spot just opposite will have the lowest negative potential, lower even than a dark section of the same crystal. It seems, however, that a good agreement with experimental facts can be reached, assuming that the equilibrium of electrons in an illuminated crystal is dynamic and consists of a continuous circulation of electrons between the bright and the dark parts of the crystal.

FIG. 1.

It would be erroneous to assume a proportionality between the bright energy absorbed in some part of the crystal and the electron concentration there. It is, however, correct to replace the ratio of concentrations n_1/n_2 in two small volumes by the ratio σ_1/σ_2 of conductivities. It is then possible to test experimentally the fundamental equation of the diffusion-theory of the photoelectromotive force, P :

$$P = \frac{kT}{\varepsilon} \log \frac{n_1}{n_2} = \frac{kT}{\varepsilon} \log \frac{\sigma_1}{\sigma_2} \quad \dots \quad (1)$$

We used a long crystal provided with four transparent gold electrodes (Fig. 1). Measuring the ratio of conductivities at both ends of the crystal, we got for σ_1 too low, and for σ_2 too high a value because of the finite thickness of the sheet measured. Taking into account this systematic error we found a satisfactory agreement between the computed and measured values of P.
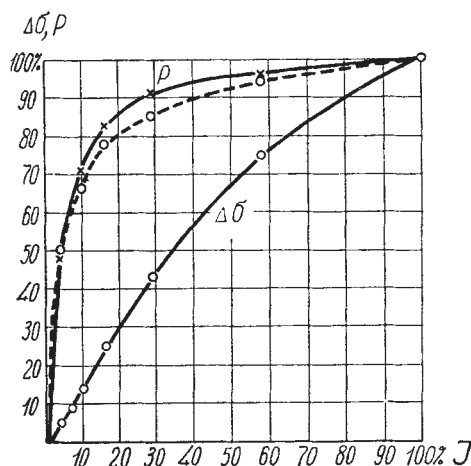

FIG. 2.

The best proof for the formula (1) is the dependence of P on the light intensity I. Using a Zeiss filter, we were able to reduce the light intensity to 4, 7, 10, 15, 30, 60, and 90 per cent of its initial value. Fig. 2 shows the corresponding values of $\triangle \sigma_1$ (photo-conductivity) of observed P (full line) and of computed P (dotted line). The small discrepancy is accounted for by the systematic error in σ_1/σ_2.

It is well known, and regarded as an anomaly[5], that photoconductivity is always restricted to the red end of the absorption band and vanishes within the region of high absorption. From curves such as Fig. 2 we computed the conductivity in a layer adjacent to the electrode and found a marked photoconductivity in the whole absorption band at liquid air temperature.

The second conclusion which we have drawn from our experiments is that the electron equilibrium in an illuminated and isolated crystal is dynamic in character. There are always two streams of electrons corresponding to two opposite and equal currents. The carriers of the photocurrent are different from the heat electrons. They are either electrons of higher energy levels or a few empty levels in a fully occupied band, acting as positive electrons. It seems to be the only possible explanation for the actual potential distribution in a crystal. The recent experiments of Deaglio, though unconvincing for the electrolytic nature of photoconductivity, show clearly a distinction between the two kinds of conductivity. Moreover, the change in the absorption curve in the excited state of an illuminated crystal gives supplementary support to the view that light produces a different kind of electric carrier from that produced by heat.

ANNE JOFFÉ.
A. F. JOFFÉ.

Physical-Technical Institute,
    Leningrad.
    July 10.

[1] H. Dember, *Phys. Z.*, **32**, 554, 856 ; 1931.
[2] H. Teichmann, *Proc. Roy. Soc.*, A, **139**, 105 ; 1933.
[3] R. Deaglio, *Z. Phys.*, **83**, 179 ; 1933.
[4] Anna Joffé and A. Joffé, *Z. Phys.*, **82**, 754 ; 1933.
[5] A. L. Hughes and L. A. Du Bridge, "Photoelectric Phenomena", 302 ; 1932.

Magnetic Moment of the Proton

THE spin of the electron has the value $\frac{1}{2} \cdot \frac{h}{2\pi}$, and its magnetic moment has the value $2 \frac{e}{m_e c} \cdot \frac{1}{2} \cdot \frac{h}{2\pi}$, or 1 Bohr magneton. The spin of the proton has the same value, $\frac{1}{2} \cdot \frac{h}{2\pi}$, as that of the electron. Thus for the magnetic moment of the proton the value $2 \frac{e}{m_p c} \cdot \frac{1}{2} \cdot \frac{h}{2\pi}$ $= 1/1840$ Bohr magneton $= 1$ nuclear magneton is to be expected.

So far as we know, the only method at present available for the determination of this moment is the deflection of a beam of hydrogen molecules in an inhomogeneous magnetic field (Stern-Gerlach experiment). In the hydrogen molecule, the spins of the two electrons are anti-parallel and cancel out. Thus the magnetic moment of the molecule has two sources : (1) the rotation of the molecule as a whole, which is equivalent to the rotation of charged particles, and leads therefore to a magnetic moment as arising from a circular current ; and (2) the magnetic moments of the two protons.

In the case of para-hydrogen, the spins of the two protons are anti-parallel, their magnetic moments cancel out, and only the rotational moment remains. At low temperatures (liquid air temperature), practically all the molecules are in the rotational quantum state 0 and therefore non-magnetic. This has been proved by experiment. At higher temperatures (for example, room temperature) a certain proportion of the molecules, which may be calculated from Boltzmann's law, are in higher rotational quantum states,

mainly in the state 2. The deflection experiments with para-hydrogen at room temperature allow, therefore, the determination of the rotational moment, which has been found to be between 0·8 and 0·9 nuclear magnetons per unit quantum number.

In the case of ortho-hydrogen, the lowest rotational quantum state possible is the state 1. Therefore, even at the lowest temperatures, the rotational magnetic moment is superimposed on that due to the two protons with parallel spin. Since, however, the rotational moment is known from the experiments with pure para-hydrogen, the moment of the protons can be determined from deflection experiments with ortho-hydrogen, or with ordinary hydrogen consisting of 75 per cent ortho- and 25 per cent para-hydrogen. The value obtained is 5 nuclear magnetons for the two protons in the ortho-hydrogen molecule, that is, 2·5 (and not 1) nuclear magnetons for the proton.

This is a very striking result, but further experiments carried out with increased accuracy and over a wide range of experimental conditions (such as temperature, width of beam, etc.) have shown that it is correct within a limit of less than 10 per cent.

A more detailed account of these experiments will appear in the *Zeitschrift für Physik*.

I. ESTERMANN.
R. FRISCH.
O. STERN.
Institut für physikalische Chemie,
　Hamburgischer Universität.
　　June 19.

Gravitational Field of an Electron

IN 1926, Einstein suggested[1] that the gravitational equations in an electromagnetic field should be taken as

$$K_{pq} - \tfrac{1}{4}g_{pq} K = -8\pi E_{pq},$$

where E_{pq} is the electromagnetic energy-tensor.

The solution of this equation for the radially symmetric field

$$ds^2 = -e^{\lambda}dr^2 - r^2 d\theta^2 - r^2\sin^2\theta d\varphi^2 + e^{\nu}dt^2$$

is found to be

$$e^{-\lambda} = e^{\nu} = 1 - \tfrac{1}{3}\alpha r^2 - \frac{2m}{r} + \frac{4\pi\varepsilon^2}{r^2},$$

where α, m, ε are constants of integration. The constants m and ε may be interpreted (as in the well-known solutions of Nordström and Jeffery) as the mass and the charge of the electron respectively. But it is difficult to interpret the second term. The most probable interpretation is that the empty space-time is de Sitterean and not Galilean. The details of the solution will appear shortly.

J. GHOSH.
Presidency College,
　Calcutta.

[1] *Mathematische Annalen*, Dec., 1926.

A Thermal Reaction between Chlorine and Formaldehyde

IT has been known for many years that chlorine reacts with the solid polymers of formaldehyde in the dark to give carbon monoxide and hydrogen chloride[1]. Furthermore, rapid reaction occurs in strong sunlight resulting in the formation of phosgene[1,2].

We have carried out some experiments with pure gaseous formaldehyde[3] and find that no measureable reaction takes place at 100°. At 150°, however, after a short induction period, a rapid reaction sets in accompanied by an increase in pressure. In such an experiment, starting with 191 mm. of formaldehyde and 183 mm. of chlorine, the pressure increased 148 mm. in 48 minutes. The reaction vessel had a volume of 156·5 c.c. and the dead space was reduced to very small dimensions by the use of a quartz spiral manometer. A known fraction of the gas was removed at this stage and cooled in a liquid air trap to condense the chlorine, formaldehyde and hydrogen chloride. The carbon monoxide which remained was collected by an automatic Töpler pump and analysed in a Bone and Wheeler apparatus. The condensate was dissolved in potassium iodide solution and the hydrochloric acid determined by titration, after removing the liberated iodine with thiosulphate. According to these analyses, 23·4 c.c. carbon monoxide and 44·8 c.c. hydrogen chloride at N.T.P. were formed in the reaction vessel. Both values are slightly greater than the theoretical amounts corresponding to a pressure increase of 148 mm., due to the fact that the induction period was extremely short in this case and some reaction had occurred before the first pressure reading could be taken.

However, it is apparent from the above as well as from other data not enumerated here that the reaction proceeds in the dark according to the following equation :

$$HCHO + Cl_2 \rightarrow CO + 2HCl$$
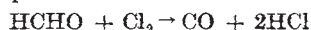
It is probable that a complex chain process is involved and a detailed study of the kinetics is in progress, with a view to further elucidation of the mechanism.

R. SPENCE.
W. WILD.
Physical Chemistry Department,
　The University, Leeds,
　　June 27.

[1] A. Brochet, *C. R.*, 121, 1156 ; 1895.
[2] W. Tishtchenko, *J. Russ. Chem. Soc.*, 479 ; 1887.
[3] M. Trautz and E. Ufer, *J. pr. Chem.*, 113, 105 ; 1926.

Origin of Monochromatic Radiation

IT is a remarkable fact that a particle possessing two degrees of freedom of rotation in co-latitude θ and azimuth φ, where θ and $\dot\varphi$ vary in a continuous manner, may give a stationary projection on the equatorial plane relatively to axes rotating in this plane with a certain *uniform* angular velocity.

Let $\theta = \theta_1 + (\theta_0 - \theta_1)e^{-at}$; $\dot\varphi = \dot\varphi_1 - (\dot\varphi_1 - \dot\varphi_0)e^{-at}$ where $\theta_0\dot\varphi_0$, $\theta_1\dot\varphi_1$ are the initial and final angular velocities respectively. Using the relations $\theta = \int \dot\theta dt$, $\varphi = \int \dot\varphi dt$, it then appears that the projected path on the equatorial plane OXY will be

$$r = a\sin\left\{ \left(\frac{\theta_0\dot\varphi_1 - \theta_1\dot\varphi_0}{\theta_0 - \theta_1} \right) t - \varphi \right\} \frac{\theta_0 - \theta_1}{\dot\varphi_1 - \dot\varphi_0}.$$

α has disappeared and relatively to axes rotating about OZ with a *uniform* angular velocity given by the coefficient of t within the bracket, the projected path will be

$$r = -a\sin\left(\frac{\theta_0 - \theta_1}{\dot\varphi_1 - \dot\varphi_0} \right) \varphi ;$$

curiously enough, this relative path will appear stationary if the total fall of one angular velocity in latitude bears any simple relation to the rise of the other in azimuth.

Perhaps it is too ambitious to try to find some 'Victorian' mechanism to explain what has remained unassailed as a postulate for the past twenty years,