and given in the second column of Table IV, and the data given in Table I, we may solve Equations 1–5 simultaneously and obtain the partial pressures of the five gases present at equilibrium. Col. 1 gives the absolute temperature, Cols. 3–7 inclusive the partial pressures in atmospheres of the hydrogen, hydrogen sulfide, sulfur dioxide, sulfur and steam, respectively.

TABLE IV.

Temp., abs.	K_{H_2S}	$[H_2]$	$[H_2S]$	$[SO_2]$	$[S_2]$	$[H_2O]$	Log K.
1160	32.8	0.0101	0.111	0.0615	0.117	0.694	5.93
1362	7.98	0.0319	0.090	0.061	0.126	0.685	4.32
1473	4.39	0.0521	0.081	0.067	0.126	0.665	3.59
1473	4.39	0.0566	0.057	0.057	0.053	0.767	3.50
1645	3.20	0.0972	0.044	0.0715	0.051	0.725	2.56

It will be shown in a later paper how these results may be used in the calculation of the free energy of sulfur dioxide. We have given in Col. 8 the log of the equilibrium constant $K_p = [H_2O]^2[H_2S]/[H_2]^3[SO_2]$ for the important reaction $3H_2 + SO_2 = 2H_2O + H_2S$. It is of course possible to calculate from the partial pressures given in Table IV the equilibrium constant for a number of different reactions. These equilibria may best be studied, however, by summing the free energies of the various substances used up and produced in the reactions.

In conclusion the authors wish to thank G. N. Lewis for his kindly interest and many suggestions during the progress of this research.

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THE SCATTERING OF ALPHA RAYS AS EVIDENCE ON THE PARSON MAGNETON HYPOTHESIS.

BY DAVID L. WEBSTER.

Received October 20, 1917.

The essential feature of Parson's theory of atomic structure[1] is the hypothesis that the electron is not a sphere, but a very thin ring, perhaps as much as 1.5×10^{-9} cm. in radius, carrying a charge of negative electricity that circulates around the ring at a very high velocity. This gives it in addition to its electrostatic properties the magnetic properties of a coil of wire carrying a current. This hypothesis was used very successfully by Parson in explaining an extraordinary variety of chemical phenomena, and I have also found it useful as the basis of a theory of heat radiation that is consistent with Planck's law and at the same time with the classical electrodynamical system and the numerous phenomena explained only by that system.[2] The magneton hypothesis, however,

[1] A. L. Parson, "A Magneton Theory of the Structure of the Atom," Smithsonian Miscellaneous Collections, **65**, No. 11 (1915).

[2] D. L. Webster, *Proc. Amer. Acad.*, **50**, 131–145 (1915).

has not been generally accepted, one of the chief reasons apparently being that Parson's theory as he developed it calls for a large sphere of diffuse positive electricity, in which the electrons, or magnetons, as he calls them, are free to move. In view of the epoch-making work of Rutherford and Darwin on the large-angle scattering of alpha particles, this positive sphere hypothesis becomes untenable, and the natural impulse in giving it up is to give up the magneton hypothesis with it. In a recent paper in THIS JOURNAL by Langmuir[1] the theory is mentioned as attractive, but dismissed at once because of the positive sphere. If the positive sphere is essential to the magneton theory, this action is necessary. If not, the sooner the two are separated, the better.

But to introduce a nucleus, the assumptions of the theory must be changed, and there is ground for the opinion that the new assumptions are more radical than the old, which are indeed radical enough. In fact G. N. Lewis,[2] in a recent paper in THIS JOURNAL, draws conclusions very much like Parson's from the chemical properties of the elements, but rejects the magneton hypothesis as a working basis, with a reference to a desire to avoid a priori assumptions. The purpose of this paper is therefore, first, to point out the possibility of substituting Rutherford's nucleus for the positive sphere and, second, to make a critical examination of the status of the magneton theory when the nucleus is introduced.

According to Parson, the positive sphere is "little more than a simple mathematical expression for the coherence and rigidity of the atom." With a nucleus exerting no forces but those of electromagnetism, the electrons would all fall into the nucleus. To hold them out, the nucleus must exert some sort of repulsion that is not electrical and varies faster than the inverse square of the distance. For any given distribution of density in the originally assumed positive sphere, it is obvious that there will be a law of variation of this new force that will accomplish the same result, so far as the positions of equilibrium of the magnetons are concerned. In the present state of our knowledge of these positions it is not yet time to attempt to derive from them the necessary law. In any case this non-electrical force, or "mystery force," as some have called it, is a new assumption to add to the theory. The question raised by the evidence of alpha ray scattering is this: Is the evidence for the magneton theory enough to justify all the assumptions involved, now that one more is added? The hypothesis that the electron is magnetic was made to explain an attraction between two electrons at moderate distances that is demanded by chemical phenomena, and the phenomena of radiation demanded also a mystery force of repulsion at short distances between two magnetons very similar to what is now assumed between a magneton

[1] I. Langmuir, THIS JOURNAL, 38, 2221 (1916).

[2] G. N. Lewis, *Ibid.*, 38, 773 (1916).

and the nucleus. Why, then, do we call the attraction magnetic? Why do we not make that also a mystery force, or as Lewis does, simply assume one law by which repulsion and attraction alternate as one electron approaches another, and make no distinction of different parts of it, one as electric, another as magnetic and a third as neither electric nor magnetic?[1]

There are, as a matter of fact, several reasons for making this distinction. For one, let us consider for a moment the character of the groupings required by chemistry. In general, they are of two sorts, one a pair of electrons closely associated, and the other a very compact group of eight.[2] We never see a group of three, or any other odd number, unless perhaps in the rare compound H_3, which may not even exist at all. Now suppose the law of force between two electrons were that of a repulsion at large distances and very small ones, with an attraction at intermediate ones. Then two electrons brought near each other would stay together in a pair. But a third one would also stick readily to them, or a fourth or a fifth or any number. There would be no tendency to stay in pairs, and certainly no distinction for the number eight. But if the attractive force is that of a pair of doublets, like bar magnets, the pair once formed may be expected to orient themselves oppositely, and thereby cancel each other's attractive forces on a third one approaching from a distance. This means that the grouping in pairs indicates that the attraction is that of doublets, while the repulsions are both spherically symmetrical. The grouping in eights, as Parson has shown, is even stronger evidence in the same direction.

But even granting this, why is the doublet necessarily magnetic, rather than electrostatic? One fact that makes this plausible, but no more, is that magnetization phenomena mean that something in the atom must be magnetic. The assumption that this something is the electron is made highly probable by the data on magnetism collected by Parson, that show paramagnetism wherever chemical phenomena indicate a loose

[1] The mystery force between magnetons might hold them, alone, apart even with a nucleus exerting no mystery force. This suggests the possibility that the nuclear mystery force is unnecessary. But the electromagnetic theorem of no equilibrium in free space makes this impossible, since even if the magnetons were all held in a rigid frame the whole frame would move until one of them struck the nucleus.

Another question that might be asked is why the mechanism holding the electrons away from the nucleus is not centrifugal action in orbits. There are two reasons against this, one the impossibility of stable orbits of the required types, and the other the absolute necessity of a static condition of the atom to explain such phenomena as the stability of shape of asymmetric molecules. The arguments on both of these points are given very clearly, both by Parson (*Loc. cit.*) and in a somewhat different form by Lewis (*Loc. cit.* and especially in *Science*, N. S., **46**, 297 (1917)).

[2] For the arguments on this point, see Parson (*Loc. cit.*) and also Lewis (THIS JOURNAL, **38**, 773 (1916)).

grouping of some of the electrons. This is exactly what one would expect if the electrons themselves are magnetic.

But even so, why should their magnetism be due to a circulation of the electricity, rather than to magnetic poles? Here the phenomena of diamagnetism are important as evidence of the existence of inductive circuits in the atom; and the obvious instability of the sort of orbital motions that would be required if the electrons were of the classical type[1] indicates that the circulation must be a continuous current. But even this does not prove that the inductive circuits causing diamagnetism are actually the same bodies as the electrons that cause paramagnetism and chemical bonds.

A phenomenon of the greatest importance in this connection is Barnett's effect of magnetization by rotation. In Barnett's experiments[2] it was found that a piece of iron, cobalt or nickel in rotation is magnetized in the absence of any external field. Now if these elementary magnets are electrons moving in orbits, the gyroscopic properties of the orbits would make them behave in exactly this way. Moreover, as Barnett proved, the amount of magnetism to be expected can be predicted from the ratio e/m and the permeability of the metal, all references to the size of the orbit or the speed of rotation having cancelled out in the calculation. The experimental results show quantitative agreement, within limits of error, with the predicted values. Similar agreement was obtained for the inverse effect, rotation by magnetization, in experiments begun later by Einstein and de Haas.[3]

But as we have seen above, and as Barnett says in his latest paper, the assumption of a discrete particle of electricity in an orbit seems untenable, and a continuous current is preferable, provided it will have the proper gyroscopic properties. Now such properties are not a mathematically necessary accompaniment of all forms of translational mass, and the quantitative agreement with the gyroscopic properties of a revolving electron is by no means obvious. The only way to make definite statements on this point is to develop the mathematical theory of the electromagnetic mass and gyroscopic properties of the magneton. This has been done by the present author.[4] It is found to involve not only a treatment of the electromagnetic forces in an accelerated or rotating magneton, but also the internal forces that hold it in shape. On these latter forces we have no very certain data. But making the most plausible assumptions a priori, it is found that formulas for the mass and gyroscopic properties in terms of the charge and dimensions can be obtained, and that these

[1] For further discussion of this point, see Parson (*Loc. cit.*) and Lewis (*Loc. cit.*).

[2] *Science*, **30**, 413 (1909); *Phys. Rev.*, **6**, 239 (1915); *Ibid.*, **10**, 7 (1917).

[3] *Deutsch. Phys. Gesell. Verh*, **17**, 8, 152 (1915).

[4] *Phys. Rev.*, **9**, 484 (1917).

formulas make the gyroscopic properties exactly those of a magnetically equivalent orbital electron of the classical type, and therefore exactly those required by the Barnett and Einstein-de Haas effects. This makes it highly probable that the elementary magnets of ferromagnetism, and probably of paramagnetism and chemical bonds also, are really magnetons.

Thus it appears that we can class the magneton hypothesis not as an assumption made a priori, but rather on the surer basis of a most probable deduction from the experimental facts. As such it cannot be lightly tossed aside even if the assumptions that go with it are somewhat complex. Consequently it seems probable that the alpha ray phenomena should not be taken as valid evidence against the magneton theory, but simply as evidence for the existence of the nucleus along with its non-electrical repulsion for magnetons.

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THERMAL LEAKAGE AND CALORIMETER DESIGN.

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Received November 15, 1917.

In measuring a quantity of heat in a calorimeter most of the care and time expended is usually demanded, directly or indirectly, on account of the thermal leakage, or interchange of heat between the calorimeter and its environment. Most of the ingenious devices which lend interest to calorimetry have been introduced, wholly or in part, in order to deal with this leakage. And yet until very recently there have been almost no quantitative data upon the effect of the air gap around the calorimeter, although the thickness of this gap, more than anything else, determines the rate of the leakage, and hence the efficiency of any method of dealing with it. As a result it has happened, almost inevitably, that some of the most skilful and carefully planned researches have been conducted with air gaps whose needlessly small dimensions caused an excessive thermal leakage, and so multiplied several times the leakage difficulty or error. One of these researches, for instance, although it incidentally included investigations which led to important improvements in calorimetric method, was yet made with a gap so small (3 mm.) that a change to better dimensions would have brought all the reduction of the leakage and its errors that is obtained by substituting the frail Dewar bulb for a well-designed simple calorimeter. And two very recent articles specially describing improvements in method make mention of air gaps so small (5 and 6 mm.) that they probably neutralized in the apparatus described the advantages gained. On the other hand, in this laboratory a special method dealing with incon-