

electron moves in a strong magnetic field, it follows a spiral path around a line of force. This motion in a spiral path radiates energy with a frequency that depends on the strength of the field, and is therefore variable. It is easily shown that in a case where the spiral is tightly wound around a line of magnetic force, the frequency is given by the equation

$$\nu = \frac{H}{2\pi} \frac{e}{m}. \quad (2)$$

From this equation it appears that the frequency is independent of the velocity of the electron and of the radius of the spiral and that it is practically proportional to the strength of the magnetic field; and since H varies continuously, the frequency can have all possible values (up to a maximum), which gives the radiation the character of a continuous spectrum.

Let us combine this conception of general X-radiation with the experimental fact that the maximum frequency due to the impact of an electron against an atom is given by equation (1). Suppose the electron to be traveling very nearly along the line of force coming from a very great distance, where its velocity is v and let x be its distance from any fixed point at the time t ; let F be the total force acting on the electron in the direction of the weaker magnetic field. Then we can show easily that

$$F = \frac{h}{2\pi} \cdot \frac{e}{m} \cdot \frac{\partial H}{\partial x}. \quad (3)$$

We find, therefore, that a force of repulsion acting on the electron, the magnitude of which is represented by equation (3), will explain why an electron of given kinetic energy can not produce radiation higher than that given by equation (1).

A force such as that represented by equation (3) should hold an electron in equilibrium at a distance somewhat smaller than 10^{-8} from an atomic nucleus, if the

nucleus had a charge e and the magnetic moment attributed to atoms and magnetons. Such a force would play an important rôle in determining the size and compressibility of atoms, the conduction of heat and specific heats, and a great variety of phenomena.

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THE RELATIONS OF MAGNETISM TO MOLECULAR STRUCTURE

MAXWELL'S classical theory of electricity and magnetism contributes little to our knowledge of molecular structure. For the portion of it which deals with material substances is exhibited in terms of quantities for which the process of definition wipes out structural distinctions. It is only through molecular theories of magnetism that magnetic phenomena may be correlated with molecular structure.

Langevin's theory of magnetism appears to be the soundest attempt to formulate such a theory. He hypothesizes the existence in the molecules of every substance of groups of electronic orbits which by virtue of the peculiarities of the structure of the molecules may be so arranged that the resultant magnetic field due to the electronic orbits in a given molecule at points without the molecule may or may not vanish. In the former case the molecule is diamagnetic, in the latter magnetic.

The effect of the application of a magnetic field to a diamagnetic substance is to change the orbital velocity of any electron. This change is in the proper direction to account for the diamagnetic polarity of the substance. Langevin's theory leads to an expression for diamagnetic susceptibility which does not involve the temperature, in agreement with Curie's law for diamagnetism. Numerous exceptions to this law exist, but the exceptions may probably all be taken care of by a slight extension of Langevin's theory as proposed by Oxley.

One of Oxley's most interesting conclusions is that the mutual magnetic field of two diamagnetic molecules in intimate contact is of the order of 10^7 gauss.

Langevin's hypothesis, while probably the most satisfactory yet advanced, leaves us quite in the dark as to a mechanical explanation of the architecture of the molecule.

In paramagnetic and ferromagnetic substances in accordance with the views of Langevin the rôle played by the molecule is not as in diamagnetic substances independent of the molecule's orientation in space, and it is necessary to assume that the effect of an applied field is to rotate the electronic orbits so that the direction of the resultant external field of a molecule tends toward that of the applied field. But the theory tells us nothing of the mechanism which will account for this orientation. Resisting the orientation will be heat agitation and perhaps inter-atomic and molecular actions of other than magnetic type. In a paramagnetic gas the resistance to orientation is supposed to be entirely due to heat agitation. The theory for such a gas leads to an expression for the susceptibility which depends upon both the impressed field and the temperature, but for fields attainable in the laboratory the susceptibility varies inversely with the absolute temperature in accordance with Curie's law for paramagnetism.

With the aid of the assumption that as regards rotation the molecules of a paramagnetic liquid behave like those of a paramagnetic gas it is possible to extend the theory of the gas to include that of the liquid, and such an extension is probably reasonably safe for liquids not given to polymerization.

In Weiss's theory of ferromagnetism it is assumed that, so far as rotation is concerned, the molecules of a ferromagnetic substance behave like those of a paramag-

netic gas, a somewhat questionable assumption in this case. The effect of neighboring molecules upon a given molecule is assumed to be that which would be produced by a very large localized magnetic field of the order of 10^7 gauss. The theory based on these assumptions succeeds to a remarkable extent in explaining many of the facts of ferromagnetism.

The large internal fields hypothesized by Weiss and by Oxley are to be regarded as devices for averaging out in a measure the complicated effects due to molecular structure.

Through experiment Weiss was led to belief in the existence of an elementary unit of magnetic moment which he called the magneton. This corresponds in electrical theory to the electron. In many instances the magnetic moment per molecule appears to be very nearly an integer number of magnetons. But the evidence is not weighty enough to justify the acceptance unreservedly of this proposed new physical unit.

The subject of magneto-chemistry is already a very extended one. Here the attempt is made to establish a connection between the magnetic moment of a compound and those of its constituents, and additive relations are sometimes found. Substantial chemical information is often found through magnetic analysis. Various attempts have been made to explain chemical valency bonds through the magnetic attractions of rotating electrons in the atoms. One of these, that of Parsons, offers promise of considerable success in this direction.

The recent magnetic experiments of Barnett and of Einstein and deHass appear to prove definitely the existence of electrons rotating in closed orbits within the molecules of material substances, and thus furnish important support to Langevin's fundamental assumptions.

From this necessarily inadequate discus-

sion you will infer that our molecular theories of magnetism are yet in a very unsatisfactory state in spite of the light which Langevin's ideas have thrown upon the subject, and that experiments upon the magnetic properties of bodies have not yet contributed in a very striking manner to our knowledge of molecular structure.

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ENROLLMENT IN SCIENCE IN THE HIGH SCHOOLS

In the issue of *SCIENCE* for February 12, 1915 (Vol. XLI., pp. 232-235), I called attention to the significance of the data given by the Commissioner of Education in regard to the enrollment in science studies in the high schools of the United States. The appearance of additional statistics for the five-year period 1910-1914 in the 1916 Report makes it possible to review the situation in the light of the new figures.

The table on page 489 of the Report of the Commissioner of Education for 1916, Vol. II., gives a summary of the enrollment in various subjects of the high-school curriculum in 1910 and 1915, both in terms of the numbers enrolled and in the percentage of the total enrollment. It is rather startling to find that in this five-year period there has been a drop of 44 per cent. in the enrollment in botany, stated in terms of the per cent. of the total enrollment, and one of 51.3 per cent. in zoology. The decline in botany has been from 16.34 per cent. to 7.19 per cent. and in zoology from 7.88 per cent. to 4.04 per cent. Physics has nearly held its own, changing from 14.79 per cent. to 14.28 per cent. while chemistry has made a slight gain, from 7.13 per cent. to 7.63 per cent. The other old-line sciences have all dropped off, physiology and physical geography quite heavily. Nor is the gain in the newer sciences enough to counterbalance the loss in the old. The percentage enrollment in agriculture has increased from 4.55 per cent. to 6.92 per cent., in domestic science from 4.14 per cent. to 12.69 per cent. The total per-

centage enrolled in science in 1909-1910 was 91.99 per cent., in 1914-1915 86.16 per cent., a drop of 5.83 per cent.

It seems strange that in an age when applied science is increasingly evident on every hand in the commonplace appliances of home, farm, factory and office that there should be any decline in the relative interest in science

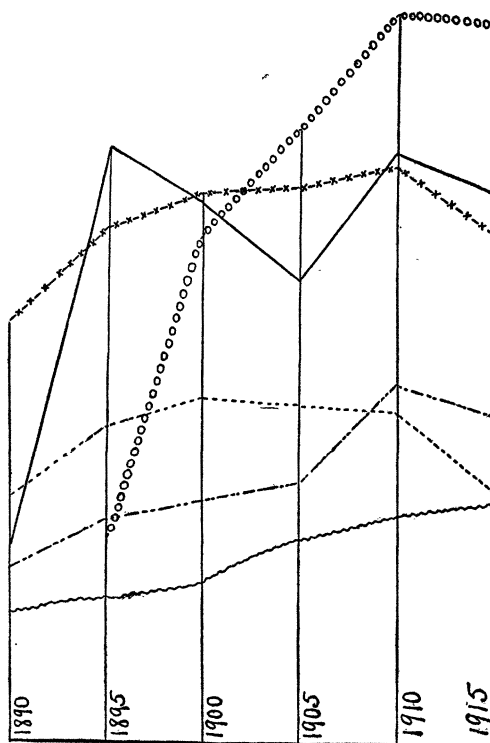


FIG. 1. Showing percentage of total enrollment in the high schools of the United States pursuing certain groups of studies, as follows: Classics, -----; English, oooooo; History — · — · — · —; Mathematics, -x-x-x-; Modern Language ~~~~~; Science, —————. 1 mm. = 1.2 per cent.

in the high schools. It is fairly evident that the high-school science course is in some way out of joint with the times. This decline in the science enrollment is not so alarming, however, when compared with changes in the other groups of subjects. The modern language group is the only one of the traditional subjects that shows an increase, that a small one of 1.5 per cent. The classics drop 11.04