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A QUASI-NULL METHOD OF MEASURING SMALL AMOUNTS OF
RADIANT ENERGY*

by

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from

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Fort Knox, Kentucky
11 July 1951

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Military Personnel in Relation to Equipment, Environment, and Military
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ABSTRACT

A QUASI-NULL METHOD OF MEASURING SMALL AMOUNTS OF RADIANT ENERGY

OBJECT

This investigation was undertaken to find a method for measuring the small amounts of ultraviolet radiant energy used in the conversion or decomposition of certain amino acids.

RESULTS AND CONCLUSIONS


The Coblentz astatic galvanometer used in this energy measuring method was found to be subject to drift and change of sensitivity, probably due to variations in torque on the suspension. To alleviate this, a micro-screw clamp was designed and built which made possible the adjustment of sensitivity without changing the relative positions of the sensitizing magnets. Having found that the linearity was best near the center of the scale, a Wenner potentiometer was permanently added to the system so that readings could always be made near zero. The smallest division on the Wenner being equivalent to 3 cm. on the galvanometer scale, and the fact that physical zero seldom coincided with scale zero gave rise to the adjusted interpolation method of evaluating the energy. All measurements were made with a mercury arc lamp which is subject to fluctuations of 2 to 3%. It is probable that this is the limiting factor in the accuracy of the method.

RECOMMENDATIONS

None.

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A QUASI-NULL METHOD OF MEASURING SMALL AMOUNTS OF RADIANT ENERGY

I. INTRODUCTION

The energy measuring method to be described in this report was developed in connection with the study of the quantitative relation between ultraviolet energy applied to the skin and the degree of erythema and pigmentation which follows. Since the amino acids phenylalanine, tyrosine, and dihydroxyphenylalanine are involved in skin pigmentation, one of the first steps in the investigation was to find the relation between the amount of ultraviolet radiation applied and the conversion or decomposition of these amino acids.

II. EXPERIMENTAL

A. Method.

Since work was done in the 250 m μ to 300 m μ region of the spectrum with substantially monochromatic radiation, and since there are no powerful and constant sources in that region, the energy to be measured was small, about 80 $\mu\text{w}/\text{cm}^2$ (of the same magnitude as the flux from a 100 W light bulb falling on an area 300 cm. distant). For this reason precautions were taken to obviate effects due to changes in the surrounding heat, light and electrical conditions.

The ultraviolet source was an A-H6 mercury vapor lamp in a quartz jacket operating at about 110 atmospheres pressure and giving approximately 10 W output in the region 250 m μ to 300 m μ . The beam of light from the A-H6 was rendered monochromatic by a Farrand Double Monochromator, Model 300 DUV.

An Eppley 12 junction linear spectrum type thermopile mounted in a vacuum case was the radiation receiver for the measurements. The thermopile was chosen in order to measure the absolute energy directly with a frequency independent instrument. The case on the Eppley pile made it possible to operate at reduced pressures so as to increase the sensitivity. This was found to be unnecessary.

A Coblentz astatic galvanometer was used. In some preliminary experiments it was found that calibration of this instrument was time consuming and good for only a short period of time. The sensitivity often changed by as much as 25% in 24 hours so the quasi-null method was set up.

A Wenner thermocouple potentiometer was permanently added to the system. This potentiometer has discrete steps for potential selection, the smallest being 0.1 μv . It is also equipped with a reversing key so that one may, by taking direct and reverse readings, compensate for any residual systematic error in the galvanometer. Since the Coblentz galvanometer was used at a sensitivity of approximately 30 $\text{cm}/\mu\text{v}$ there was a throw of 3 cm for the smallest division of the potentiometer. Therefore two settings on the Wenner and an adjusted interpolation were used to compensate for the slow zero drift which, in practical application, cannot be eliminated and was found to be linear over relatively short periods of time (8 to 10 hours). The interpolation is illustrated later by an example.

The sensitivity of the Goblentz galvanometer was controlled by the two sensitizing magnets which were supported by rods which slide in sleeves mounted on the top shield of the system. The galvanometer gave the greatest accuracy if, at the rest position, there was no torque acting rather than if there were compensating torques acting. As delivered from the manufacturer, the sensitizing magnets on the instrument can be rotated and translated independently. As a result of this the no torque condition was extremely difficult to attain. With parallel lines scribed on the bottom of the top shield, and by projection of shadows the sensitizing magnets were aligned so that their common line of action passed thru the astatic suspension. By this adjustment extraneous torques were reduced to as near zero as possible. In this position the sensitizing magnets were clamped, as a unit, so they could be raised or lowered by means of a micro-screw, but could not be individually rotated with respect to the astaticizing magnets. Rotation could be effected by turning the top shield.

The measurement was made as follows: The lamp was set in front of the entrance slit of the monochromator, with the shutter closed, and the galvanometer spot brought on scale by rotating the top shield. The direct and reverse zeros were brought together by adjusting the potentiometer. Upon opening the shutter the spot was deflected from the scale and was brought back by means of the voltage dials of the Wenner. The next step was to find the optimum position of the lamp. The lamp was moved so that the spot was sent off scale due to the thermopile. Then more voltage was tapped from the Wenner to bring the spot back on scale. The moving of the lamp and changing of the Wenner potential was repeated until, after a series of these approximations, a condition was reached where movement of the lamp in any direction would result in a deflection of the spot due to the potentiometer. This was the optimum position of the lamp.

The shutter was now closed and the potentiometer was turned back to zero. Next, four readings were taken: (a) zero, (b) minimum deflection by means of the voltage dials of the Wenner, (c) minimum deflection the other side of zero, (d) zero. A set of readings from actual measurement illustrate the method. Only direct deflections are shown, it being kept in mind that in actual practice a set of reverse readings also were taken, the average of the two readings helped compensate for any error due to residual torque not precluded by the clamp.

	Potentiometer reading μv	Galvanometer reading cm.
Zero	0.0	11.6 black
Minimum deflection one side of zero	3.7	10.6 "
Minimum deflection other side of zero	2.6	13.0 "
Zero	0.0	12.2 "

There were three equal time intervals between the first and last zero readings and the zero shifted 0.6 cm. toward the black in the time between these readings. Assuming constant drift in equal time intervals between readings, the drift between readings was 0.2 cm., 0.2 cm., 0.2 cm. Then the adjusted zeros were:

Zero_{3.7} 11.8 black
Zero_{2.6} 12.0 black

All readings were normalized with respect to scale zero. That is to say, the zero and the reading for 3.7 μv were moved 11.8 cm. toward the red.

$$10.6 \text{ B} - 11.8 \text{ B} = 1.2 \text{ Red}$$

$$13.0 \text{ B} - 12.0 \text{ B} = 1.0 \text{ Black}$$

Then the fraction of the scale distance that zero was away from the smaller μv reading toward the larger was found to be (red numbers were arbitrarily called negative) -

$$\frac{1.0 - 0.0}{1.0 - (-1.2)} = \frac{1.0}{2.2} = 0.455$$

The distance corresponded to 0.455 of 0.1 μv or 0.05 μv . This value was added to the smaller of the μv readings:

$$3.6 + 0.05 = 3.65 \mu\text{v}$$

The μv readings were converted to energy values (joules) by use of the calibration figure of the thermopile ($0.0454 \frac{\mu\text{v}}{\mu\text{w}/\text{cm}^2}$), the area irradiated, and the time of radiation.

B. Example of utilization of method:

Quantitative determinations were made of the production of tyrosine from phenylalanine and of dihydroxyphenylalanine (dopa) from tyrosine. These were done as part of a more complete investigation reported in detail by K. Schocken (1). The other experiments were not concerned with the amount of energy so are not pertinent to this report.

4.0 mg. of phenylalanine in 4 ml. of buffer solution of pH 7 was irradiated with a band width of 10 m μ centered at 270 m μ . Using Arrow's procedure, with 1.5 ml. of this solution, the following results were obtained with 1.5 mg. phenylalanine:

<u>Irradiation time (hrs.)</u>	<u>Energy supplied (joules)</u>	<u>Yield of tyrosine (mg)</u>
8	22.2	0.008
4	9.0	0.004
2	4.5	0.002

It appears that the increase of tyrosine was approximately proportional to the energy supplied.

Next to be examined was the conversion of tyrosine to dopa. In this case, 1.6 mg. of tyrosine was irradiated in 4 ml. of buffer solution of pH 7. As before, the band width was 10 m μ centered at 270 m μ . The table gives the results:

<u>Irradiation time (hrs.)</u>	<u>Energy supplied (joules)</u>	<u>Yield of dopa (mg.)</u>
8	51.0	0.006
8	49.5	0.006
8	42.7	0.004
8	42.2	0.004
6	29.4	0.004
8	14.0	0.004

In this case there appears to be an equilibrium or saturation of dopa beyond which the amounts of energy applied would not alter the mixture. Since the melanin content increased with increase in energy it seems safe to conclude that the production of dopa does go on but after a certain level there is just as much dopa going to melanin as is being formed.

III. CONCLUSIONS

The method is a definite improvement over a direct measuring method since it obviates any change in sensitivity of the Coblentz galvanometer and it makes use of the galvanometer at, or near, its position of mechanical rest, where the deflection can be expected to be linear.

IV. RECOMMENDATIONS

None.

V. BIBLIOGRAPHY

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