Letters to the Editor.

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The Isotopes of Selenium and some other Elements.

THE first experiments with selenium some time ago were not successful. Very satisfactory mass-spectra have now been obtained by vaporising the element itself in the discharge tube. The interpretation of these is quite simple and definite, so that the results may be stated with every confidence. Selenium consists of six isotopes, giving lines at 74 (*f*), 76 (*c*), 77 (*e*), 78 (*b*), 80 (*a*), 82 (*d*). The line at 74 is extremely faint. The intensities of the lines are in the order indicated by the letters, and agree well enough with the chemical atomic weight 79·2. Measurement of the lines shows no detectable deviation from the whole number rule.

Application of the method to cadmium and tellurium has failed to give the mass lines of these elements. The employment of the more volatile $TeCl_3$ was also unsuccessful, but incidentally gave evidence of great value, which practically confirms two facts previously suspected, namely, that chlorine has no isotope of mass 39, and that aluminium is a simple element 27.

During some work requiring very prolonged exposures with a gas containing xenon, two new isotopes of that element were discovered at 124, 126, making nine in all. The extreme faintness of both lines indicates that the proportion of these light isotopes in the element is minute.

It will be noticed that the first of these is isobaric with tin, and that the seleniums 78, 80, 82 are isobares of krypton. All isobares so far discovered, including the radioactive ones, have *even* atomic weights.

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Cavendish Laboratory, Cambridge, November 6.

Bohr's Model of the Hydrogen Molecules and their Magnetic Susceptibility.

BOHR'S model of the molecules of hydrogen explains very satisfactorily the light dispersion of hydrogen,[1] and gives the same value for the moment of inertia as that deduced from the specific heat;[2] but it is generally believed that the model does not explain the diamagnetic property of the gas.[3] For, according to P. Langevin's theory,[4] the hydrogen molecules must have paramagnetic susceptibility, while as a matter of fact the gas is diamagnetic, as determined by Dr. T. Soné.[5] But, as this note will show, this conclusion is not correct.

It is well known that, besides three degrees of freedom for translation, hydrogen molecules possess two degrees of rotational freedom. According to Bohr's model, this rotational motion must, from the point of view of symmetry, take place about an axis perpendicular to the magnetic axis of the molecules—that is, an axis perpendicular to the line joining two positive nuclei. This rotational motion is uniform and increases with the rise of temperature. Hence the magnetic effect of each molecule due to the revolving electrons vanishes on account of the rotational motion. In this case, therefore, Langevin's theory of paramagnetism is not applicable. Obviously his theory can be applied only when the gas molecules have no degree of rotational freedom, or when they revolve only about their magnetic axes.

If a strong field acts on a uniformly revolving magnet in its plane of revolution (Fig. 1), the rotation begins to become slightly accelerated in the half-revolution in the direction of the field and retarded in the other half, this causing a diamagnetic effect.[6] In the case of the molecules of hydrogen the moment of inertia about the axis of rotation is, however, very large on account of the positive nuclei being apart from each other; hence, during rotation, these two revolving nuclei behave like a large flywheel, and before the revolution of the molecules is sensibly accelerated it is newly excited by thermal impacts. Hence we may assume that this rotation is not sensibly affected by the action of a strong magnetic field, and therefore, in the mean, remains uniform throughout. The hydrogen gas is then diamagnetic, and its susceptibility can be calculated by Langevin's theory of diamagnetism.[7]

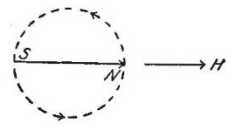

FIG. 1.

Assuming Bohr's new model of the hydrogen molecules (in which the electrons have elliptic orbits), we have for the major axis of the orbit

$$a = \frac{h^2}{4\pi^2 me^2}\left\{\frac{2}{(1+\kappa^2)^{\frac{3}{2}}} - \frac{1}{4}\right\}(n+n')^2,$$

$$\kappa = \frac{1}{\sqrt{3}}, \qquad 1-\epsilon^2 = \frac{n^2}{(n+n')^2},$$

where h is Planck's universal constant, m the mass of the electrons, and e their charge; ϵ is the eccentricity of the orbit, n and n' are the azimuth and radial quantum numbers.

In the case of $n+n'=1$, the possible orbit is $n=1$, $n'=0$, which reduces to a circle, the radius of which is

$$a = 0{\cdot}507 \times 10^{-8},$$

$\frac{h^2}{4\pi^2 me^2}$ being $0{\cdot}532 \times 10^{-8}$.

The magnetic susceptibility of the gas per gram-molecule is given by

$$\chi = -\frac{nm}{12}\left(\frac{e}{m}\right)^2 \Sigma a^2,$$

where n is the total number of electrons and Σ is to be taken for different orbits. Applying this formula to the above case, we have

$$\chi = -0{\cdot}712 \times 10^{-6}.$$

In the case where $n+n'=2$, $n=n'=1$ corresponds to the elliptic orbit. Here $\epsilon^2=3/4$, and the equivalent radius of the circle is

$$a = 1{\cdot}433 \times 10^{-8} \text{ cm.},$$
$$\chi = -5{\cdot}70 \times 10^{-6}.$$

The diamagnetic susceptibility $\chi = 3{\cdot}96 \times 10^{-6}$ observed by Dr. T. Soné lies between these two. In actual cases a certain fraction of the whole number of molecules may have the first orbit ($n=1$, $n'=0$), and the other fraction the second orbit ($n=n'=1$), etc. As the orbit becomes greater there is a greater chance that it will collapse into a smaller orbit;

[1] Debye, Münchener Akademie (1915), 1.
[2] Reiche, *Ann. der Phys.*, **58** (1919), 682.
[3] J. Kunz, *Phys. Rev.*, **12** (1918), 59.
[4] P. Langevin, *Ann. de Chem. et de Phys.*, **8** (1905), 70.
[5] Sci. Rep. **8** (1919), 115.
[6] K. Honda and J. Okubo, Sci. Rep. **5** (1916), 325.
[7] P. Langevin, *l.c.*