requires that both levels be inverted, but the small differences involved may easily be due to the terms neglected in his approximations. The separation ratio of the *P* term is 14:1 instead of 10:1 as given by the theory. The ratio of the 3*D* separation to the 2*P* separation is of the order of magnitude predicted. The arrangement of the 4*D* terms is assumed to be the same as that of the 3*D*, and the separation is roughly determined from the measurement of 4471. The 3*P* term is assumed to be the same in arrangement as the 2*P* term, although its close components have not been resolved, and its wider separation is determined by the measurements. Thus this work confirms the theory of Heisenberg in its essential points.

In this way the experimental work, by showing that the helium spectrum contains singlets and triplets, confirms the theoretical predictions and thus removes this spectrum from its anomalous position.

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[1] Nutting, *Astroph. J.*, **23**, 64, 1906; Lohman, *Zeit. Wiss. Phot.*, **6**, 1 and 41, 1908; R. Brunetti, *Accad. Lincei, Atti.*, **33**, ii, 413, 1924; Ruark, Foote and Mohler, *Opt. Soc. Amer. J.*, **8**, 17, 1924; MacNair and McCurdy, *Nature*, **117**, 159, 1926.

[2] W. Heisenberg, *Zeit. Physik*, **39**, 499, 1926.

[3] Houston, *Physic. Rev.*, March, 1927.

[4] Merrill, *Astroph. J.*, **46**, 357, 1917.

[5] D. Burger, *Zeit. Physik*, **38**, 437, 1926.

[6] McCurdy, *Phil. Mag.*, **2**, 529, 1926.

TWO REMARKS ON SCHRÖDINGER'S QUANTUM THEORY

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1. As our first remark we wish to point out that the method of reduction of Schrödinger's equation which the author used in his treatment of the Stark effect[1] permits also an extremely simple treatment of the relativity effect in the neutral hydrogen atom. The Hamiltonian equation in this case has the form

$$mc^2\sqrt{1 + (\nabla S)^2/m^2c^2} = E' + e^2/r, \tag{1}$$

where e, m are the charge and mass of the electron, c the velocity of light, and where the energy E' includes the inner potential energy mc^2 of the electron ($E' = E + mc^2$). Solving with respect to ∇S:

$$(\nabla S)^2 - [(E' - e^2/r)^2 - m^2c^4]/c^2 = 0. \tag{2}$$

We obtain the wave equation of the problem replacing ∇S by the operator $iK\nabla$ (where $K = h/2\pi$)

$$\nabla^2\psi + [(E' - e^2/r)^2 - m^2c^4]\psi/K^2c^2 = 0. \tag{3}$$

As in the non-relativistic case, we substitute

$$\psi = \chi(r)P^n_{k-1}(\cos\vartheta)\cos n\varphi, \tag{4}$$