vations was made on the summit of Hawaii by the American geodesists. Can not these be published? They would be of the greatest interest. I think that I have read that on Mauna Loa, or possibly Mauna Keua, a long series of meteorological observations was made, but I can not find where the results were published. It would be of the greatest importance to our knowledge of the return upper trades, that Hergesell and Rotch could not find over the Atlantic Ocean, if the observations at great heights in Hawaii had been published. As Preston made gravity determinations at 3980 meters surely there must have been meteorological observations. A permanent station on Mauna Keua would certainly be a desideratum in meteorology.

It is greatly to be hoped that our Hawaiian observers will see what can be done toward discovering and publishing all the observations that have been made at great altitudes in Hawaii. The variations of rainfall, relative humidity, wind velocity, and cloudiness with altitude especially demand observation and study.—*C. A.*

THE PHOTOELECTRIC PROPERTIES OF SELENIUM CELLS.

By Prof. K. E. GUTHE, The State University of Iowa, Iowa City, Iowa. Dated May 14, 1906.

The recent application of the photoelectric properties of a selenium cell during the eclipse on August 30, 1905,[1] has again directed the attention of scientists to the selenium cell as a possible means for measuring intensity of illumination or its use for meteorological observations.

(1) The strongest objection to the use of any instrument for measuring light intensity lies in the fact that the latter is not a physical quantity in the strict sense of the word, but a subjective phenomenon, for which we have been unable so far to find any adequate unit of measurement. In all problems of this kind it should be well understood that usually we estimate luminosity by the subjective effect of light upon our eye, and it is apparent that the estimation of its intensity depends to a considerable extent upon the sensitivity of our eye to the various wave lengths and upon the distribution of the energy of radiation in the spectrum; at the same time, the impression made depends greatly upon the fatigue of the eye and upon after-images. In fact, the measurement of intensity of lights of different colors, or even different shades, is, from a physicist's point of view, a still unsolved problem. The only satisfactory method of determining the sensitivity of the eye consists in the comparison of the so-called threshold values, i. e., the energy of light of different wave lengths which will just be perceived as light by a well-rested eye. While these comparisons are usually made for the different rays of a given spectrum, it is clear that the relative distribution of energy in the spectrum must be taken into account in order to remove all uncertainty in the results, since different light sources show entirely different relative energy intensities of their components.

In the accompanying fig. 1 I have drawn the threshold values, as given by Ebert,[2] for the different colors of the spectrum, the energy of radiation being the same for all colors. It is claimed, however, that the form of the curve will vary with the intensity of the light. (Purkinje's phenomenon.[3])

Assuming for the sake of argument that the relative sensitivity of the eye for different colors remains unaltered by the degree of luminosity, the first condition to be fulfilled by an instrument intended as a substitute for the eye is that its relative sensitivity for different colors must be the same as for the eye. Pfund[4] has given us constant energy curves for the sensitiveness of selenium cells as a function of the wave length, i. e., curves showing the ratio of the change of electric conductivity to the original under the influence of the various spectral colors. I have reproduced one of them in fig. 1, taking (as in the first curve or that for the eye) the maximum sensitiveness as unity. A comparison between the two curves shows that the selenium cell is much more affected by red rays than by any other, while the eye is most sensitive to green. A reddish light will therefore appear much brighter to the selenium than to the eye, and a direct comparison of lights of different colors will always give unsatisfactory results if made by means of the selenium cells.[5]

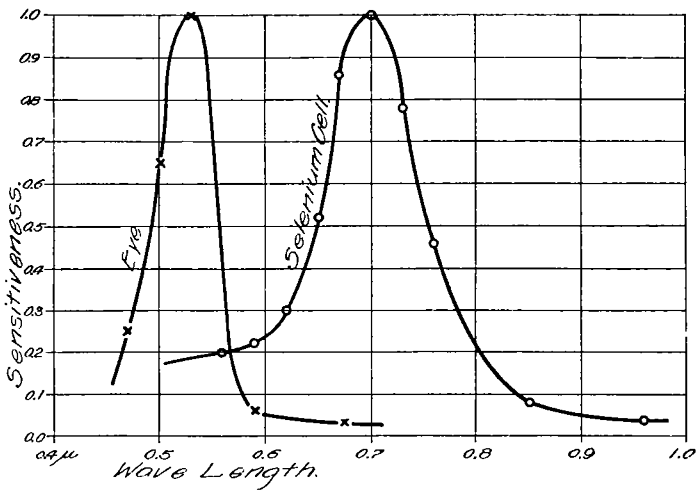

FIG. 1.—Sensitiveness of eye and selenium cell to light of different wave lengths.

The same objection can, however, be made to any other instrument for measuring intensity of illumination, for example, to the one used by Elster, Geitel, and Harms,[6] in which the results are obtained from the loss in quantity of electricity by a negatively charged metal plate when illuminated. In this case only wave lengths between 0.32μ and 0.50μ were used.

(2) Let us suppose that we select arbitrarily the selenium cell as the standard instrument for measuring luminosity; still other conditions must be fulfilled if the apparatus is to prove of value for our purpose. The relation between the intensity of light and the physical quantity from which we calculate the former must not be too complicated. Several attempts have been made to express the relative increase of conductivity as a function of the intensity of illumination. Hesehus[7] gives the following equation:

$$I = a(b^m - 1),$$

where I is the intensity, m the relative change of conductivity, a and b constants, which differ for different cells and even for the same cell vary considerably if the intensity is very strong. There is a great difference in the behavior of different types. The "hard" cells show great sensitiveness to variations in light if the latter is intense and much less for relatively weak illumination, while the "soft" cells show just the opposite. Thus, Ruhmer[8] found that the resistance of a hard cell fell with a change of luminosity from 0 to 4.6 lux 25 per cent and with a change from 22 to 20,000 lux 42 per cent, while the corresponding values for a soft cell were 56 and 25 per cent, respectively.

Every cell must, therefore, be calibrated empirically before any measurements can be made with it. It may be that the new method of preparing cells with pure selenium by using carbon instead of metal electrodes will lead to more constant results in this respect. Recent investigations[9] with such cells

[1] Wulf and Lucas, Phys. Zeitschr., 6, 838, 1905; Astroph. Journ., 23, 153, 1906.

[2] Ebert, Wied. Ann., 33, 150, 1888.

[3] Wundt, Physiologische Psychologie, 5th ed., II, 174.

[4] Pfund, Phil. Mag., 7, 26, 1904.

[5] Wulf and Lucas, l. c.

[6] Elster, Geitel, and Harms, Terrestr. Magnet., 11, 31, 1906.

[7] Hesehus, Phys. Zeitschr. 7, 163, 1906.

[8] Ruhmer, Phys. Zeitschr. 3, 470, 1902.

[9] Pfund, l. c.; Berndt, Phys. Zeitschr. 5, 121, 1904; Coste, C. R., 149, 715, 1905.

have led to the conclusion that Bidwell's theory as to the important rôle of the selenides is unsatisfactory, and that the conductivity depends almost wholly upon the metallic selenium formed throughout the amorphous modification when heated to a temperature of about 200° C. Hesehus has developed an interesting theory of the "allotropic dissociation of selenium," which, on the whole, explains satisfactorily the behavior of the cells.

(3) The constants of the cell must change only little in time, with temperature and atmospheric conditions; but, in this respect also, the selenium cell is by no means perfect. A sensitive cell has a granular structure with numerous minute pores and interstices between the granules, doubtless due to the fact that with the transformation of the amorphous modification to the metallic, which latter has a considerably larger density, irregular contraction will occur and cracks be formed. Expansion caused by an increase of temperature will be followed by a closer electrical contact between the granules and a lowering of resistance. In some cases this temperature effect is very large and it differs in cells of different construction.[10] Carpini[11] found that on heating a cell through 80° or 90° C. the resistance dropped to almost one-tenth of its original value, an enormous change which may, however, in part be due to some transformation into the conducting modification.

Increase of external pressure will also decrease the resistance, as Brown[12] has shown.

Moisture absorbed by the pores doubtless influences the electrical conductivity and thus necessitates the use of a vacuum chamber for the cell.

If I add to this that in course of time the sensitiveness changes, that the contact between the selenium and the electrodes often loosens, and that there is a very annoying after effect, i. e., that the action of the cell is quite sluggish, especially in its return to the original high resistance after the light is shut off, it is apparent that we have not as yet a cell which can be used with any degree of satisfaction for the measurement of intensity of illumination.[13]

Of course it is a different matter if we wish to determine a definite instant at which a sudden change of illumination takes place, as Wulf and Lucas have done in their investigation in connection with the eclipse. It seems that they were able to determine accurately the exact time of first apparent contact of the sun's and moon's disks as well as the end of totality; but only the most sanguine admirer of the selenium cell would dare to draw any conclusion as to the actual change of intensity from the curve given by these investigators, even if we suppose that all spectral colors from the sun are diminished in the same ratio as the eclipse progresses.[14]

[10] Aiki and Tanakadate, Math. and Phys. Soc., Tokyo, 16, 217, 1904.

[11] Carpini, Lincei Rend. 14, 667, 1905.

[12] Brown, Phys. Rev. 20, 185, 1905.

[13] See also Dorsey, Monthly Weather Review, 27, 99, 1899, and Berthier, L'Ecl. electr., 38, 441, 1904.

[14] Schwarzschild and Villinger, Phys. Zeitschr., 6, 737, 1905.

WEST INDIAN CHART.

Among the changes in the WEATHER REVIEW for 1906 many will note the absence of the chart of isobars and isotherms for the West Indies. This chart has been kept up in the hope that its usefulness might lead to some system of cooperation among the isolated West Indian services and stations, and eventually to the publication of more complete and satisfactory meteorological and climatological data. Such a union of effort has not yet been attained, but may be realized hereafter, and meanwhile we shall hope to publish occasional references to current sources of information.

The weather of tropical regions is popularly supposed to be very uniform from day to day and year to year, but for this very reason a slight change in temperature or moisture, sunshine or rainfall, has a disproportionately large influence on plants and animals. The large changes that we experience in temperate zones would be disastrous in the Tropics. The regular publication of continuous meteorological details, as well as the different charts for the West Indies, is as important to the student as are the similar publications for the United States. In fact, however, their value to biological studies is not the most important argument for the publication of such monthly charts. The changes in location of the general or tropical areas of high and low pressure, wind, and rain that produce variations in West Indian weather are undoubtedly due to great changes in the general atmospheric conditions over the whole globe. Storms form as the result of these conditions, and we need a daily chart of the West Indies and adjacent regions, with weekly and monthly synoptical charts, such as Hildebrandsson has published, showing the departures from normal, in order to realize the intimate relation between the equatorial and the polar oscillations.—*C. A.*

PHENOLOGICAL STUDY.

E. N. Transeau, Professor of Biology, Alma College, Michigan, in acknowledging the receipt of a copy of Bulletin 36, says:

> Regarding phenological data I believe the Weather Bureau could secure sufficient data to publish a really valuable map and discussion of this interesting phase of plant geography. The data would have to be secured largely from amateur collectors, for so far as I know very little has been published along this line in this country. Data might also be obtained from herbarium specimens in the larger collections.

Phenology—considered as the study of the development of plants from one epoch to another throughout life—does not belong to meteorology, but to biology, and indeed requires the services of a skilled botanist. If this study should be well organized, under the proper division and bureau of the Department of Agriculture, then many Weather Bureau observers would doubtless be pleased to cooperate, but we can not take the initiative in this matter.—*C. A.*

BACK NUMBERS OF THE WEATHER REVIEW.

The editor will be glad to hear promptly from anyone who desires to complete his set of the MONTHLY WEATHER REVIEW, as it is possible that the accumulation of back numbers may now enable us to complete such sets.—*C. A.*

RESTRICTIONS ON PUBLICATIONS AND THEIR DISTRIBUTION.

In connection with the publication of the MONTHLY WEATHER REVIEW it is proper to remind our correspondents and recipients of the General Order (No. 96, April 14, 1906) recently issued by the Secretary of Agriculture:

> In view of the restrictions placed on the funds available for printing and binding for this Department, and in view of the constantly increasing demands upon these funds, it becomes necessary to adopt restrictive measures in regard to the issue of publications. It is quite as incumbent upon the Department to publish the information it has acquired as to conduct the laboratory work and field and other investigations by which this information is obtained. The only limit placed upon the acquisition or diffusion of this information is that it shall be of value to agriculture.[1] Four ways only seem available by which the expense of the printing and binding for this Department may be judiciously restricted:
>
> First, by prevention of the waste inevitably accompanying a general gratuitous distribution.
>
> Secondly, by careful editing (in the manuscript) of every document submitted for publication, with a view to presenting the facts in the briefest, most succinct style compatible with clearness.
>
> Thirdly, by rigid suppression of the tendency to reedit in the proof, and,

[1] Undoubtedly this is to be interpreted as including all the work of the Department of Agriculture.—EDITOR.