LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

The Vectorial Photoelectric Effect in Barrier-Layer Cells

It is a well-known fact that polarized light falling on the surface of a photoelectric cell has a greater effect if its electric vector lies in the plane of incidence than if it is perpendicular to the plane of incidence. H. E. Ives[1] has developed an explanation of the effect which checks the experimental results very well.

Although barrier-layer photovoltaic cells are different in construction from photoelectric cells in several respects, the action in both cases consists of the movement of electrons across a boundary. Hence it seems probable that there should be an effect in the case of barrier-layer cells similar to that in photoelectric cells although perhaps not so marked. L. Bergmann[2] carried out an experiment with a selenium barrier-layer cell to test this possibility and came to the conclusion that no such effect was present. However his calculations of the light absorbed were, as he stated, not rigorous and his results are therefore somewhat doubtful.

The author, realizing that calculations for this type of cell are not reliable, designed an experiment to obviate this difficulty. The light absorbed was measured instead of calculated so that the results are more valid.

A Weston photronic cell was chosen as the cell for the experiment. Its sensitive disk was removed from the Bakelite case to get rid of the shadows cast by the rim and also to cut out absorption by the glass. For the purpose of measuring the absorbed light a small spherical integrator was used. The sensitive disk was placed inside and the light reflected at various angles of incidence was measured. The light absorbed was assumed to be the difference between the reflected light and the incident light. The total amount of light falling on the surface was measured by replacing the cell by a piece of magnesium carbonate such as is commonly used in photometric measurements. The piece used had a reflection factor of 99.5 percent so that only a very small error was introduced by this procedure.

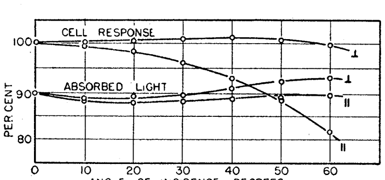

FIG. 1. The comparison of observed light and cell response referred to values for zero angle of incidence. The symbols ⊥ and || refer to the orientation of the plane of polarization to the plane of incidence.

The integrator was a sphere twelve inches in diameter, coated on the inside with precipitated magnesium carbonate. The light source used was one electrode of an S-1 sunlamp. The light from the electrode passed through a large Nicol prism and then through a collimating tube so that it was parallel within 15′. The angle of incidence of the beam could be measured within about 15′.

The response of the cell to polarized light at the different angles of incidence was measured at the same time as the amount of light reflected. The two values were compared. The result shows definitely an effect of the kind expected. The two sets of curves in Fig. 1 show the data obtained.

The difference between the effects of light polarized in and perpendicular to the plane of incidence is not as marked as in the case of most photoelectric cells. The fact that the light has to pass through a thin layer of silver undoubtedly affects the results to some extent. It is practically impossible to analyze the effect of the silver layer and of the irregularities of the surfaces involved and no attempt was made to do so. The results then are purely qualitative as far as any conclusions which may be drawn from them go.

ROBERT G. WILSON

University of Dubuque,
Dubuque, Iowa,
January 12, 1938.

[1] H. E. Ives, Phys. Rev. **38**, 1209–1218 (1931).
[2] L. Bergmann, Physik. Zeits. **33**, 17–19 (1932).

Evidence Against the Existence of Heavy Beta-Particles

Jauncey[1] has suggested that all the beta-particles from a given species of nucleus have the same total energy, the slower ones being endowed with a rest mass greater than that of a planetary electron. Earlier, Zahn and Spees considered a similar hypothesis, and concluded that their deflection experiments[2] definitely contradict it. At the December, 1937, meeting of the American Physical Society Jauncey reported deflection experiments and interpreted them as supporting his hypothesis.

We have made an independent test of the hypothesis. Champion[3] obtained 35,000 magnetically curved cloud chamber tracks of Ra E beta-particles in nitrogen and oxygen. Thus he observed 15 close collisions between beta-particles and electrons, of quality suitable for an accurate test of the conservation of energy and momentum. Fourteen of these satisfied the conservation relations closely, and are suitable for the present study. Let βc be the velocity of a beta-particle whose rest mass is R times greater than that of an ordinary electron, and let

$\gamma=(1-\beta^2)^{-\frac{1}{2}}$. On Jauncey's theory,

$$R\gamma=\gamma_m,$$

where γ_m corresponds to the upper limit of the spectrum; its value is 3.44 ± 0.06 for Ra E.[4] Assuming strict conservation of energy and momentum, and also that the incident particle has a mass Rm_0, we have calculated values of $R\gamma$ from Champion's data. $R\gamma$ represents the energy of the incident beta-particle, in units m_0c^2. $R\gamma$ ranges from 1.65 to 2.74, most of the values being below 2. Their mean is less than 2, while Jauncey's theory predicts the constant value of 3.44 for this product. These results constitute a definite disproof of the hypothesis of heavy beta-particles, supplementing the evidence given by Zahn and Spees.

Our conclusion has no bearing on the possibility that the heavy particles reported in cosmic-ray experiments are electrons of exceptional rest mass. Results which are valid in the region of one million electron volts should be extrapolated to the domain of one billion electron volts.

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Chapel Hill, North Carolina,
January 12, 1938.
ARTHUR RUARK
CREIGHTON C. JONES

[1] Jauncey, Phys. Rev. **53**, 106 (1938).
[2] Zahn and Spees, Phys. Rev. **52**, 524 (1937).
[3] Champion, Proc. Roy. Soc. **136**, 630 (1932).
[4] O'Conor, Phys. Rev. **52**, 303 (1937).

Heavy Beta-Rays—More Theory and Experimental Evidence

Positives of the fifth and eighth films taken with the apparatus described in my third letter[1] are shown in Fig. 1. The line A is due to alpha-rays and the line C to ordinary beta-rays. According to my view the band B is due at least partly to heavy beta-rays. The data for the photographs are:

Film	H	V	β	s	p
5B	318	3372	0.338	1.02	3.37
8B	125	1296	0.328	.47	2.80
8C	125	1296	0.328	1.40	1.07

By reversing both fields I found that the alpha-line was shifted by an amount $H\times1.0\times10^{-4}$. Correction has been made for this in determining s. The value of $p=1.07$ for the C line of film 8 shows that the apparatus records ordinary electrons and removes all doubt as to the electric field in the selector. The theoretical value of p for the heavy electrons from Ra E for $\beta=0.328$ is 2.89 in excellent agreement with the experimental value. Film 8 was not covered with aluminum, while film 5 and films 1, 2, 3 of my third letter[1] were covered with $\frac{1}{2}$ mil of aluminum. The absorption in aluminum varies very rapidly with p and the center of the B band is shifted. This is possibly the explanation of the high values of p found from films 3 and 5.

The expression on the right side of (1) is the force on the particle in the velocity selector and $1/\rho'$ is the curvature of the path in the selector:

$$pm_0\beta^2c^2/\rho'e(1-\beta^2)^{\frac{1}{2}}=e(H\beta c-E). \tag{1}$$

There are two solutions for $\rho'=\infty$: (a) $\beta=E/Hc$ and (b)

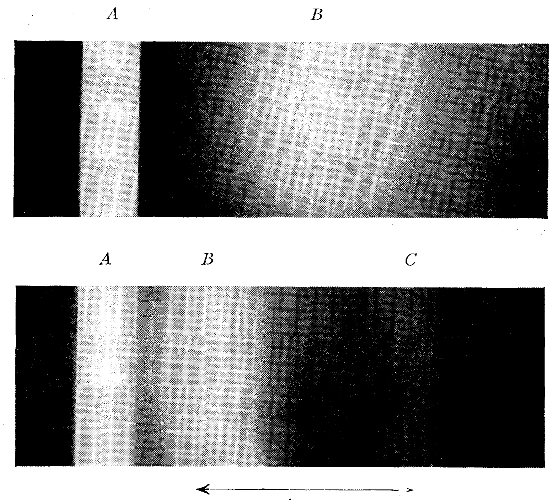

FIG. 1. Mass spectra of electrons. Film 5, top; film 8, bottom.

$\beta=1$. For each solution there is a maximum tolerance given by $\rho'=l^2/8w$, where l is the length and w the distance apart of the selector plates. For film 5 the tolerance for (b) is $\beta=0.964$ to $\beta=1$, when $p=1$. This should give a band from $s=0$ to 0.32 cm. No such band appears. Moreover the maximum β for Ra E is 0.945. The conclusion that the B band is due to heavy electrons seems inescapable.

Comparing B and C of film 8, we find a width in the band due to the heavies over and above the width of the line due to the ordinaries. I suggest that part of this extra width may be due to the heavies changing back to the ordinaries. Following the theory outlined in my first two letters,[2] the conservation principles yield

$$\alpha'=(p^2-1)/2p_{\max}(1-\beta\cos\phi), \tag{2}$$

where $\alpha' m_0c^2$ is the energy of a photon emitted in a direction ϕ with the direction of the velocity βc of a heavy electron of mass pm_0 when it returns to mass m_0 and recoils with a velocity $\beta' c$ in a direction θ. The change from pm_0 to m_0 may occur at any point along the arc either in the selector or in the magnetic field. That ordinary electrons of the selector velocity are produced in the selector has been shown by placing $\frac{1}{2}$ mil of aluminum first in front of the film when the line for the ordinaries of $\beta=0.44$ was missing on the film and then transferring the aluminum foil to a position between the Ra E and the selector when the line for the ordinaries appeared again on the film. These ordinaries are produced as secondaries at the plates of the selector or are produced from the heavies. Ordinaries would always be found in Doctor Zahn's arrangement. In closing, I repeat my statement at Indianapolis that evidence for heavy beta-rays is shown in Bucherer's papers.[3]

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January 14, 1938.

[1] Jauncey, Phys. Rev. **53**, 197 (1938).
[2] Jauncey, Phys. Rev. **52**, 1256(L) (1937); **53**, 106(L) (1938).
[3] Bucherer, Ann. d. Physik **30**, 974 (1909).