No variation of e.m.f. with thickness was found if the thickness of bismuth (2×10^{-4} cm) was held constant and the thickness of the antimony varied from 5×10^{-6} cm to 10^{-4} cm. When the thickness of antimony (3×10^{-5} cm) was held constant and the thickness of bismuth varied, a decided effect was found for thicknesses less than 10^{-4} cm. A plot of the results obtained are shown in Fig. 1.

Thicknesses above 10^{-4} cm yield a thermal e.m.f. corresponding to that of massive Bi-Sb. Burger and van Cittert,[1] in a study of evaporated films of Bi-Sb found the thermal e.m.f. of this couple the same as that of massive metal. However their thickness was 10^{-4} cm—corresponding to the flat part of our curve.

We have no theoretical reason to anticipate that the thermal e.m.f. of thin thermocouples should be different from that of the massive metals. It is possible, however, that the low e.m.f. is due to an effect of contamination by gases during the sputtering process—an effect which might manifest itself more in thin layers of metal. Nevertheless the smoothness of the curve seems to indicate a more regular change than such a contamination might produce. A different crystalline orientation in thin layers of bismuth seems more likely to be the cause. R. M. Holmes[2] found no effect of change of thermal e.m.f. with thin layers of gold and platinum. Whether the effect is present only for bismuth—a metal showing rather abnormal properties—or is a more general phenomenon will be the subject of further investigation.

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November 2, 1933.

[1] Burger and van Cittert, Zeits. f. Physik **66**, 210 (1930).
[2] R. M. Holmes, Phys. Rev. **22**, 137 (1923).
[3] Round Hill Research Division, Department of Electrical Engineering.
[4] Contribution from the Research Laboratory of Physical Chemistry, No. 314.

The Inert Gas Molecules

There is evidence from the behavior of the helium band spectrum in discharge tubes[1] carrying small currents that the helium molecule, although theoretically able to be produced in any excited state, is actually produced under discharge conditions from one normal and one metastable helium atom. The reaction can be represented by

$$He(1^{1,3}S)+He(2^{1,3}S)\rightarrow He_2(2^{1,3}\Sigma).$$

Since the visible helium bands require further excitation of the He_2 molecule for production of their initial states, it follows that the molecule formed in the first instance must have a sufficiently long lifetime for it to encounter an electron able to excite it further, before it passes alternatively to the unstable $1^1\Sigma$ ground state. From electrical analysis of the discharge[2] it can be shown that this requires the molecule first formed to be metastable, which is true of the $2^3\Sigma$ state, but not of the $2^1\Sigma$ state. It appears then that the possibility of observing the visible helium band spectrum at all is closely associated with the metastability of the $2^3\Sigma$ level.

This also gives a reason for expecting that the band spectra of the molecules Ne_2, A_2, etc., will be difficult, if not impossible to excite, for, compared with He_2, any metastability will be less strong on account of the greater number of electrons to the molecule. This will not however impair the efficiency of "quenching" of metastable atoms of these gases by their own normal atoms, a reaction of the type of the above equation being followed by emission of ultraviolet radiation in a transition to the spontaneously dissociating molecular ground state. The chance that a molecule will be formed, temporarily or otherwise, remains nevertheless smaller and is probably $<10^{-6}$ per kinetic theory collision between the parent atoms in the discharge.[1]

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November 6, 1933.

[1] Emeleus and Duffendack, Phys. Rev. **44**, 322A (1933).
[2] Details of the calculations will be published later.

Disintegration of Fluorine Nuclei by Neutrons and the Probable Formation of a New Isotope of Nitrogen (N^{16})

Three thousand two hundred pairs of photographs of a large Wilson cloud chamber filled with a mixture of 30 percent by volume of difluor-dichlor-methane with 70 percent of helium exhibit ten nuclear disintegrations. The momentum and energy relations, together with other evidence, indicate that most, and probably all of these are disintegrations of fluorine nuclei.

Each nucleus which disintegrates is found to break apart into two parts, one of which has from two to eleven times the range of the other. The line density of the two fog tracks, which are coincident with respect to time of formation, is found to be approximately the same for the light as for the heavy nucleus. The only known nucleus which gives the relations found for the lighter particle is that of helium. Thus for disintegrations in which the neutron is captured the reaction may be considered to be represented by

$$F_1^{19}+n_1^1\rightarrow F_2^{20}\rightarrow N_2^{16}+He_0^4,$$

in which the subscripts represent the isotopic numbers and the superscripts the atomic masses.

The velocity of the neutron (v_n) immediately before the disintegration, the corresponding kinetic energy of the neutron (KE_n), and the loss of kinetic energy ($-\Delta KE$) during the disintegration, are given for the seven disintegrations for which both photographs are suitable for measurement. (See Table I.) In agreement with what has been found for the disintegration of neon and oxygen, it is found that in every case kinetic energy disappears when fluorine is disintegrated. With nitrogen it disappears, or less often is conserved. It seems probable that at least a part of this kinetic energy is converted into γ-rays in the disintegration of fluorine, as well as with the other atoms.

TABLE I. *Disintegration of fluorine nuclei by neutrons.*

No.	v_n (cm per sec. $\times 10^{-9}$)	KE_n (electron-volts $\times 10^{-6}$)	$-KE$
	A. By capture of a neutron.		
1	2.6	3.5	1.9
2	3.5	6.4	2.1
3	4.0	8.4	3.9
	B. Related to a scattered neutron (assuming capture).		
4	3.4	6.2	1.8
5	3.7	7.2	2.9
6	3.8	7.4	3.3
7	4.0	8.5	5.9

The average energies in millions of electron-volts of the neutrons which have been found to disintegrate light nuclei by capture of the neutron are 5.8 for nitrogen, 6.1 for fluorine, 7.0 for oxygen, and 11.6 for neon. However the number of disintegrations of fluorine by capture is too small to insure its order in this list to be correct.

The number of disintegrations obtained with fluorine is approximately the same as with nitrogen with the same concentration of atoms and of neutrons. The number decreases in the order N or F, O, Ne, C, Cl.

The possibility should be mentioned that an electron, the track of which cannot be seen in the photographs, may be emitted at the time of the disintegration, in which case O_0^{16} would be formed. However the assumption that nitrogen 16 is what is formed is more in accord with what has been found in the disintegration of nitrogen, oxygen, and neon, by neutrons. If nitrogen 16 is unstable it may disintegrate subsequently, but this would not affect the calculations given in this paper.

The relations of the transverse momentum, that is the momentum perpendicular to the line which gives the path of the neutron, make it obvious that it is the fluorine, rather than the chlorine nuclei which are disintegrated. In addition if it is assumed that the chlorine, rather than the fluorine nuclei are disintegrated, the mean kinetic energy of the neutrons which cause the disintegrations is found to be 21.4 million electron-volts, an impossibly high value.

The disintegrations cannot be due to oxygen, since too little of this element is present. While any one of the ten disintegrations found may possibly be that of a carbon nucleus, earlier work[1] indicates only one chance in two that one of the disintegrations is that of this atom.

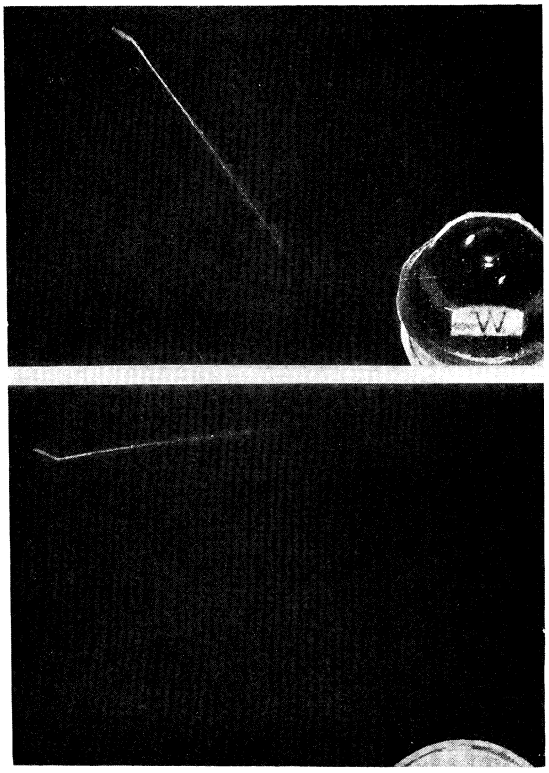

FIG. 1. Stereoscopic photographs of the disintegration of a fluorine nucleus by a neutron.

Experiments are in progress with carbon tetrafluoride and difluormethane, neither of which gives the possibility of the disintegration of chlorine. Fig. 1 shows two views of one of the disintegrations discussed in this paper.

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November 10, 1933.

[1] Harkins, Gans and Newson, Phys. Rev. **44**, 529 (1933).

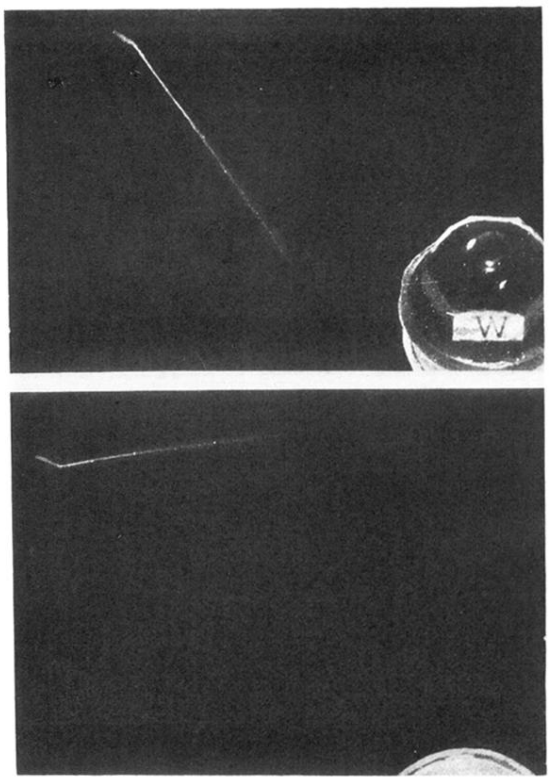

FIG. 1. Stereoscopic photographs of the disintegration of a fluorine nucleus by a neutron.