A STUDY OF ULTRA-VIOLET RADIATION IN THE SUNLIGHT IN KNOXVILLE

by

JAMES FORTUNE

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I. Introduction.

A. Relation of Ultra-violet Radiation to Health.

The health of the residents of any city is a subject of great importance, not only to those living in that city at present but also to those who will move there later as well as to the future generations.

The rays of the sun that reach the earth's surfact at any point will have a large part to play in the health of the place where they fall. Rickets, colds, tuberculosis and many other diseases are most successfully treated with the rays of sunlight. While some of the health propertities of the sun are varied it is known that the ultra-violet radiation will aid in the cure of rickets and colds. Thus it can be seen why the most prized climates are places where the humidity is low and the air is clear, for it is in those places that the rays of the sun have their highest intensity.

Knoxville is now the center of a great experiment in social planning and betterment of living conditions of the people by the government. As this city grows larger its health will become increasingly important.

Taking the biological factor as an indication of the insufficiency of ultra-violet radiation here proved of no avail, because statistics on rickets are not regularly kept at the Bureau of Health of the city of Knoxville. Here they are interested in keeping records of communicable diseases primarily and rickets is not a communicable disease.

B. Factors which Affect Ultra-violet Radiation in Knoxville.

1. Low yearly percentage of possible sunshine.

According to the statistics of the United States Weather Bureau[1] the average percentage of possible winter sunshine in Knoxville is very low. Detroit is the only other city of any size that has a lower possible percentage of winter sunshine, and Memphis is the only other place to have a lower average percentage of possible sun-

1. United States Weather Bureau Report, 1930

shine.

Knoxville also has a fairly low percentage of relative humidity. These two factors do not both act to cut down the intensity of the ultra-violet rays as the first named would undoubtedly cut down the amount of ultra-violet rays reaching Knoxville, but the latter would tend to aid the radiation.

From the above statements it is needless to say that the season of the year and the hour of the day influence greatly the intensity of the ultra-violet radiation. As the sun reaches its peak at a certain time of the year and a certain hour of the day, one would expect to find the greatest intensity of ultra-violet radiation to correspond to these points of greatest intensity of ultra-violet radiation. The highest variation is found in regions where there is the highest variation in humidity and in the average percentage of possible sunshine. In different localities this has been shown to vary considerably. In Colorado where the air is clear and the humidity low during all seasons of the year the summer sunshine contains not quite three times as much ultra-violet light as the winter sunshine[2]

2. Lewis, R. C., Furmess, J. M., and Stein, H. B. Am. J. Dis. of Children 41, 71 (Jan., 1931)

This is a variation from the generally found condition. For example, Pisdall and Brown[3] found eight times as much ultra-violet light in the sunlight in Toronto, Canada, in summer (April to August) as in the winter months. In Little, Rock, Arkansas, the intensity in July was fifteen times higher than in December and Janurary.[4]

Clark states that in Baltimore, summer sunshine has eight times as much ultra-violet radiation as that found in winter radiation.[5]

It has also been shown from the above reports that there is an increase of about fifteen (15) to twenty (20) percent in intensity during the morning hours, after which the intensity decreases. The highest point is between the hours of eleven (11) o'clock A. M. and one (1) o'clock P. M. The highest point in Baltimore

3. Tisdall, F. F. and Brown. Am. J. Dis. of Children 34, 860, 1927.

4. Day, P. H., "The Seasonal Variation in Antirachitic Potency of Arkansas Sunshine", Read at meeting Am. Chem. Soc., May, 1930.

5. Clark, J. H., Am. J. Hygiene 9, 646, 1929.

was found to be twelve(12) o'clock noon[6]. From a geographical standpoint Knoxville should receive an average amount of ultra-violet rays, as the highest intensity of ultra-violet rays is found near the equator, and the lowest near the poles, with the temperate zones in an intermediate position.[7]

2. Soot and smoke.

As has been shown by the Smoke Surveys of Knoxville, the amount of smoke and soot that contaminate the air here is rather large. According to Free[8],

> Worst of all obstacles against ultra-violet rays for city dwellers is the smoke---a virtually impenetrable pall to these rays and one which roles the street levels of such cities as New York and Chicago measurements show of more than three-fourths of the rays which otherwise they would receive.

One can readily see from this that a large proportion of these health giving rays never reach

6. Earp, J. R., Am. J. Hygiene 11, 594, 1929.

7. Blunt, K., and Cowan, R. Ultra-Violet Light and Vitamin D in Nutrition. University of Chicago, 1930.

8. Free, E. E., Harpers 158; pp 338-344 Feb. 1929.

the level of the Knoxville streets.

The surveys conducted by the University of Tennessee revealed that Knoxville[9] has a high soot fall as compared to that of other cities of the United States. These soot-fall studies were carried out under the direction of Dr. J. H. Robertson of the Chemistry Department of the University of Tennessee[10], and found to be 262.17 tons per square mile per year, for the year 1930 This large amount of soot in the air screens out much of the ultra-violet rays coming from the sun. Shrader, Coblentz, and Korff[11], of the Department of Health of Baltimore, Maryland experimented with three different samples of air which had been contaminated with"fullers earth", street sweepings and lamp black. They found that fifty percent more of the ultra-violet light was absorbed by the lamp black, which represented city smoke, than by street

9. Quinn, Cooper, Burton, Calhoun, Burnett, Bachelor's Thesis, The Univ. of Tenn., 1927-1930.

10. Dept. of Chem. "Smoke Surveys" U. of Tenn. 1927-1930.

11. Shrader, J. H., Coblentz, M. H. and Korff, F. A., Am. J. Pub. Health, 19, 717, 1929.

sweepings. This shows that smoke absorbs more ultra-violet rays than any other type of pollution of the air.

In Baltimore, Chicago, and Knoxville tests have been made on the intensity of the ultra-violet radiation in the center of the city and at a point some miles away from the center of the city where the air is relatively free from pollution.

In Baltimore[12] there was fifty per cent (50%) more intensity in the country than there was in the city, and the amount of smoke solids in the country was approximately six times less than in the city.

In Chicago[13] the intensity of the ultra-violet radiation at the "clear points" tested was found to; be fifty one per cent (51%) more in summer and fourty three per cent (43%) more in winter than that of the "smoky" districts.

In Knoxville[14] according to Susong, an average of twenty-six (26) percent of the total light rays which decompose oxalic acid are screened out by

12. Shrader, J. H., Coblentz, M. H., and Korff, F. A. Am. J. Pub. Health 19, 717, 1929.

13. Tonney, F. O., Somers, P. P. and Marti, W. C. J. Prev. Med. 2, 493, 1928.

14. Susong, Suella, Master's Thesis, University of Tennessee, 1931.

smoke and other air pollutions at noon in Knoxville, in April and an average of thirty-six (36) per cent of the antirachitic rays are lost at noon in Knoxville in April due to smoke and other pollutions.

3. Fog.

Being next to the river there is necessarily some fog in Knoxville at various seasons in the year. This fog is especially noticable in August and September and during most of the winter months. This fog screens out the rays of the sun during the early hours of the morning, but is usually dispelled by ten (10) o'clock A. M. No tests have been run to determine how much of the ultra-violet rays are lost because of this factor; but this fog must be one of the main reasons for the low percentage of possible sunshine in Knoxville during the winter months.

C. Purpose of This Study.

The aim of this study is to measure the relative intensity of ultra-violet radiation on the solarium of the Knoxville Y. M. C. A. at 605 W. Clinch Avenue. This point is almost in the business district and while there is much contamination in the air due to smoke from a railway yard, two laundries and from heating plants, the intensity of the ultra-violet

radiation is fairly large.

This study will also include the effect of the temperature and humidity upon the ultraviolet radiation and also the comparative intensity at various hours of the day, and the ratio of the intensity of the ultra-violet rays to the total intensity of the rays of the sun.

II. Work of Previous Investigators at the University of Tennessee.

Various investigations have been carried out in this field of chemistry by investigators at the University of Tennessee. The Smoke Survey was carried on by Quinn, Cooper, Burton, Calhoun and Burnett from the year 1927 to the year 1930; and Albert Bacon of the Dept. of Chem. of the University made a smoke survey for the city in the year 1929. This work together with the Master's Thesis by Suella Susong on the ratio of the intensity of the ultra-violet radiation in Knoxville and a near-by rural community constitute the work done in this field up to the presant time.

The first investigation measured quantitatively

the annual soot-fall per square mile in Knoxville.

III. Methods of Meausring the Intensity of Ultra-violet Radiation.

A. Biological Method.

This method is one of the oldest means of determining the intensity of the ultra-violet Radiation. It consists of placing rats or guinea pigs that have been feed on a ricket-producing diet in the sunlight and then studying the degree to which they are protected from rickets.

This method is unsatisfactory because the results are largely dependent upon other factors that the ultraviolet radiation. This method also requires time and money to obtain enough information to be of any value.

B. Physical Methods.

1. Photo-electric cell.

The most exact method of measuring the ultra-violet radiation makes use of the photo-electric cell. There has been developed recently one which will measure directly the ultra-violet radiation. This meter is described in detail by its inventor,

Dr. H. C. Rentschler[1]. It will read directly the intensity as an ordinary electric meter, but the units are not fixed and it is therefore not generally used.

While this method is exact, it is objectionably expensive and requires a skilled technique.

2. Thermopile.

This method is exact but it also has the disavantage of requiring expensive apparatus and skilled technique. It is best in this case to use light of a narrow range of wave lengths and of measured intensity. The intensity of the radiation is measuredwith a thermopile, which consists of a series of junctions of unlike metals, converted to a galuanometer. Alternate junctions are heated by exposure to the radiation and the galvanometer deflections are proportional to the intensity of radiation. The junctions are covered with blackened metal strips of very low heat capacity, which converts radiation of all wave lengths into heat. The galvanometer readings may be converted into ergs of radiation per second per square millimeter striking the thermopile,

1. Measuring Ultra-violet Rays, Sci. Am. 143, p, 389, N' 1930.

by calibrating with a standard carbon filament lamp from the United States Bureau of Standards.

By use of a proper filter the intensity of the desired wave length can be measured. The light is passed through this filter and the undesired wave lengths are filtered out and the intensity of the wave length which is to be measured can be determined by allowing it to strike on the junction of the thermopile and thus obtain a reading on the galvanometer which is then converted into ergs or calories. In order to get very accurate results it is best to use monochromatic light, because the thermopile measures the total effect of all radiation while the absorption process may be restricted to only a portion of the wave lengths.

C. Actinometers.

While the measurements of ultra-violet radiation can be made most accurately with a thermopile, it may be measured by the amount of photochemical reaction produced in an actinometer.

1. Theory of actinometers.

Certain substances when exposed to light, either artifical or real, will produce a photochemical change.

The ones discussed here are zinc sulphide, methyl blue, and oxalic acid sensitized with uranyl nitrate or sulphate. An instrument for measuring light intensity by determining the amount of chemical change produced by the light is called an actinometer.

Quoting from Getman and Daniels,[2]

> One of the earliest reactions used for photochemical reactions was the combination of hydrogen and chlorine in the presence of light to give hydrochloric acid. Bunsen and Roscoe in 1857 used such an actinometer. The gases were produced in equimolecular proportions by electrolyzing hydrochloric acid, and the shrinkage in volume on illumination was caused by the photochemical formation of hydrochloric acid and its solution in water. The rate of decrease in volume is proportional to the intensity of light, and the actinometer is sensitive to small amounts of visible or ultraviolet light. If the light is intense, an explosion may occur.
>
> In the mecuric oxalate actinometer, a mixture of mecuric chloride and oxalic acid is exposed to ultraviolet light and the amount of evolution of carbon monoxide and carbon dioxide is proportional to the intensity of light. Both of these actinometers involve chain reactions in which the chemical effect of the light is greatly magnified.
>
> The best actinometer is that employing uranyl oxalate. The results of early investigators did not check, but the recent research of Leighton and Forshee

2. Getman, F. H. and Daniels, F. "Outlines of Theoretical Chemistry", 5th ed. p. 548, 1931.

3. Forshee and Leighton, J. Am. Chem. Soc. 52, 3139, 1930.

> constitutes perhaps the most exact photochemical investigation yet described. Although the quantum efficiency changes slightly with the wave length, it may be assumed that in a solution M/100 in uranyl sulphate and M/20 in oxalic acid that 0.57 molecule of oxalic acid is decomposed for each quantum of light adsorbed between the wave lengths of 254 and 435 millimicrons. In other words each mol of oxalic acid decomposed is equivalent to 1.75 einstein or to 166,000 calories assuming an average wave length of 300 millimicrons.

From this may be gained an insight as to the importance of actinometers or the use of actinometers in measuring photochemical reactions.

This method of actinometers is easy to manipulate and inexpensive in cost, and it is the method used in this study. The results can easily be correlated with respect to some standard. Tonney[4] suggests the comparison of it with the erythema reaction and Clark[5] suggests the comparison found by using samples under quartz and under glass.

2. Zinc Sulphide.

A method used by Clark[5] of John Hopkins University in a determination of the ultra-violet radiation in Baltimore depends upon the fact that zinc sulphide will darken when exposed to sunlight. The zinc sulphide

4. Tonney, F. O., Somers, P. P., and Marti, M. C., J. Prev. Med. 2, 493, 1928.

5. Clark, J. H., Am. J. Hygiene, 9, 646, 1929.

is ground to a paste and then exposed under quartz to the sunlight.

The color is judged by comparison with a set of standard grey paper chats or a Macbeth Illuminometer. According to Clark[6] one-sixth of the darkening is due to light rays shorter than three hundred and ten (310) millimicrons. The unit used is taken as the time required to darken the paste to a fifty (50) percent reflection factor. It is called one (1) zinc sulphide unit of ultra-violte energy.

3. Fading of color (Methyl Blue)

Another chemical method involving a photochemical reaction was devised by Webster, Hill and Eidenow. This method makes use of the fact that ultra-violet light will cause the fading of color. The most rapid fading is due as explained by Gillam and Morton[7] to the rays of light shorter than two hundred and seventy five (275) millimicrons. The light rays of lenghts up to three hundred and twenty five also cause a certain degree of fading.

6. Clark, J. H. Am. J. Hygiene, 9, 646, 1929.

7. Shrader, J. H., Coblentz, M. M. and Korff, F. A., Am Jov. Pub. Health., 19, 717, 1929.

4. Decompostion of oxalic acid.

This method uses a solution of oxalic acid sensitized with some radio active salt such as uranyl nitrate or uranyl sulphate. Upon exposure to light either real or artifical this oxalic acid decomposes. This method was sued originally by Anderson and Robinson[8] for measuring the intensity of artifical light. It was later modified by Tonney[9] who used it for measuring sunlight.

The manner in which the ultra-violet radiation is measured by this method is as follows: A solution of oxalic acid of known strength is sensitized with some radioactive salt. This solution is exposed to sunlight for a certain length of time and then titrated against a solution of potassium permanganate of known strength. The reaction is represented by the equation:

$$5\ H_2C_2O_4 + 2KMnO_4 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O$$

8. Anderson, W. T., and Robinson, F. W. , J. Am Chem. Soc. 48, 718, 1925.

9. Tonney, F. O. Somers, P. P. and Marti, W. C., J. Pref. Med. 2. 493, 1928

IV. Experimental

A. Apparatus

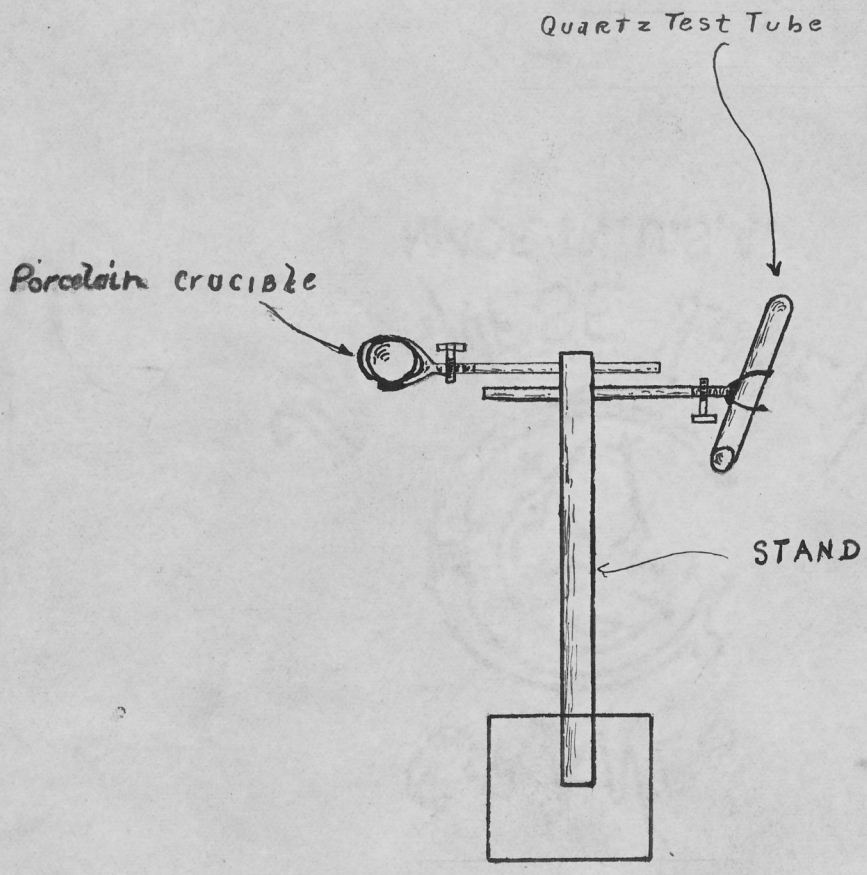


Figure I. Apparatus for Measurament of
Ultra-violet Radiation

B. Procedure:

The method employed in this study depends upon the fact that a solution of oxalic acid, which has been sensitized with some radio active salt such as uranyl nitrate or uranyl sulphate will decompose upon exposure to sunlight or to artifical light. This method was first used by Anderson and Robinson[1] for measuring the artifical light and was later modified by Tonney[2] who used it to measure sunlight.

According to Getman and Daniels[3] the equation for this reaction may be written as follows:

$$C_2H_2O_4 + \text{Ultra-violet} = CO + CO_2 + H_2O$$

After this reaction has taken place for the length of time that is desired it is then covered with a dark cloth and taken to the laboratory, where five (5) cc of sulphuric acid is added and it is then heated just to the boiling point, precautions being taken while heating to keep as much light away from the solutions as possible. It is then titrated

1. Anderson, W. T. and Robinson, F. W., J. Am. Chem. Soc. 48, 718, 1925.
2. Tonney, F. O.,Somers, P. P. and Marti, W. C., J. Prev. Med. 2, 493, 1928.
3. Getman, F. H. and Daniels, F. "Outling of Theorical Chemistry", 5th ed. p. 548, 1931.

against a solution of potassium permanganate whose strength has just been checked against another sample of the same oxalic acid solution which has not been exposed to light. From the data thus obtained the amount of the oxalic acid which has been decomposed can be determined.

In this determination exactly five and three hundredths (5.03) grams of uranyl nitrate and six and three tenths (6.30) grams of oxalic acid were completely dissolved in one liter of pure distilled water. This solution was then placed in a dark colored bottle and set away for twenty four (24) hours. To another liter of pure distilled water three and sixteen hundredths (3.16) grams of potassium permaganate was dissolved, and this solution allowed to stand for twenty four (24) hours.

These two solutions were then taken and titrated against each other until the end reaction, denoted by a slightly violet or pink color, appeared. It was found that when ten cubic centimeters (10 c.c.) of the oxalic and uranyl nitrate solution with about one cubic centimeter (1 c.c.) of sulphuric acid was diluted to one hundred cubic centimeters (100 c.c.), heated just to the boiling and titrated immediately for an end point with the potassium permanganate sol-

ution that exactly eleven and eight tenths cubic centimeters (11.8 c.c.) were required before a pink color that would not fade within one (1) minute appeared. This reaction was checked several times and before every titration to determine if the value was constant and it was found that it was correct. From this data one finds that one (1) cubic centimeter of potassium permanganate solution was equivalent to exactly five thousand three hundred and thirty nine millionths grams (0.005339) of oxalic acid. This value was checked before each determination so as to avoid error through change in concentration of the permanganate solution.

In this investigation the solutions of oxalic acid were taken in a covered bottle to the point where it was to be exposed to sunlight and exactly ten cubic centimeters (10 c.c.) for the hourly tests and twenty cubic centimeters (20) for daily tests taken out with a covered pipette and placed in a white porcelain crucible covered around the sides with black tar tape or in a fused quartz test tube covered with black shoe polish around the sides so that the rays of the sun would strike as nearly perpendicular as possible. Over the white crucibles was placed a piece of ordinary window glass in some cases and in others the solution was left uncovered. These test solutions were left in the rays of the sun for the

lenght of time desired and then washed into a one hundred and twenty five cubic centimeter (125 c.c.) flask with seventy five (75 c.c.) cubic centimeters of distilled water. These were covered with a dark cloth and taken into the laboratory and titrated against the potassium permanganate solution. Solutions that were compared with each other were exposed to the sunlight as nearly as possible for the same lenght of time.

In the tests run on the mercury vapor arc lamp manufactured by the Burdick Company of Milton, Wisconsin, the above procedure was used in the first case with the solutions in the porcelain crucibles. The results showed that so little oxalic acid had been decpmposed for the six (6) minutes that the solutions were exposed, that a similar test was again run. This time quartz test tubes were used in addition to the crucibles and twenty five cubic centimeters (25 c.c.) of solutions were used and the time of exposure increased to twelve (12) minutes, but the results were still negative.

Tests were run on these solutions at various hours separately and also collectively for the hours between seven (7) o'clock A. M. until four (4) o'clock P. M. on the solarium of the Knoxville Y. M. C. A.

B. Tabulation of Results.

The results of these tests are tabulated in Tables I, II, and III.

Graph I shows the relation between the milligrams of oxalic acid decomposed and the hours of the day.

Figure I shows a sketch of the apparatus used.

TABLE II.

Amount in Milligrams of Oxalic Acid Decomposed Under Quartz and Glass for various hours and under varying conditions of weather.

May	Hours	Milligrams of oxalic decomposed under quartz	Milligrams under glass	Difference due to u-v	Condition of weather*
7th	1-2PM	34.7	32.57	2.13	Relative Humidity 7AM Noon 7PM 84 38 42 Hourly temperature 7AM-5PM 66-70-75-78-80-83-86
7th	2-3PM	27.7	22.88	4.82	
7th	7-4PM	122.263	115.52	6.743	88-86-88-86
8th	12:30 4:30PM	109.62	95.34	14.28	Relative Humidity 7AM Noon 7PM 44 20 26 Hourly temperature 7AM-5PM 68-70-73-75-77-79-82
8th	7AM-4PM	136.81	118.57	18.24	84-85-86-84
9th	7AM 4PM	128.75	119.23	9.52	Relative Humidity 7AM Noon 7PM 58 38 47 Hourly temperature 64-70-77-80-81-83-85 87-86-87-86
9th	1:30 2:30PM	22.17	20.96	1.21	
9th	1:30 3:30PM	29.88	25.41	4.47	
10th	10-11 AM	31.61	28.78	2.83	Relative Humidity 7AM Noon 7PM 54 46 90 Hourly temperature 69-72-76-78-79-81-83 86-85-86-70
10th	11-12 AM	39.34	35.65	3.69	
10th	1-2PM	74.4	51.27	23.13	
12th	11:30 12:30	43.78	35.67	8.11	Relative Humidity 7AM Noon 7PM 65-22 44 Hourly temperature 58-64-69-74-74-75-76 78-80-79-76
12th	1-2PM	34.23	31,92	2.31	

*U. S. Weather Bureau Report, 1934.

TABLE II.

Milligrams of Oxalic Acid Decomposed by Direct Exposure to Sunlight and ratio in percentage between this and amount. decomposed by u-v for same hours.

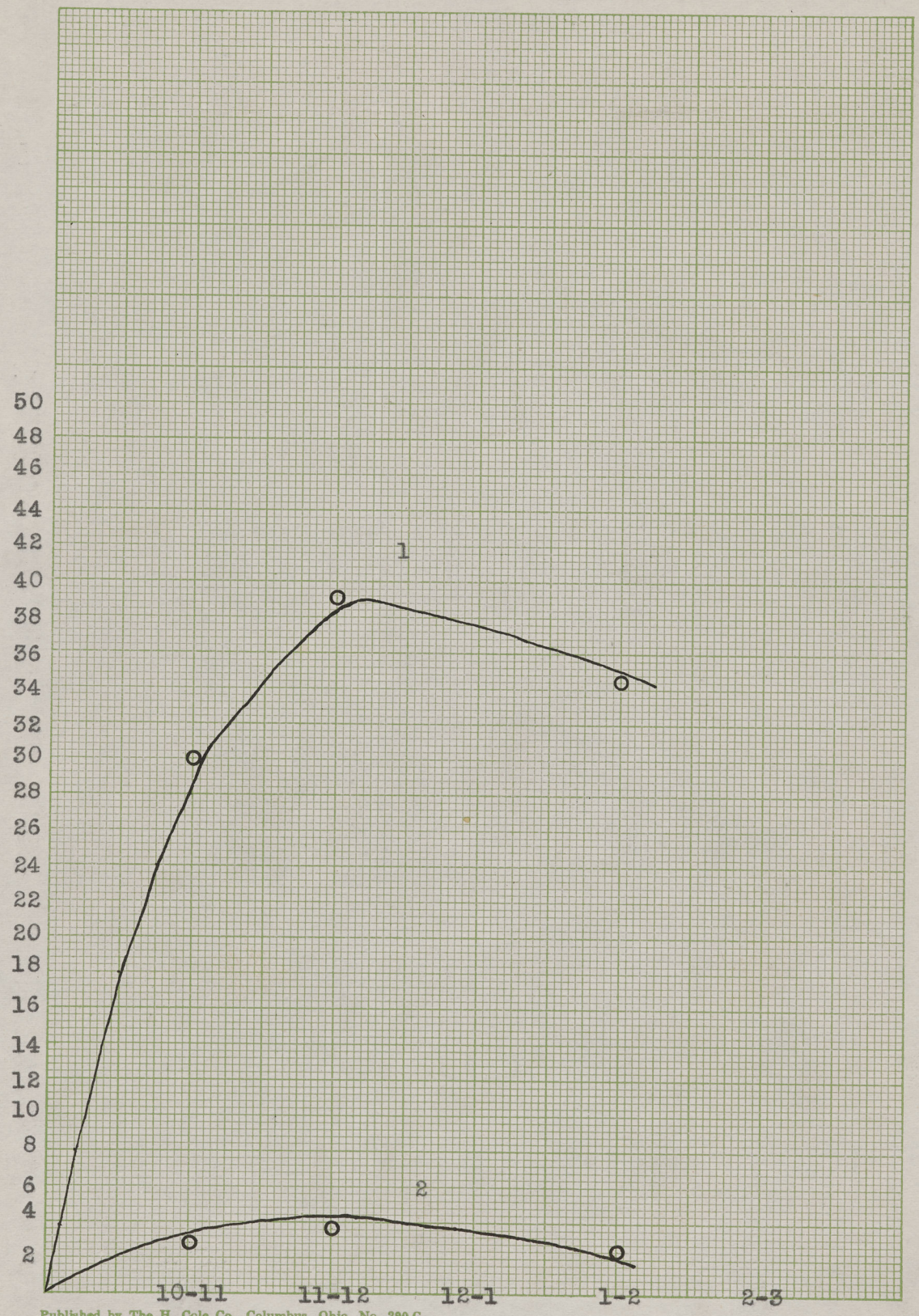
May	Hours	Milligrams of oxalic decomposed nocover	due to u-v	Ratio in % between total decomposition which is due to;ultra-violet rays.
10th	10-11 A. M	37.94	2.83	7.45
10th	11-12 Am M.	40.64	3.69	9.10
10th	1-2 P. M.	55.86	23.13	41.40
12th	11:30 AM 12:30 P.M.	45.23	8.11	17.93
12th	1-2 P. M.	35.59	2.31	6.49

TABLE III.

Results of Test on Mercury-vapor, Arc Lamp

Decomposition in grams.

	Quartz test tube content of oxalic	Quartz test tube	Quartz crystal	Under Glass	No Cover
Before exposure	.1575	.1575	.1575	.1575	.1575
After exposure	.1575	.1575	.1575	.1573	.15693
Difference	.00000	.000000	.00000	.00000	.00057



Published by The H. Cole Co., Columbus, Ohio, No. 290 G.

Graph. 1

1. Milligrams decomposed under quartz.
2. Milligrams decomposed by ultra-violet rays.

V. Summary and Conclusion.

This work was done on the solarium of the Central Y. M. C. A. at 605 West Clinch Avenue in Knoxville. This is a point almost in the center of the city. It is only three blocks from the main street, and is only two blocks from the Louisville and Nashville railroad yards. It can be seen from this description that the factors which would effect the results would likely be due to smoke or other air pollutions. While these tests were being run, however, the air was fairly clear in almost every case and the rays of the sun were fairly intense. The maximum of sunlight was also obtained (that is it was not screened out by clouds). On May the twelth there was some but the effect that this produced could not be determined.

The most likely cause of error would be found in the equiptment used. While the quartz test tubes were fairly transparent, they were not as clear as they should have been and some of the ultra-violet radiation may have been adsorbed in its passage through these tubes.

In some cases where a small amount of test solution was used (10 c.c.) there could arise a considerable error due to losing or spilling of the solution. If only one half of one ($\frac{1}{2}$) cubic centimeter was lost and only twenty cubic centimeters were present, the percentage of error would be approximately two and one

half ($2\frac{1}{2}$) per cent.

As the data from the Weather Bureau shows there is a large variation in the relative humidity during the hours of seven (7) A. M. and five (5) P. M. and this factor along with the wider variation of the total percentage of possible sunshine no doubt have a decided effect upon the results.

Table I shows that when the humidity was low and the temperature high, the intensity of the ultra-violet radiation was greatest. This point was generally reached between the hours of eleven (11) A. M. and one (1) P. M. The ratio in per cent between the milligrams decomposed when the oxalic acid solution was exposed directly to the sun and that decomposition due to ultra-violet radiation, had a maximum of fourty one and four tenths per cent (41.4%) and a mimimum of six and forty six hundredths per cent (6.46%). The highest value was probably in error as the average of the rest is ten and twenty four hundredths (10.24%) per cent.

The tests run on the mercury vapor arc lamp manufactured by the Burdick Company of Milton, Wisconsin gave negative results. The first test was made using a quartz crystal, glass, and no cover at all over three different solutions. The ratio of

ultra-violet radiation in this lamp to that of summer sunshine is ten to one (10:1) or six minutes under this lamp is equivalent to one hour of exposure to summer sun. These solutions were allowed to stand under the rays of this machine for six (6) minutes and then taken directly to the laboratory and titrated with the standard potassium permanganate solution. The results showed such a small amount of decompostion in every case that it was thought that an error was made and another test run on this machine. In this test the quartz crystal, two quartz test tubes, and one glass covered and one uncovered solutions were exposed for twelve (12) minutes. Those solutions were again tested very carefully and the results showed that only fifty seven hundredths (0.57) of a milligram had been decomposed in the case of the solution with no cover and none had been decomposed in either of the other solutions.

Taking a summary of these results one finds that the greatest intensity of ultra-violet radiation is reached between the hours of eleven (11) A. M. and one (1) P. M. The intensity is also greater when the relative humidity is low and the temperature is high. The pollution of the air is another factor in determining

the intensity of the ultra-violet radiation at this point. While there was no fog on the days when these tests were run no statement can be made concerning its effect on the intensity of the radiation of the ultra-violet rays.

The results on the mercury vapor arc lamp tested were negative for reasons which the present study failed to show. The only fact that can be offered for this result is one from Getman and Daniels[1] which says:

> In the mercury-vapor arc lamp ozone is produced from oxygen. Ozone is synthesized by the short ultra-violet rays and decomposed by the longer ultra-violet rays (2800). The actual yield of ozone depends then on the ratio of the intensities in these two regions, and this ratio depends on accidental conditions such as the age and rate of cooling of the lamp. Experimental checks under uncontrolled conditions of this type are not to be expected.

The odor of ozone could be easily detected while the tests described in this study were being run so it seems as if some ultra-violet rays must have been radiated. Just why no decomposition resulted can not be explained, bacuase enough tests were not run to enable one to make an authoritive statement.

This study undoubtedly carries a number of sources of error as far as ultra-violet radiation is concerned, which could not be eliminated. The whole study was based

1. Getman, F. H. and Daniels, F. "Outline of Theoretical Chemistry", 5th ed. pl 548, 1931.

upon the assumption that the ultra-violet rays decompose the oxalic acid without a chain raction. If this assumption is false then the results of this study would carry another large source of error.

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APPROVAL

The foregoing thesis is hereby approved as a creditable study of an engineering subject, carried out and presented in a manner sufficiently satisfactory to warrant its acceptance as a prerequisite to the degree for which it has been submitted. It is to be understood that by this approval the undersigned does not necessarily endorse or approve any statements made, opinions expressed, or conclusions drawn therein, but approves the thesis only for the purpose for which it is submitted.

Name Judson H. Robertson

Title Professor of Chemistry