ered and put into order in such a form that an original thinker who would encompass all of them would find it possible to do so in a lifetime and still have left that energy which is necessary to fuse and unite the whole material in the fire of his intellect and mould it into a great (even though tentative) synthesis of scientific truth.

Such a work can not be done once for all. Science continues to grow and novel thoughts arise occasionally in its progress. These will ever require new syntheses if they are to be comprehended properly. No such work of philosophic interpretation can ever be final, for science itself can never reach a final and completed stage. Each generation or century will need to do it again; but this lack of finality does not make the work of any the less importance.

It is important that the great scientific ideas of each generation should come out of their technical dress and be set forth in a literary form which makes them pleasingly accessible to all cultivated persons with a tendency to philosophic interpretation. To this double work of the synthesis of truth and the putting of it into an accessible form the editors of *Scientia* have committed that journal, and it is going forward with increasing success towards the realization of this high aim.

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SPECIAL ARTICLES

PARAMAGNETISM AND THE THEORY OF QUANTA

THE last issue of the *Journal de Physique* contains an interesting and meritorious review by B. Cabrera of the extensive work done by different observers on the magnetism of salts of metals of the iron group. A conspicuous part of this work is due to Professor Cabrera himself and to his pupils and was heretofore outside the reach of most of the scientific readers, because it was published in Spanish journals.

I wish to draw the attention of the physicists engaged in magnetic research to an interpretation of which the material presented by Professor Cabrera is susceptible, and which seems to me to be a strong support of the quantum theory of magnetism. It is well known that the theory of electrons gives a simple relation between the magnetic moment of an atom m and its chief moment of momentum G

$$(1) \qquad m = \frac{e}{2\mu} G$$

e/μ being the ratio of the charge of an electron to its mass. On the other hand, the theory of quanta admits only certain discreet values of the moment of momentum G, *to wit,* whole multiples of the value $h/2\pi$, where h denotes Planck's universal constant of action. The result is that the magnetic moment of an atom (or ion) is also a whole multiple of an elementary value

$$m_0 = \frac{eh}{4\pi\mu}$$

so that

$$(2) \qquad m = j\, m_0$$

where m_0 is called the "Bohr-Magneton" and the integer j (in *Sommerfeld's* terminology) the "internal quantic number" of the atom.

The conception that the atomic magnetic moment is a multiple of a "magneton" was originally introduced empirically by *P. Weiss.* However, the empirical "Weiss-Magneton"

Ion	m in W.-M.	j	m' in W.-M.	m' in M_0	$\chi \cdot 10^4$ calc.	$\chi \cdot 10^4$ obs.
Cr^{+++}	19.0	3	15.2	3.04	4.8	5.0
Cr^{++}	24.0	4	20.2	4.04	7.7	7.9
Mn^{++}	29.0	5	25.2	5.04	11.3	11.6
Fe^{+++}	28.9		25.1	5.02		11.5
Fe^{++}	26.0-29.0	4	22-24.4	4.4-4.9	7.7	9.3-11.6
		5	22.6-25.2	4.5-5.04	11.3	
Co^{++}	24.0	4	20.2	4.04	7.7	7.9
Ni^{++} saturated	16.0	3	12.9	2.6	4.8	3.5
Ni^{++} unsaturated	13.0	2	9.5	1.9	2.5	2.3
Cu^{++}	9.1	1	5.26	1.05	1.0	1.1
Cu^{+}	0	0	0	0	0	0

(W.-M.) has a value almost exactly five times smaller than the theoretical "Bohr-magneton." *Weiss* obtained his values for the atomic magnetic moments of ions in solutions from the measured susceptibilities χ by means of *Langevin's* formula based on classical statistics

$$(3) \qquad 4\pi\chi = \frac{Nm^2}{3kT}$$

Where N denotes the number of atoms (or ions) in unit space, k Boltzmann's constant and T the temperature. *Cabrera* uses the same method of theoretical analysis and derives values of m in Weiss-magnetons as units.

It has been, however, pointed out by *W. Pauli* (*Phys. Zeitschr.* 1920, xxi, p. 615) that the statistics of the quantum theory lead to a different result and that *Langevin's* formula must be replaced by the new one

$$(4) \qquad 4\pi\chi = \frac{(j+1)\ (2j+1)}{6j^2}\ \frac{Nm'^2}{kT}$$

We see that from the point of view of the quantum theory the values m derived by *Cabrera* need a correction, and that the new value m' will be $m' = \alpha m$, where the correction factor α has the form

$$(5) \qquad \alpha = \frac{j}{\sqrt{(j+1)\ (j+\frac{1}{2})}}$$

j:	1	2	3	4	5	6
α:	0.577	0.730	0.802	0.842	0.870	0.890

The application of these considerations to Cabrera's material is contained in a following table. The second column gives the values of m in Weiss-magnetons, which this author considers as the best mean of the results of different observers. It may be remarked that some of the authors find values lying rather far from whole numbers, so that the integral nature of this quantity does not seem quite assured to the unprejudiced observer. In order to find the corrected value m', it is necessary to make a hypothesis as to the number j of Bohr-Magnetons in the atom. This hypothetical j is given in the third column, while the fourth contains the result of the correction in Weiss-Magnetons, from which the value of m' in Bohr-Magnetons is obtained by dividing by five (fifth column). The agreement of the final result of the fifth column with the hypothetical j of the third gives a measure of the extent to which the hypothesis was justified. It will be remembered that j represents the number of Bohr-Magnetons m_0 contained in an atom, so that the third column gives our hypothesis as to this number, while the fifth contains the same number as derived from Cabrera's experimental material. We see that there exists an apparent discrepancy in Ni^{++} in saturated salts and for Fe^{++}. However, the case of Fe^{++} is without any significance, because the uncertainty of the experimental values is here so large as to prevent any conclusions. The rest of the paramagnetic salts shows an excellent agreement with the quantum theory.

There may be suggested still another and more convenient method for checking these results. By means of formula (3) we can compute the susceptibilities (referred to the grammatom of material) corresponding to the individual integer j. We have tabulated these values of the susceptibility in the sixth column, while in the seventh the actually measured values are given for comparison.

Again we see that a discrepancy larger than the limits of experimental error exists only for *Ni*. Physicists engaged in magnetic research would therefore promote the development of the theory of quanta by paying particular attention to the ions Fe^{++} and Ni^{++}.

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Studies by a new method of analysis of complex crystal structures and normally and abnormally reflected secondary X-rays characteristic of chemical elements in crystals: GEORGE L. CLARK. (1) A new ionization spectrometer method of analyzing crystals has been designed to be applicable to variable parameter systems (triclinic, monoclinic, orthorhombic), and to be independent of previous determinations of structure, number of molecules per unit, wave-length and densities. Wave-lengths producing particular effects are accurately evaluated by an experimental determination of the critical voltage in the quantum law $Ve = hc/\lambda$. (2) By this method crystals and powders of the following compounds have been