evidence for a broad resonance level giving a group of yield approximately 0.4 that of the main group was found, but there was no sign of any second group of range greater than 4 cm produced by the full range alpha-particles.

In spite of this the magnetic deflection was tested. The minimum range entering the counter was reduced to 5 cm and a comparison made with protons from coal gas. The curves show a resonable agreement and the conclusion is that the short range products from nitrogen are principally protons.

Thus we have found no evidence of emission of deutons in polonium alpha-particle disintegrations of boron and nitrogen.

We wish to thank Professor A. F. Kovarik for his advice and help in discussion, Professor H. C. Urey for a gift of heavy water, and Dr. C. T. Lane for advice in running the magnet.

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        August 11, 1934.

[1] F. Perrin, C. R. **194**, 2211 (1932).
[2] Rutherford, Chadwick and Ellis, *Radiations from Radioactive Substances*, p. 290.
[3] G. Stetter, Zeits. f. Physik **34**, 158 (1925).
[4] Rutherford and Kempton, Proc. Roy. Soc. **A143**, 724 (1934).
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The Absorption Spectra of Formaldehyde and Hydrogen Cyanide in the Far Ultraviolet

We have recently found a new absorption spectrum of formaldehyde in the region 1750–1150A. The absorption is very strong and most of the bands appear at a pressure of 0.1 mm in the spectrograph, the light path being about 1.5 meters. They consist mainly of two electronic series going to the same limit. About seven members of each series were found. The lower members are accompanied by many vibrational transitions. The higher ones can be extrapolated in the form of a Rydberg series to an ionization potential of 10.9 volts. This agrees very well with the value 11.3 ± 0.5 volts found by Jewitt[1] employing the usual methods of electron impact.

In this connection it is interesting to note the agreement between the limits of the electronic series in acetylene and ethylene[2] with the values for their ionization potentials as given by Tate and Smith,[3] and Kallman and Dorsch.[4] The values we obtain are 11.4 and 10.4 volts, respectively, which are in good agreement with the values 11.6 ± 0.1 and $10.0\pm$? volts determined by the methods of electron impact.

The bands of formaldehyde show very strong predissociation in the region 1740A. If it is assumed that this is due to interaction with the initial state the process being $H_2CO \rightarrow H_2C + O$ we find the strength of the $C = O$ bond to be 164 cal./mol. in fairly good agreement with thermochemical data.

The general similarity between the ultraviolet absorption spectra of acetylene, ethylene and formaldehyde is quite striking. They all have spectra in the region 3000A to 1800A which come out at fairly high pressures. They also possess spectra of an apparently different type having much higher transition probabilities below 1800A. These latter consist of electronic series going to the ionization potentials of the molecules.

The investigations on HCN revealed bands extending from 1450A to well below 1000A. The bands in the region 1400A are single headed and are shaded towards the red. They are given very well by the following formula

$$\nu = 68{,}645 + 901(v + \tfrac{1}{2}) - 22(v + \tfrac{1}{2})^2. \qquad (1)$$

Slight predissociation sets in at the $v = 4$ band. The same vibration pattern does not repeat itself in the bands at lower wave-length, the vibration frequencies being considerably larger. The latter bands are too diffuse to be analyzed thoroughly but it is probable that they form an electronic series going to the ionization potential of HCN at 14.8 volts. The bands given by (1) come out at somewhat higher pressures than those at lower wave-lengths. This indicates that here again we have the two types of absorption found in the previously mentioned molecules.

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Department of Physics,
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        August 11, 1934.

[1] Private communication from Professor R. G. J. Fraser.
[2] W. C. Price, Phys. Rev. **45**, 843 (1934).
[3] Tate and Smith, Phys. Rev. **39**, 270 (1932).
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Surface Magnetization in Ferromagnetic Crystals. II

We reported in a recent Letter to the Editor[1] certain peculiarities of the surface magnetization of a single crystal of silicon iron, the polished face of which was not much inclined to a plane of form {100}. In order to explain the maze-like pattern of narrow lines formed by temporary condensation of a magnetic colloid close to this surface, and the enhancement of alternate lines of the maze by normal magnetic fields of the two possible signs, we had to suppose that the surface consisted of small blocks (possibly cubes) of square section, magnetized parallel to the surface along axes of form $<100>$ and $<110>$, the former being preferred. These two directions are, respectively, directions for easiest magnetization and for next-to-easiest magnetization in single crystals of silicon iron.

It occurred to us that the patterns obtainable on a {100} plane in nickel should be different from those found in iron; for even if the surface still broke up into square blocks, all directions of easiest magnetization—here of form $<111>$—would now lie at 35° to the polished surface. After some optical difficulties occasioned by the smaller scale of the patterns developed on a suitable polished disk cut from a single nickel crystal,[2] we are able to show that conditions are, indeed, different from those in silicon iron. Fig. 1 gives two pictures of the same region with normal magnetic fields of opposite sign. The colloid particles collect in dots of various density which we find show best under slightly oblique illumination, so that each seems to cast a shadow.
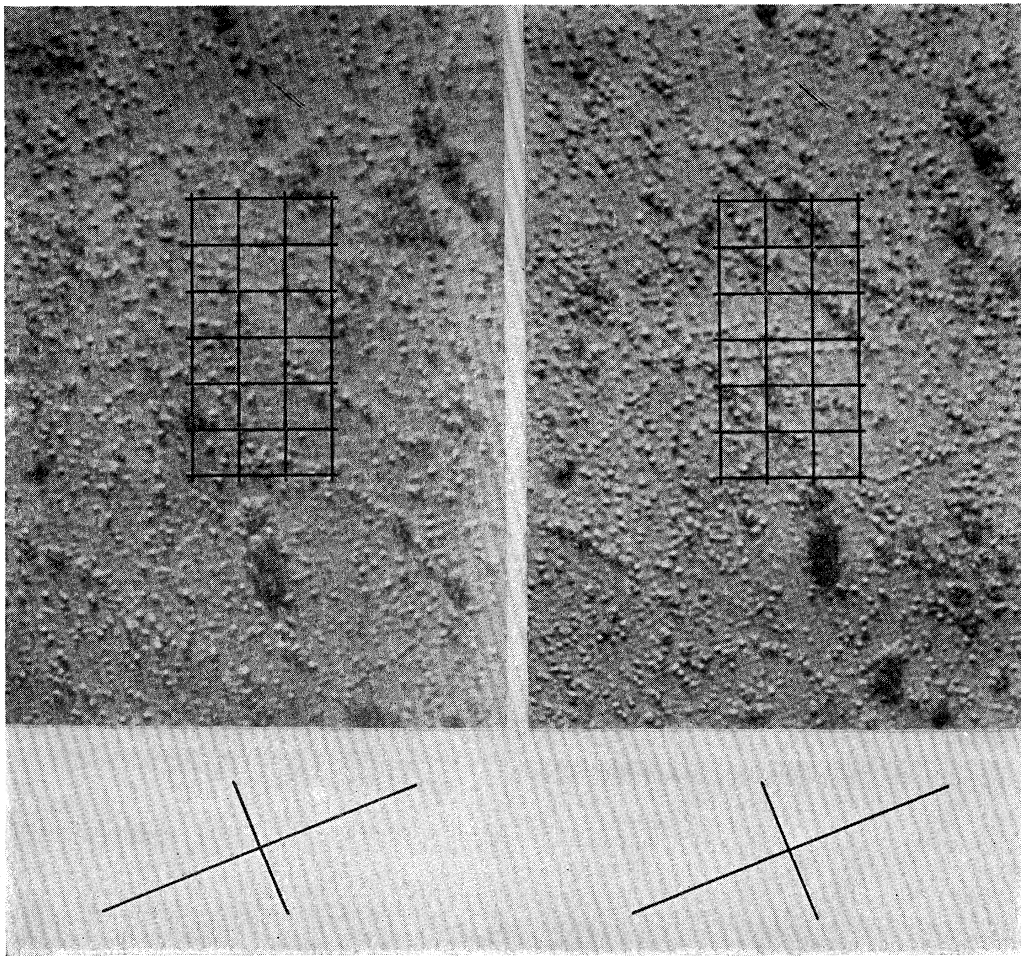
FIG. 1. Colloid patterns on nickel with **H** normal to the surface. The plane of the surface is 12° from a plane of form {100}, and the traces of the two other planes of this form have the directions shown beneath each photograph. The grille of 18 squares is $24\mu \times 12\mu$.

The minimum distances between well-defined dots is about 0.6μ.

Careful comparison of the two patterns here shown, and of others less clearly resolved, shows that associated pairs of patterns are reciprocal in a limited sense, conspicuous dots on one falling in nearly featureless regions on the other. Dots on a single pattern line up in several directions, but these directions are so numerous, and differ so much in nearby regions that we are as yet unable to say whether a structure of equal blocks exists or to specify the local directions of magnetization.

A possibility which we have particularly considered is that the surface is composed of cubes, each spontaneously magnetized along a direction of form $<111>$. If this is correct we should expect a normal field to increase the inclination of the local magnetization to the surface in about half of the blocks, decreasing this inclination in the rest of the blocks. Fig. 2 has been constructed to illustrate what might then be observed with normal fields in the

two possible directions. A region containing $15 \times 22 = 330$ blocks of the size shown in one corner of each diagram has
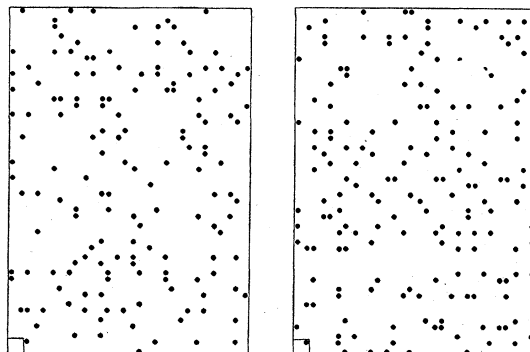

FIG. 2. Loci of strong stray fields in the surface of a layer of 330 equal cubes originally magnetized at random along body diagonals, for two directions of applied field normal to the paper. One cube is outlined in the corner of each drawing.

been represented. A direction of magnetization, of form <111>, has been assigned at random to each block. About half of them therefore have a component of I up from the paper. A black dot has been placed in the appropriate corner of each such square in the left-hand diagram. These dots would be enhanced by an applied field toward the observer. The rest of the squares have a component of I into the paper. A black dot has been placed in the appropriate corner of each such square in the right-hand diagram. These dots would be enhanced by an applied field away from the observer. The halves of Fig. 2 are reciprocal in the same sense as the halves of Fig. 1, but show even fewer collineations and other groups. If the suggested model is at all similar to the actual magnetic structure of a polished nickel surface it seems probable that the magnetization of adjacent blocks is not completely independent.

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August 14, 1934.

[1] L. W. McKeehan and W. C. Elmore, Phys. Rev. [2] 46, 226 (1934).
[2] Grown by the method described by S. L. Quimby, Phys. Rev. [2] 39, 345–353 (1932).

High Energy Gamma-Rays from Lithium and Fluorine Bombarded with Protons

We have shown that some of the light elements, when bombarded with protons or deutons emit γ-rays, and we have in several instances measured the absorption coefficient of the radiation in lead, and from this attempted to estimate the quantum energy. Recently Professor Oppenheimer has called our attention to the fact that, owing to the rapidly increasing probability of pair production with increasing quantum energy the quantum energy of a γ-ray is not always uniquely determined by the absorption coefficient in a single substance. This is seen from Fig. 1,
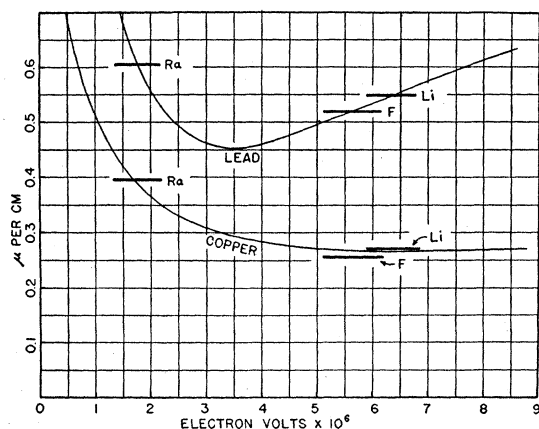

FIG. 1. Total absorption coefficient (Klein-Nishina +photoelectric +pair) of γ-rays in lead and in copper, as a function of their quantum energy.

which shows the total absorption coefficient for γ-rays in lead and in copper, as a function of quantum energy, plotted from theoretical figures kindly supplied us by Professor Oppenheimer.

In confirmation of this double valued absorption coefficient McMillan[1] has reported γ-rays from fluorine bombarded with protons and has shown, by measurements in various substances, that their absorption coefficients are correctly predicted by the theory if the quantum energy is about 5.5 m.e.v.

This consideration made it desirable to reinvestigate some of the γ-rays upon which we have previously reported, by making absorption measurements in at least one substance in addition to lead. This we have done in the case of the γ-rays emitted by lithium and by fluorine* bombarded with protons,[2] using lead and copper absorbers. The absorption coefficients found are indicated by horizontal lines intersecting the theoretical curves in Fig. 1. A correction for scattering has been applied to these values, and will be discussed below. Although the absorption coefficients in lead of these γ-rays are not very different from that of radium γ-rays, it is clear from the corresponding absorption coefficients in copper that their quantum energy is such as to place them on the high energy side of the minimum, at about 6.3 m.e.v. for lithium, and 5.6 m.e.v. for fluorine, rather than on the low energy side, as we previously supposed.

It is difficult to estimate the correction to be applied for scattering, over such a wide range of energy, especially where the mechanism of absorption is different at the high and the low energies. With the present experimental set-up we find an apparent absorption coefficient for radium γ-rays which is about 10 percent too low. However, while the attenuation of the radium γ-rays is due primarily to Klein-Nishina scattering, only about 40 percent of the attenuation of the 5.6 m.e.v. radiation from fluorine is due to Klein-Nishina scattering and the remaining 60 percent to pair formation. The 60 percent absorbed in pair formation contributes no scattered radiation directly, since the quantum is supposedly completely absorbed, but the resulting high velocity positive and negative electrons, in traversing the lead, give rise to some continuous x-radiation, in addition to the two 0.5 m.e.v. quanta resulting from the ultimate annihilation of the positron. Since in the high energy region this latter radiation tends to compensate for the smaller amount of scattered radiation, we have retained the 10 percent correction found for radium γ-rays, and have applied it uniformly to all our data.

In order to obtain the quantum energy of the above γ-rays in an independent way, and to check the theoretical absorption curves, we have undertaken to investigate by means of a cloud chamber the energy spectrum of negative and positive electrons ejected from a lead plate.

Fig. 2 shows the energy spectrum of the negative and positive electrons ejected from a 3 mm lead plate by the radiation from CaF_2 bombarded with 0.8 m.e.v. protons. The energies were determined by measuring the curvature in a magnetic field of 1200 gauss. A total of 641 measurable tracks above 0.5 m.e.v. were obtained; 434 negatives and 207 positives. From these curves we find, after applying
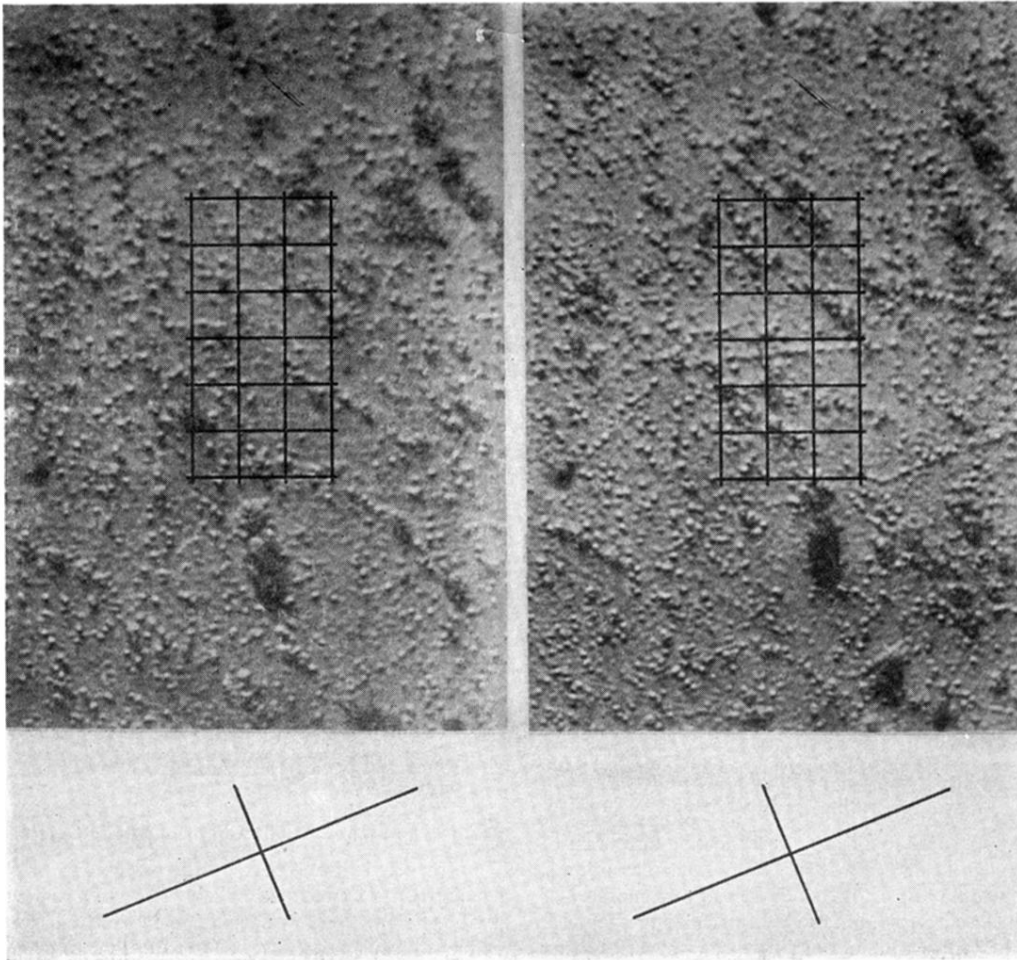
FIG. 1. Colloid patterns on nickel with **H** normal to the surface. The plane of the surface is 12° from a plane of form {100}, and the traces of the two other planes of this form have the directions shown beneath each photograph. The grille of 18 squares is $24\mu \times 12\mu$.