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AN INVESTIGATION OF THE THERMO- AND ACTINO-
ELECTRIC PROPERTIES OF MOLYBDENITE

The thesis presented to the
Graduate Faculty of the Kansas
State Teachers' College, Hays,
in partial fulfillment of the
requirements for the degree of
master of Science.

by
William
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K. S. T. C.

Approved by

May 28, 1931

Harvey A. Finney



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INTRODUCTION

Considerable work has been done on various mineral substances and chemical compounds within recent years to ascertain, if possible, whether the substance possessed any degree of photo- or thermo- sensitivity; and, to determine the characteristics of these responses. Among the most prominent substances which have been tested are selenium, bismuth, antimony, hematite, stibnite, and molybdenite. In carrying on such tests the following phases of photo-sensitivity must be considered:

1. The thermo-electric, or Seebeck, effect¹ which designates the e.m.f. generated when the junction of two unlike substances is heated by thermal conduction or by thermal radiations.

2. The actino-electric effect² which designates the e.m.f. generated in a crystal when exposed to a source of light. A characteristic of the actino-electric effect is that it disappears immediately upon extinguishing the light.

3. The photo-resistant effect³ which designates the change in resistance that a substance exhibits when subjected to an outside e.m.f. and exposed to light.

1. Starling, S. G. Electricity and Magnetism. P. 203.

2. Coblenz, W. W. Some New Thermoelectric and Actino-electric Properties of Molybdenite. B. S. Bul. No. 486, p. 377. 1924.

3. Loc. cit.

It was the purpose of this investigation to summarize the phenomena that have occurred within samples of molybdenite under the following conditions:

1. The effect of light upon the samples, or the actino-electric effect.
2. The effect of light and heat upon the samples, or the combined actino- and thermoelectric effects.
3. The effect of heat upon the samples, or the thermo-electric effect.
4. The effect of an outside e.m.f. upon the samples when in the dark.
5. The effect of light in addition to an outside e.m.f. upon the resistance of the samples, or the photo-resistant effect.
6. The effect of light, heat, and an outside e.m.f. upon the resistance of the samples, or the combined photo-resistant and thermo-electric effects.
7. The effect of heat only, with an outside e.m.f. upon the resistance of the samples.

HISTORICAL DATA

Koenigsberger and Weiss ⁴ found the thermo-electric power of molybdenite against iron to be near 750 mv at 23° C. Coblenz ⁵ found the thermo-electric power of molybdenite against copper to range from 700 to -1,000 mv at 25° C. The thermo-electric power was considered positive when the current flowed from the hot to the cold junction.

Coblenz ⁶ explored the actino-electric effect of different areas (0.2 mm by 0.2 mm) of molybdenite and discovered that different parts of a sample may show different magnitudes of sensitivity; in fact, one spot may show a positive current and another spot a negative current. Furthermore, these locations may be as close as 0.5 cm to each other. Coblenz ⁷ found on dehydrating the samples, by baking for several hours, and then cooling that the actino-electric sensitivity was apparently unaffected.

-
4. Koenigsberger and Weiss. Ann. der Phys. v. 32, p. 10. 1911.
5. Coblenz, W. W. Some New Thermoelectric and Actino-electric Properties of Molybdenite. B. S. Bul. No. 486, p. 389. 1924.
6. Ibid. p. 391-95.
7. Ibid. p. 395-96

Coblentz ⁸ also found that the deflection of the galvanometer may be positive (or negative) depending upon the wave length of the radiations. Moreover the lowering of the temperature shifts the maximum of the actino-electric reaction towards the low wave lengths but has no marked effect on the intrinsic value.

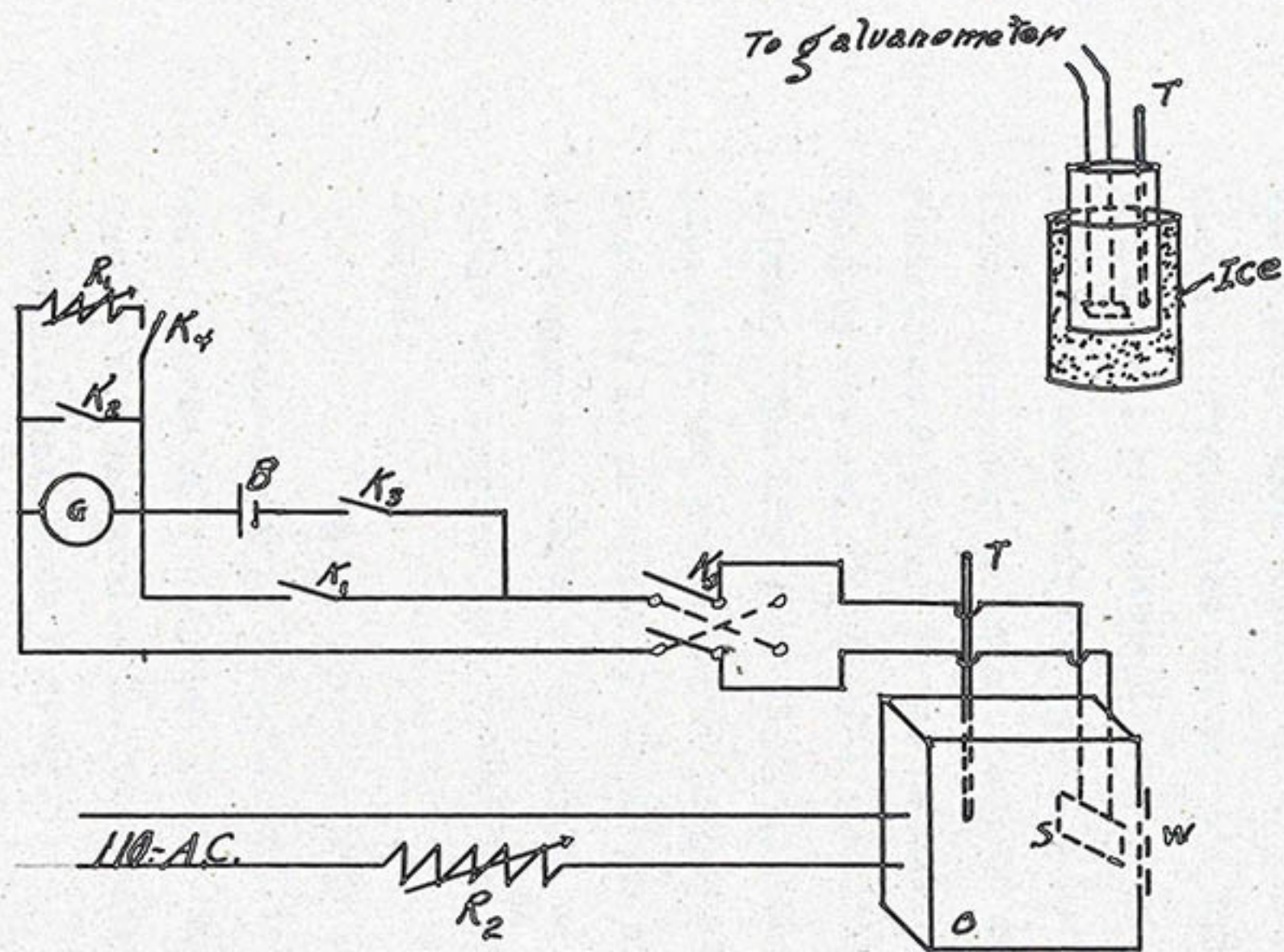
Coblentz ⁹ tested the photo-resistant effect of molybdenite after the samples had been heated for several hours. Raising the temperature to 100° C and testing while hot showed a decreased photo-resistant effect, but on cooling they resumed their original resistances. If the samples were heated to 500° C, cooled and then tested, there was no apparent effect, but on heating to a glow the photo-resistant effect was permanently destroyed. At -178° C ¹⁰ the resistance of the samples was 150 to 2,000 times as great as it was at room temperature.

8. Ibid. p. 407-16.
9. Coblentz, W. W. Various Photo-electric Investigations. B. S. Bul. No. 462, p. 537-38
10. Coblentz, W. W. Some Optical and Photo-electric Properties of Molybdenite. B. S. Bul. No. 333, p. 146. 1919.

APPARATUS AND METHODS OF PROCEDURE

The samples of molybdenite to be tested were about 2.5 cm long, 1 cm wide, and 0.1 cm in thickness, and were mounted on pieces of sheet asbestos (4 cm by 6 cm in size), being held in place by clips made of spring brass which were fixed to the asbestos by small stove bolts. Copper leads were then fastened to the clips. An oven in which the samples were subsequently heated was made by wrapping an electrical heating element around a tin box and covering it with a layer of wet asbestos cement. The heating element was insulated from the tin box by asbestos strips. After the asbestos had dried the element was placed in a larger tin box and the vacant space filled with dry asbestos cement. Leads for electrical connections were insulated from the tin by small glass tubes. The oven door contained a window 4 cm in diameter which could be covered when it was necessary to exclude the light. The glass was capable of transmitting ultra-violet light.

The source of light was a 100-watt frosted bulb operating on a 220-volt alternating current. The figure of merit of the galvanometer was found to be 2.56 times 10^{-10} amperes per millimeter deflection when the scale was one meter distant. Fig. 1 shows a sketch of the apparatus. O represents the oven, T the thermometer, S the sample of molybdenite, and W the window. The source of light was at L.



* L

Fig. 1 Apparatus

The order in which the different effects were tested is the same order as listed above. When testing the thermo-electric effect the window was covered to exclude the light. When testing the actino-electric and thermo-electric effects the battery B (0.8 volts) was cut from the circuit by opening K_3 and closing K_1 . To test the photo-resistant effect K_3 was closed and K_1 open. At times it was necessary to shunt part of the current through the resistance R_1 , then it was necessary to calculate the deflection by the law of parallel circuits. K_5 is a reversing switch. The source of light was 50 cm distant for all samples with the exception of sample 14 in which case the light was only 10 cm distant. Readings were taken every 25 degrees of temperature between the range of 25° and 300° centigrade. Later the samples were tested for all effects at ice temperatures.

The actino-electric and combined actino-electric and thermo-electric effects were to be tested using X-rays as a source of light, but it was impossible, with the apparatus that was available, to obtain rays that were steady enough to make such a study.

DISCUSSION OF RESULTS

Sample 2

This sample was slightly actino-electric active at room temperature showing a galvanometer deflection of 5.4 cm. The combined actino- and thermo-effects gave a deflection ranging from 4.5 cm at 25° to 830 cm at 300°, while the thermo-effect alone gave a deflection ranging from 0.5 cm at 25° to 509 cm at 300°. This difference would indicate that the actino-effect was affected by the application of heat. Figs. 2 and 3 depict these results. At ice temperature the actino-effect gave a deflection of 2 cm while the thermo-effect gave no response.

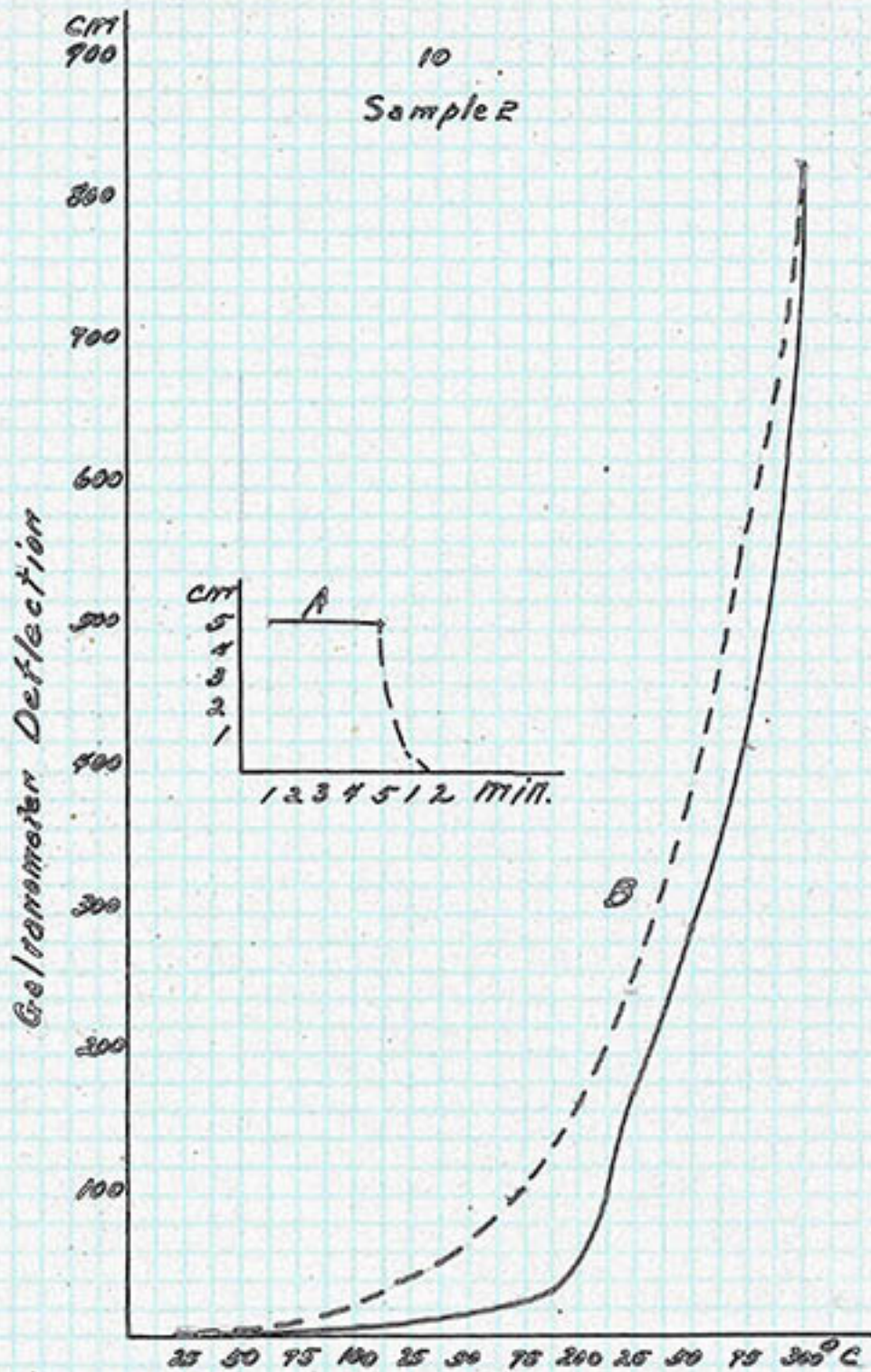
With e.m.f. in series with the sample there was no reaction when light was applied at room temperature but at 300° there was a deflection of approximately 203,800 cm. At room temperature and with the e.m.f. in series, the sample being in the dark, a deflection of 1,300 cm was noted and at 300° the deflection was 200,800 cm. These responses are shown by Figs. 4 and 5. Upon reducing the temperature to that of ice it was found that the photo-resistant effect was not noticeably altered.

Sample 2

Time Galvanometer Deflection		Time Galvanometer Deflection	
1 min	5.4 cm		
2	5.4		
3	5.4	2 min	0.1 cm
4	5.4	1	1.2
5	5.4	Recovery Read Up	

Actino- plus thermo- electric effects

Temp. °C	Galvanometer Deflection In Centimeters			Galvanometer Deflection In Centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	4.5	4.5	4.5	5.4	5.5	5.45
50	4.9	4.6	4.75	6.4	6.3	6.35
75	4.9	4.9	4.9	10.1	10.1	10.1
100	4.9	4.9	4.9	20.0	20.0	20.0
125	8.4	8.2	8.3	44.0	44.0	44.0
150	16.3	16.8	16.55	68.0	68.0	68.0
175	23.0	27.5	27.75	98.0	106.0	102.0
200	44.4	45.0	44.7	180.0	170.0	175.0
225	175.0	170.0	172.5	238.0	250.0	244.0
250	275.0	288.0	281.5	396.0	382.0	389.0
275	420.0	417.0	418.5	560.0	530.0	570.0
300	820.0	840.0	830.0	Recovery Read Up		



A = Actino-effect

B = Actino- + Thermo-effects.

Fig. 2.

Sample 2

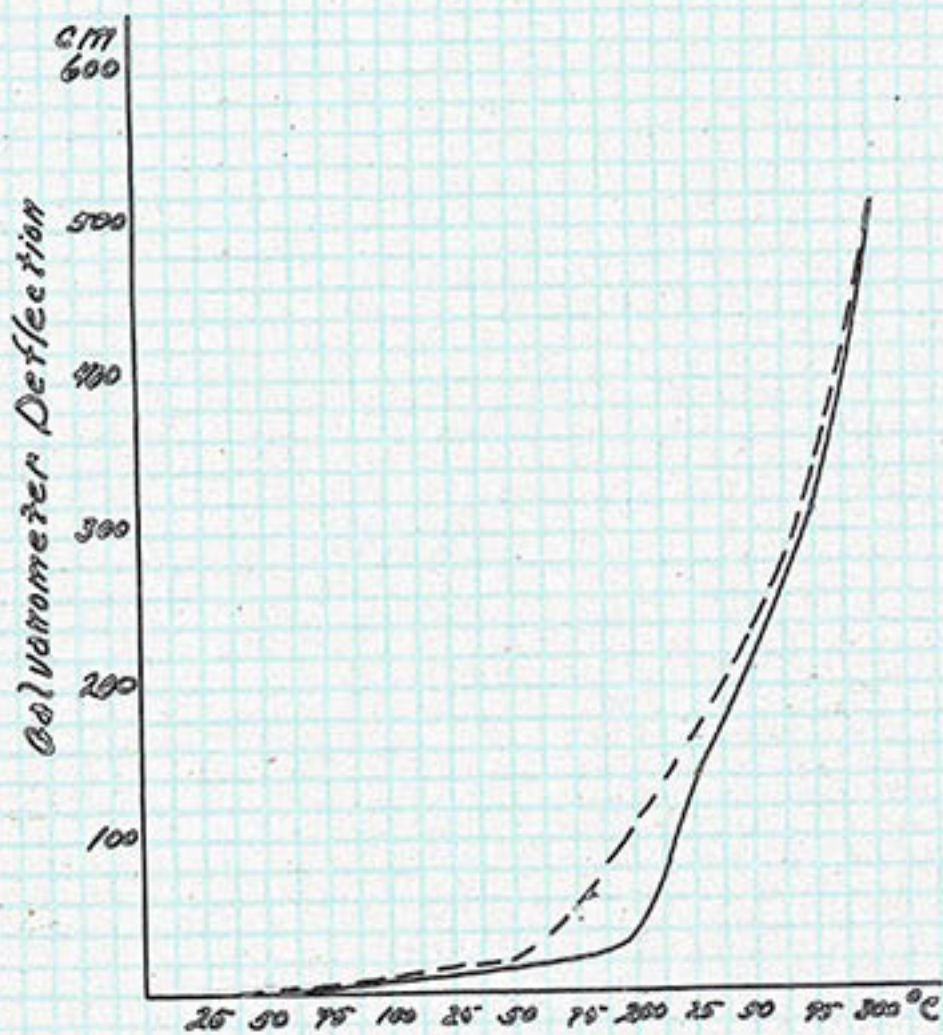


Thermo-electric effect

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	0.5	0.5	0.5	0.6	0.5	0.55
50	2.3	2.2	2.25	2.25	2.25	2.25
75	4.4	4.5	4.45	5.3	5.6	5.7
100	8.1	7.9	8.0	8.2	8.8	8.5
125	10.5	10.7	10.6	12.4	11.2	11.8
150	14.7	14.5	14.6	13.5	14.4	13.95
175	20.7	20.9	20.8	62.5	42.5	52.5
200	32.6	32.0	32.3	102.0	105.0	103.5
225	142.0	140.0	141.0	170.0	155.0	162.5
250	212.0	210.0	211.0	230.0	237.0	233.5
275	312.0	316.0	314.0	325.0	305.0	315.0
300	517.0	502.0	509.0	Recovery Read Up		

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Sample 2



Thermo-effect

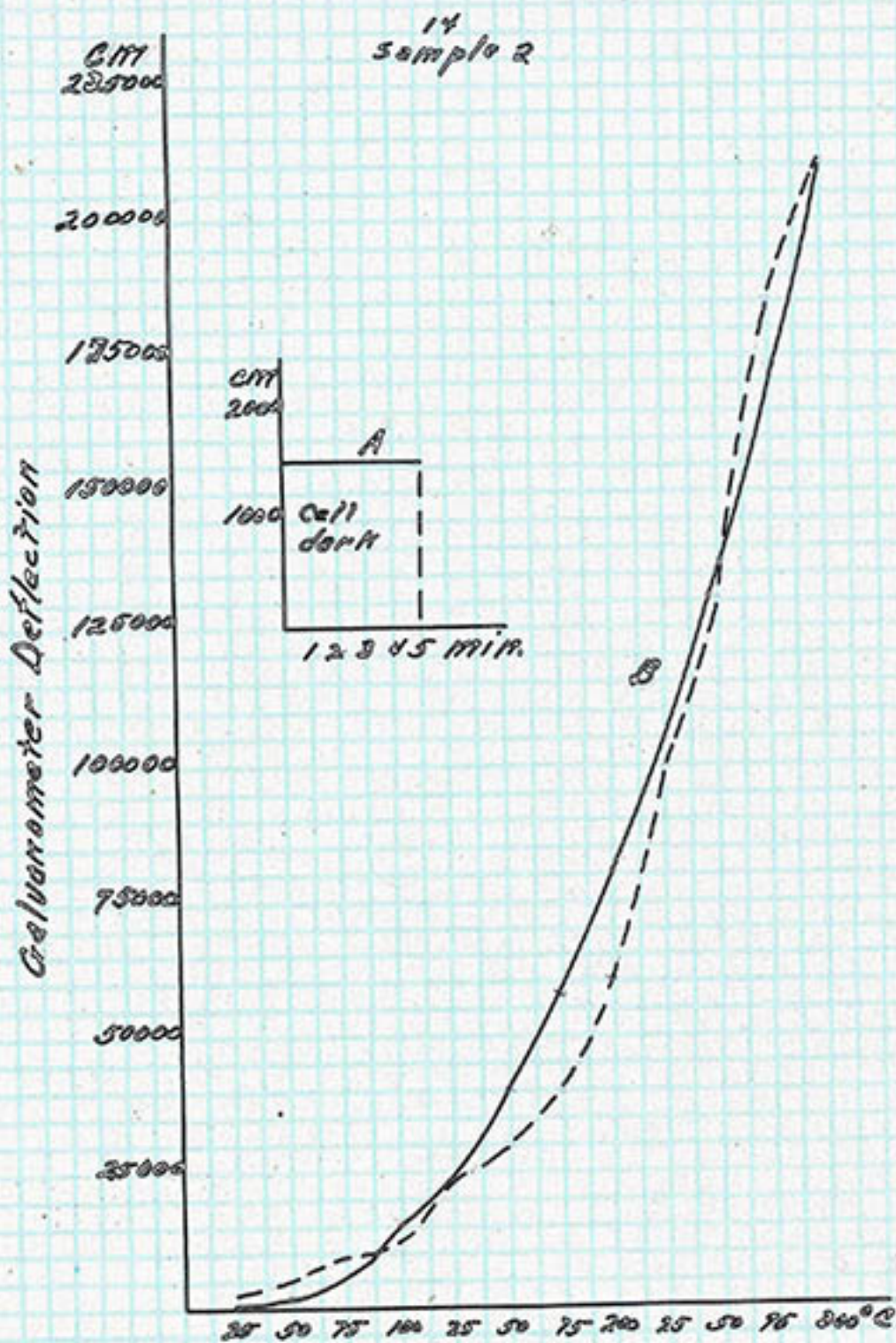
Fig. 3

Sample 2

This sample gave a deflection of 1,560 cm at room temperature when in the dark and with the e.m.f. in series. It was not photo-resistant at room temperature.

The effect of e.m.f., light, and heat.

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	1300	1300	1300			
25	1560	1560	1560	3600	3600	3600
50	2520	2520	2520	5140	5140	5140
75	5620	5620	5620	8935	8935	8935
100	15600	15600	15600	13765	13765	13765
125	23700	23400	23550	22400	25200	23800
150	38400	39200	38800	30400	30400	30400
175	56800	56800	56800	36800	37600	37200
200	80800	80800	80800	60800	60800	60800
225	103200	104000	103600	88000	90400	89200
250	136000	136000	136000	132800	128800	130800
275	176000	171200	173000	184800	184800	184800
300	208000	209500	208800	Recovery Read Up		



A = Conductivity due to e.m.f.

B = conductivity due to e.m.f.
light and heat.

Fig. 4

Sample 2

The effect of e.m.f. and heat

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	1300	1300	1300			
25	1300	1300	1300	2580	2580	2580
50	1600	1600	1600	3660	3660	3660
75	3420	3420	3420	6660	6660	6660
100	5320	5380	5350	9800	9800	9800
125	12100	12200	12150	16200	16200	16200
150	21000	20900	20950	22400	22400	22400
175	32400	32600	32500	34600	34600	34600
200	57600	57600	57600	51200	51200	51200
225	73600	73600	73600	79200	79200	79200
250	111200	109600	110400	131200	131200	131200
275	147200	145600	146400	170400	170400	170400
300	200300	200200	200200	Recovery Read Up		

Sample 2

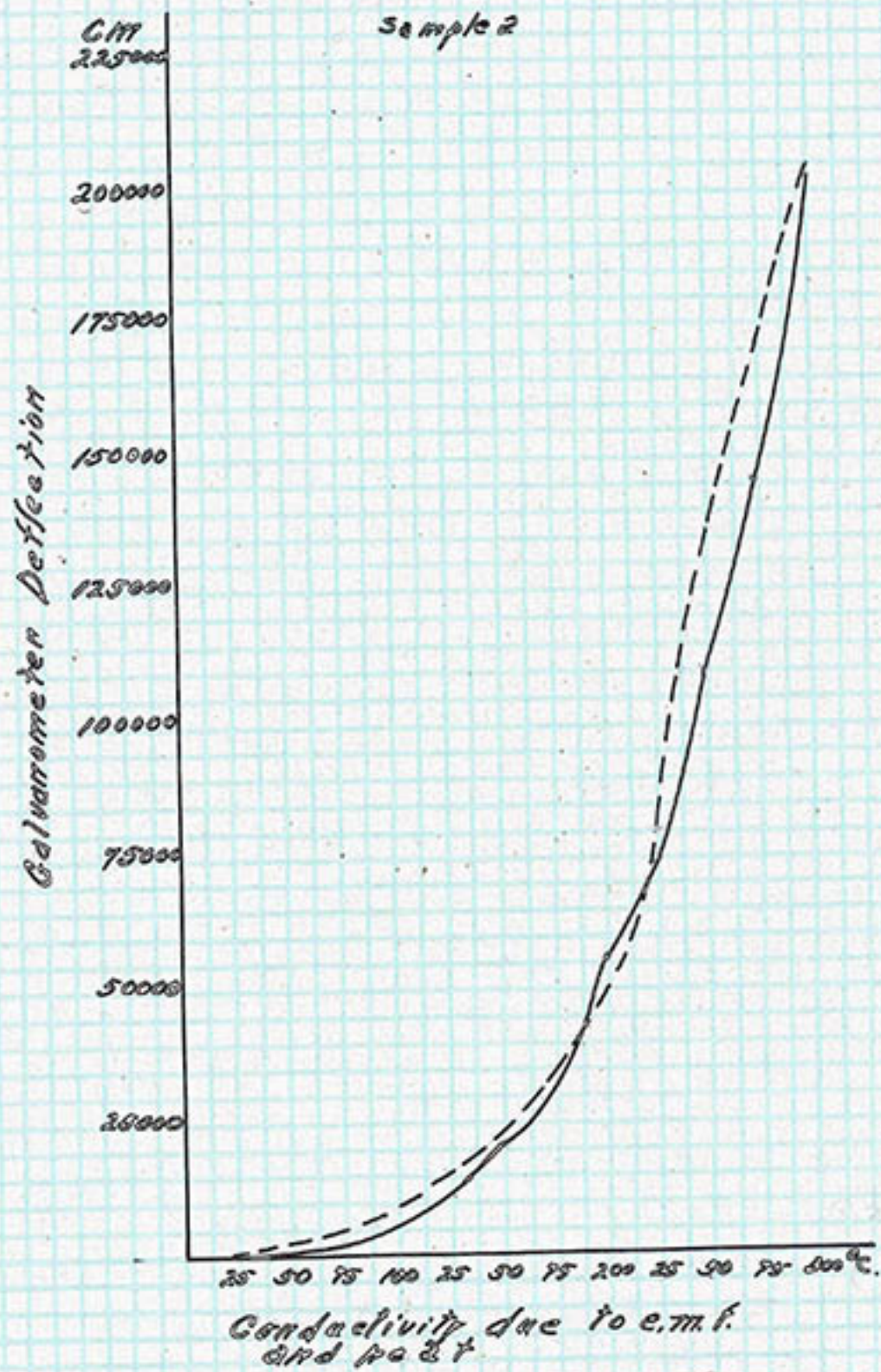


Fig. 5.

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Sample 8

This sample was slightly actino-active at room temperature giving a deflection of 7.4 cm. Under the influence of heat the deflection decreased to 4.6 cm at 25° and reached zero between 50° and 75°. Upon increasing the heat still more the deflection began to increase but in a negative direction, until at 300° the reading was -37.75 cm. A peculiar result was observed in that the sample did not recover to its original deflection upon reducing the temperature to that of the room. The sample was found to be thermo-active at room temperature but negative to that of the actino- reaction. There was no noticeable change in the current until the temperature had reached 125°, but at this point there was an increase in the current until at 225° the deflection was -8.4 cm. The deflection decreased at temperatures higher than 225° finally reaching zero at near 250°, then an increase was observed but in a positive direction. Upon reducing the temperature, the samples recovered to its original deflection. Figs. 6 and 7 illustrate these results. Upon reducing the temperature to that of ice and testing the actino- and thermo- effects it was found that there was no reaction.

The sample was not photo-resistant at room temperature but was quite active with the application of heat. With an e.m.f. in series with the sample and the application of light there was a galvanometer throw of 76,000 cm at 300°. With the application of heat only there was a deflection of 74,400 cm at 300°. These results are shown graphically by Figs. 7 and 8. Neither of the effects was altered by reducing the temperature

Sample 8

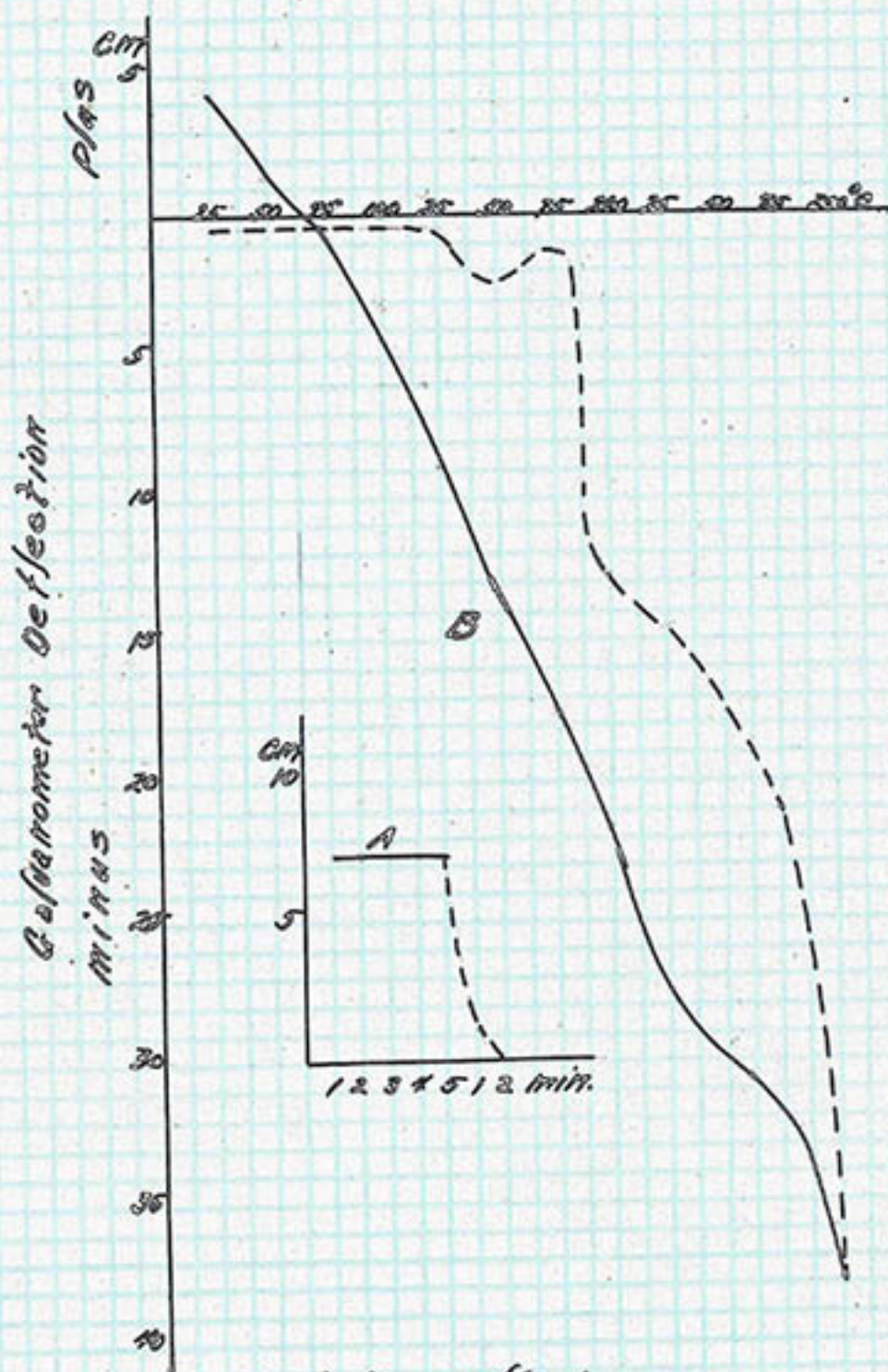
Actino-electric effect

Time	Galvanometer Deflection	Time	Galvanometer Deflection
1 min	7.4 cm		
2	7.4		
3	7.4	2 min	0.1 cm
4	7.4	1	0.1
5	7.4	Recovery Read Up	

Actino- plus thermo- electric effects

Temp. ° C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	4.6	4.6	4.6	-0.4	-0.4	-0.4
50	2.0	1.5	1.75	-0.4	-0.4	-0.4
75	-0.65	-0.65	-0.65	-0.4	-0.5	-0.45
100	-4.3	-4.3	-4.3	-0.5	-0.5	-0.5
125	-8.7	-8.9	-8.8	-0.4	-0.4	-0.4
150	-13.5	-13.6	-13.55	-2.4	-2.5	-2.45
175	-17.4	-17.5	-17.45	-1.0	-1.8	-1.4
200	-21.7	-22.0	-21.85	-7.4	-7.5	-7.45
225	-27.5	-27.5	-27.5	-14.2	-14.8	-14.5
250	-28.2	-31.5	-29.85	-20.5	-21.5	-21.0
275	-30.0	-32.5	-31.75	-20.5	-21.5	-21.0
300	-36.8	-38.9	-37.75	Recovery Read Up		

Sample 2



A = Actino-effect

B = Actino- + Thermo-effects.

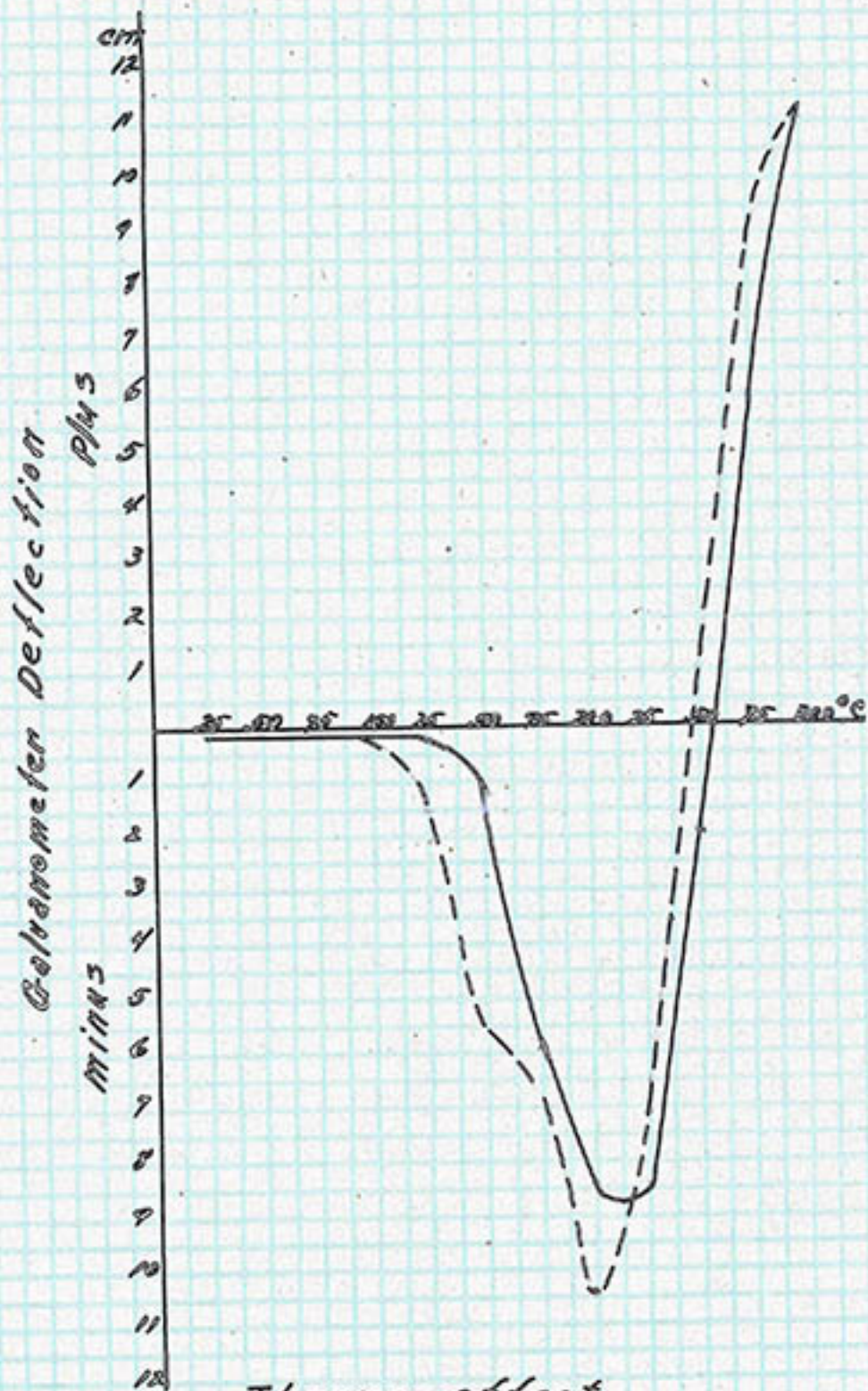
Fig. 6.

Sample 8

Thermo-electric effect

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	-0.1	-0.1	-0.1	0.0	0.0	0.0
50	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1
75	-0.2	-0.2	-0.2	-0.1	-0.1	-0.1
100	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
125	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
150	-1.1	-1.1	-1.1	-5.3	-5.7	-5.5
175	-6.1	-5.8	-5.95	-6.7	-7.1	-6.9
200	-8.2	-8.6	-8.4	-10.4	-10.4	-10.4
225	-8.4	-8.4	-8.4	-7.0	-6.5	-6.75
250	-1.7	-1.7	-1.7	1.2	1.2	1.2
275	6.0	6.0	6.0	8.5	9.0	8.75
300	11.0	11.3	11.15	Recovery Read Up		

21
Sample 8



Thermo-effect.

Fig. 7

Sample 8

When in the dark and with the e.m.f. in series, this sample gave a deflection of 450 cm at room temperature.

The effect of e.m.f., light, and heat.

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	270	270	270			
25	450	450	450	430	430.0	430.0
50	612	612	612	755	760	757.5
75	700	690	695	1190	1190	1190.0
100	1710	1710	1710	2220	2260	2240.0
125	2900	2900	2900	3400	3400	3400.0
150	3400	3400	3400	5800	5800	5800.0
175	6500	6500	6500	8800	8800	8800.0
200	10500	10600	10550	10400	10600	10500.0
225	19800	19400	19600	21100	21200	21150.0
250	30200	30600	30400	36800	36800	36800.0
275	53600	53600	53600	5660	56700	56650.0
300	75200	76800	76000	Recovery Read Up		

Sample 8

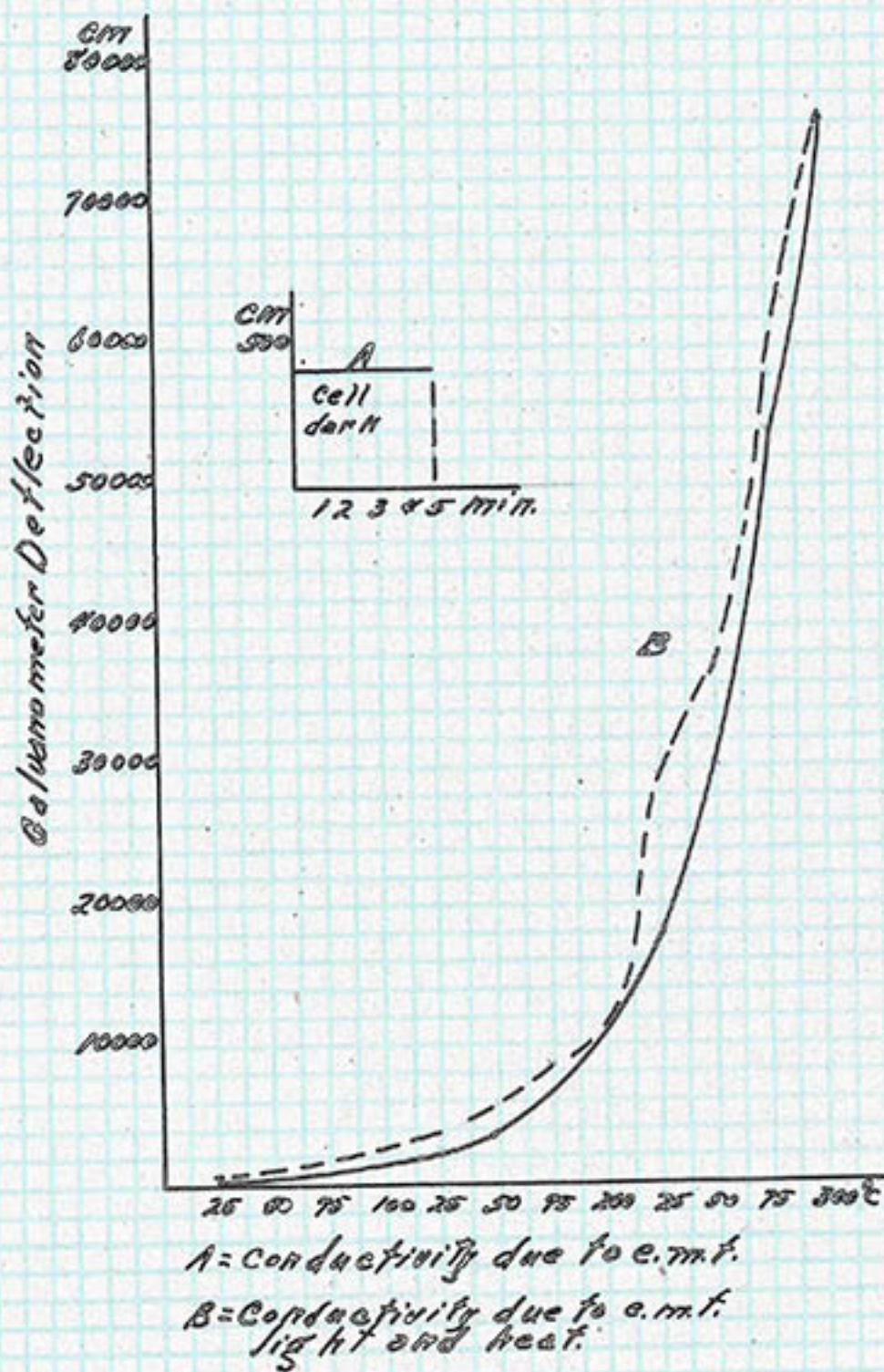


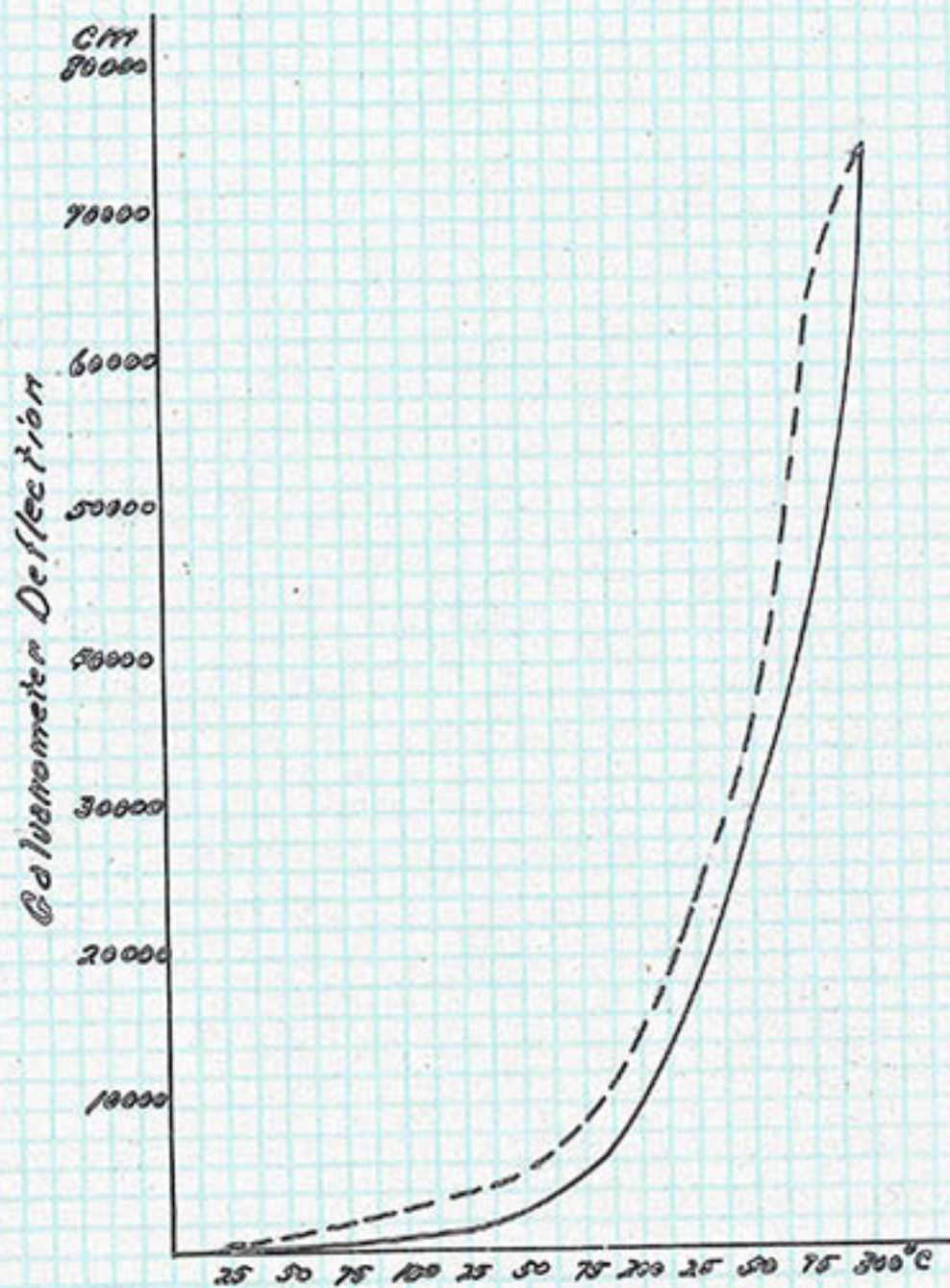
Fig. 8

Sample 8

The effect of e.m.f. and heat

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	270	270	270			
25	270	270	270	330	330	330
50	300	300	300	490	490	490
75	420	420	420	1300	1300	1300
100	780	780	780	2670	2670	2670
125	1720	1720	1720	3800	3800	3800
150	3100	3100	3100	5800	5800	5800
175	5600	5600	5600	8900	8900	8900
200	10600	10700	10650	14500	14500	14500
225	18300	18400	18350	24600	24500	24550
250	30200	30400	30300	36800	36800	36800
275	41600	41600	41600	62400	63200	63800
300	7440	7440	7440	Recovery Read Up		

25
Sample 3



Conductivity due to e.m.f.
and heat.

Fig. 9.

Sample 11

This sample was only slightly actino-active at room temperature but gave a deflection of nearly 42 cm at 300° . Upon testing the thermo- effect it was found that the sample was not active at 25° but upon heating to 300° there was a deflection of approximately 29 cm. The difference between these results will give the true actino- effect. Figs. 10 and 11 show these reactions. These same tests were made later at ice temperature and it was found that the sample was not light active, but the thermo-effect gave a deflection of 3.2 cm.

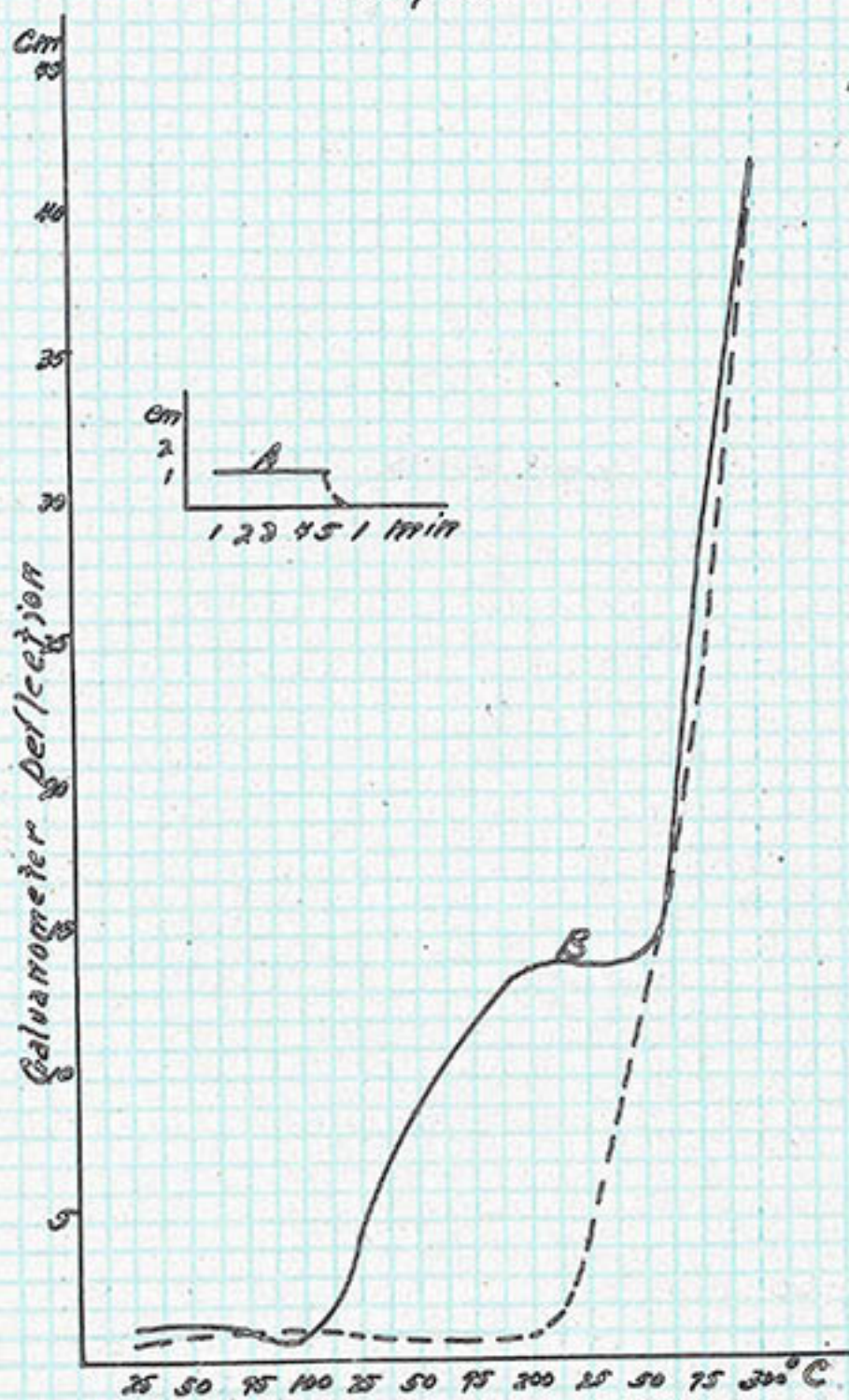
This sample was not photo- sensitive at room temperature, but under the influence of heat, light, and e.m.f. there was a galvanometer deflection of 30,800 cm at 300° . At 300° the e.m.f. alone gave a deflection of 30,150 cm, which is approximately that of the photo-resistant effect. Figs. 12 and 13 depict these reactions. It was found that there was no apparent difference between the results at ice temperature and those of room temperature.

Sample 11

Actino- plus thermo- electric effects

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	1.2	1.2	1.2	0.4	0.4	0.4
50	1.4	1.4	1.4	0.8	0.8	0.8
75	1.9	1.9	1.9	1.05	1.05	1.05
100	0.7	0.7	0.7	1.05	1.05	1.05
125	4.4	4.5	5.45	0.8	0.75	0.775
150	8.7	8.8	8.75	0.9	0.9	0.9
175	11.8	11.2	11.5	0.85	0.7	0.775
200	14.6	14.8	14.7	0.7	0.7	0.7
225	15.2	14.2	14.7	4.1	4.1	4.1
250	15.2	14.1	15.15	13.9	14.2	14.05
275	28.1	28.3	28.2	23.5	23.3	23.4
300	41.6	41.9	41.75	Recovery Read Up		

Sample II



A = Actino-effect
 B = Actino- & Thermo-effects.

Fig. 10

Sample 11

Thermo-electric effect

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	3.2	3.2	3.2			
25	0.0	0.0	0.0	0.0	0.0	0.0
50	0.1	0.1	0.1	0.0	0.0	0.0
75	0.4	0.4	0.4	0.05	0.05	0.05
100	0.2	0.2	0.2	0.05	0.05	0.05
125	0.1	0.1	0.1	0.05	0.05	0.05
150	0.15	0.15	0.15	0.2	0.2	0.2
175	0.6	0.6	0.6	0.34	0.4	0.375
200	1.4	1.45	0.425	0.6	0.6	0.6
225	2.5	2.6	2.55	2.3	2.3	2.3
250	6.8	6.4	6.6	8.4	9.2	8.8
275	13.6	13.7	13.65	19.2	18.8	19.0
300	28.7	28.8	28.75	Recovery Read Up		

30

Sample 11

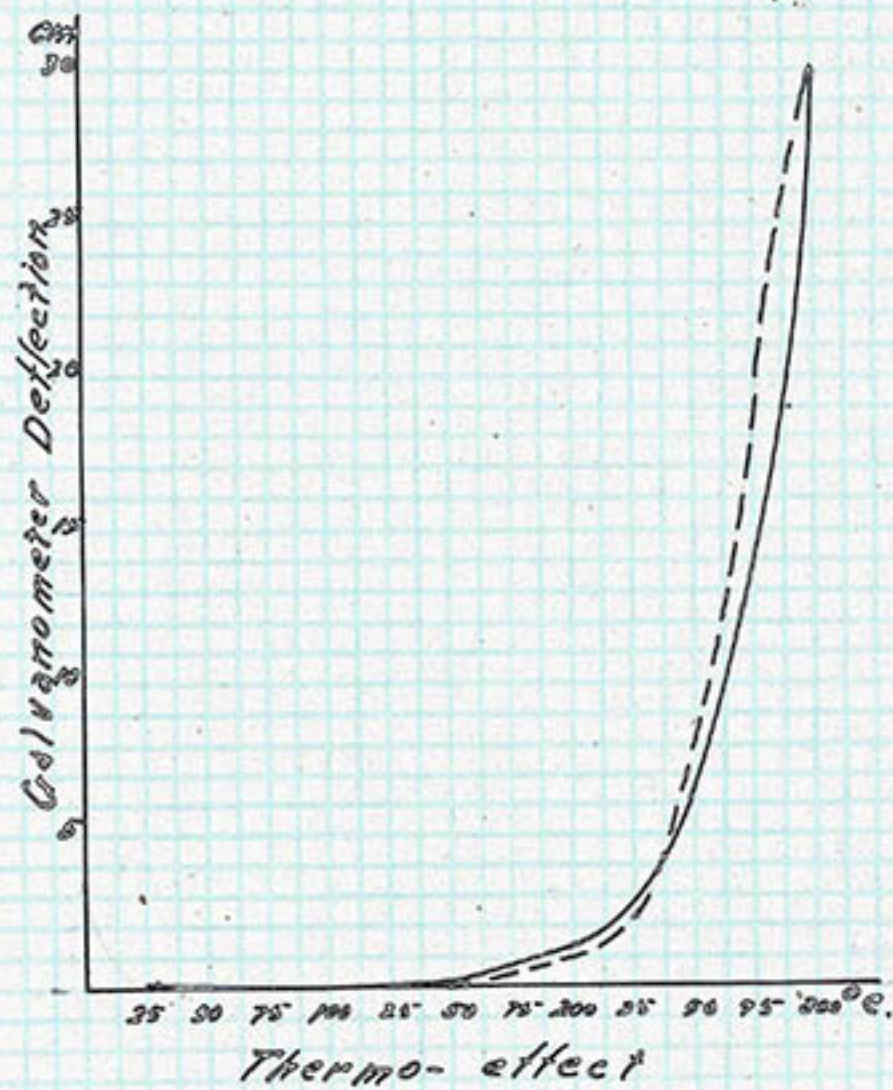


Fig. 11.

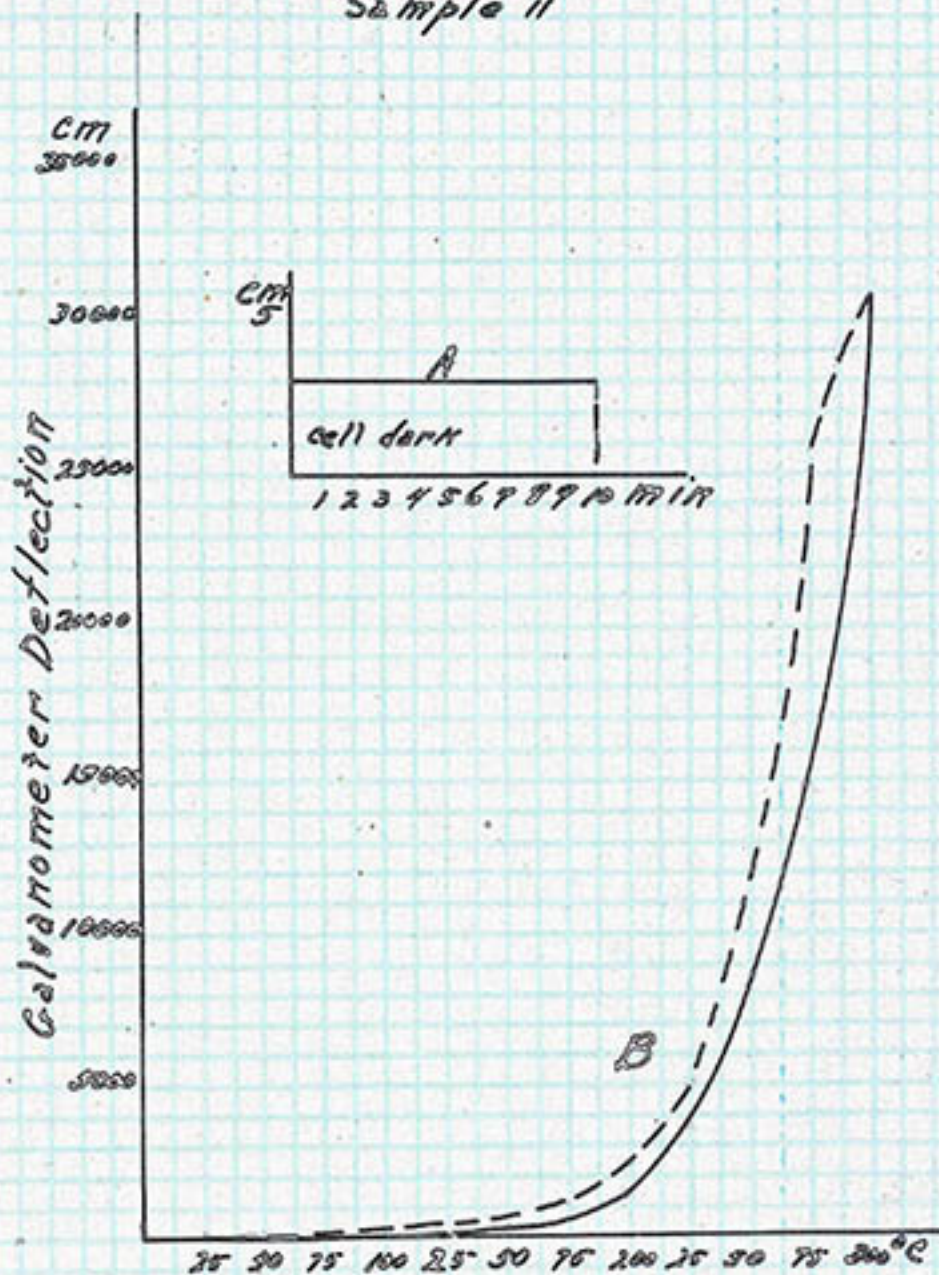
Sample 11

The effect of e.m.f. at room temperature gave a deflection of 3 cm.

The effect of e.m.f., light, and heat.

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	3.	3.	3.	3.	3.	3.
50	7.1	7.4	7.25	5.2	5.2	5.2
75	11.	11.	11.	25.	25.	25.
100	64.	65.	64.5	100.	100.	100.
125	158.	157.	157.5	204.	202.	203.
150	492.	493.	492.5	500.	500.	500.
175	770.	770.	770.	860.	800.	830.
200	1540.	1560.	1550.	2300.	2400.	2350.
225	3700.	3600.	3650.	4800.	4600.	4700.
250	8100.	8400.	8250.	11700.	11900.	11800.
275	14800.	14600.	14700.	26200.	25800.	26000.
300	30900.	30700.	30800.	Recovery Read Up		

Sample 11



A = Conductivity due to e.m.f.

B = Conductivity due to e.m.f.
light and heat.

Fig. 12

Sample 11

The effect of e.m.f. and heat

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	9.6	9.6	9.6	28.	28.	28.
50	25.	25.	25.	65.	65.	65.
75	58.	58.	58.	310.	310.	310.
100	138.	138.	138.	640.	640.	640.
125	400.	400.	400.	1060.	1040.	1050.
150	730.	740.	734.	2420.	2440.	2430.
175	1280.	1280.	1280.	3820.	3820.	3820.
200	2000.	1990.	1995.	5300.	5300.	5300.
225	5200.	5200.	5200.	6300.	6300.	6300.
250	990.	10000.	9950.	12100.	12100.	12100.
275	16100.	16100.	16100.	22600.	22400.	22500.
300	30100.	30200.	30150	Recovery Read Up		

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Sample 11

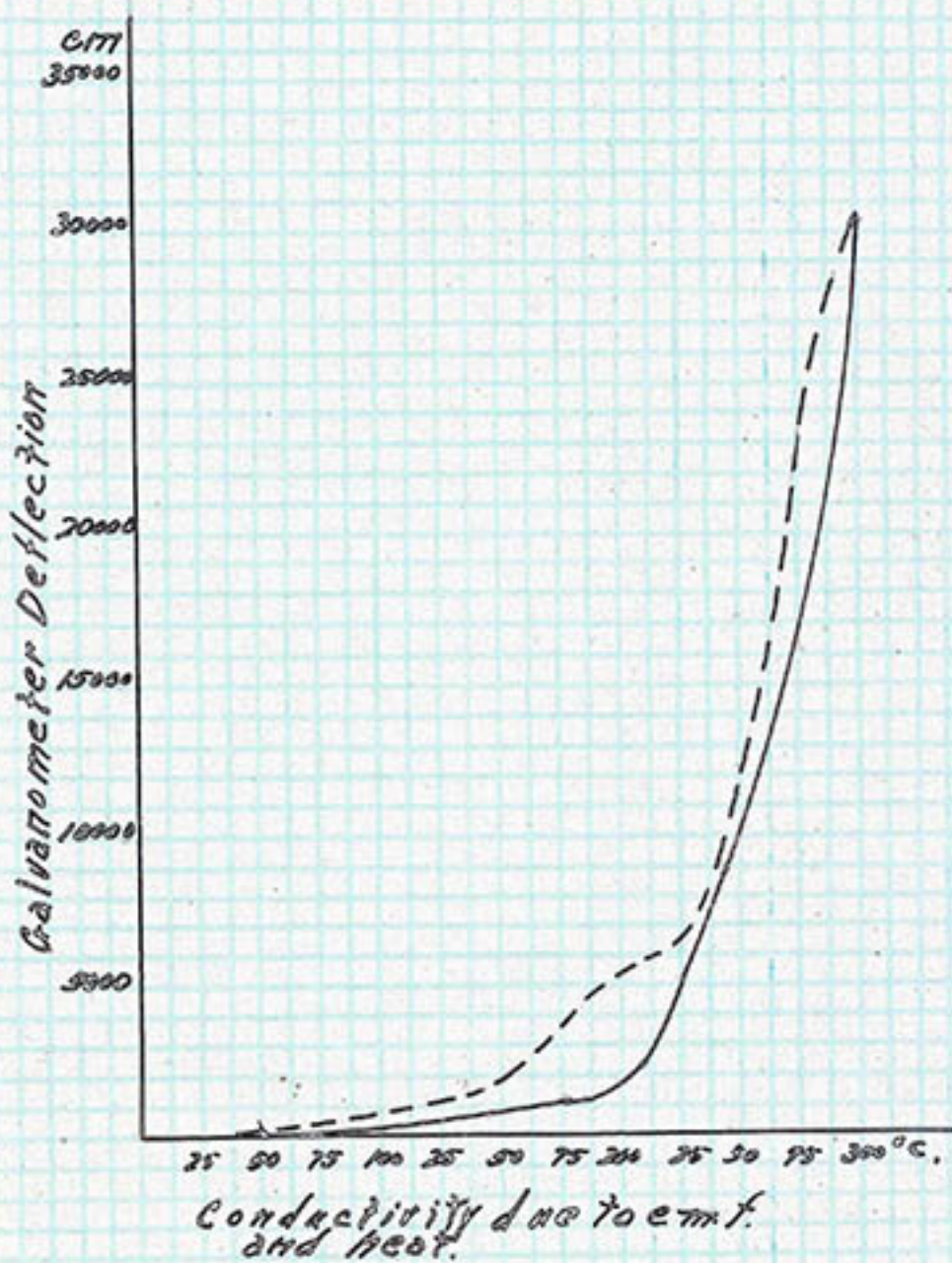


Fig. 13.

Sample 12

As shown in Fig. 14 this sample was actino-active at room temperature but upon applying heat it was observed that the current became zero at between 50° and 75° . Beyond this temperature the current increased to about 21 cm but in a negative direction. It will be observed that the sample did not recover to its original deflection upon reducing the temperature to that of the room. The sample was found to be slightly thermo-active and in a negative direction to that of the actino-effect at room temperature. This reaction is shown by Fig. 15. These same tests were carried on at ice temperature and it was discovered that the actino-effect gave a deflection of 14 cm and the thermo-effect a deflection of -2.5 cm.

At room temperature the e.m.f. alone gave a deflection of 16.6 cm but upon adding light the reading increased to 20 cm. Upon testing the photo-resistant effect under the influence of heat it was found that the sample gave a galvanometer deflection of 5,500 cm at 300° . Testing the sample under the influence of heat and e.m.f. gave a reading of 6,100 cm at 300° . These results are shown graphically by Figs. 16 and 17. Reducing the temperature to 0° did not apparently affect these reactions.

Sample 12

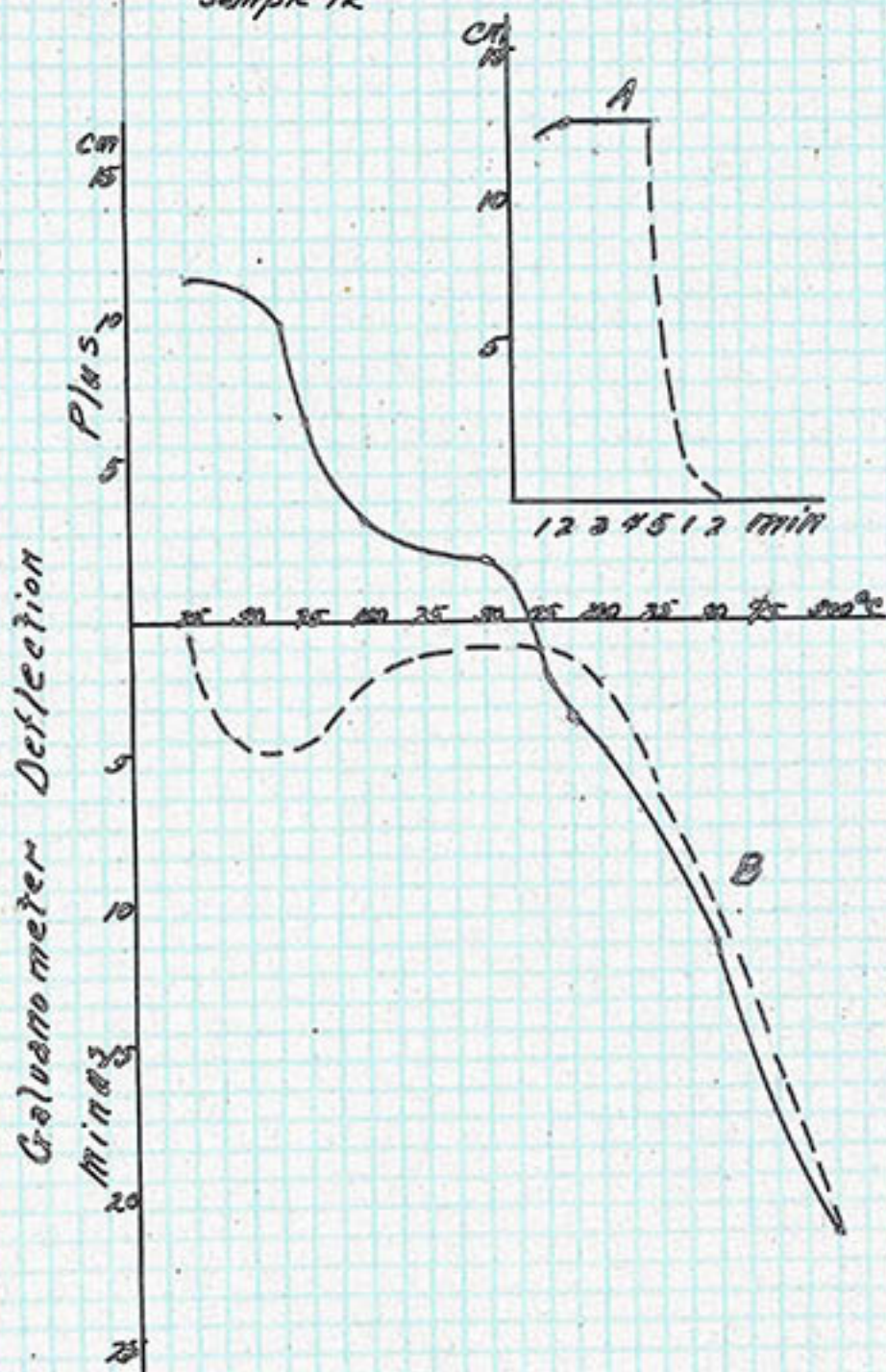
Actino-electric effect

Time	Galvanometer Deflection	Time	Galvanometer Deflection
1 min	12.5 cm		
2	13.0		
3	13.0	2 min	12.5 cm
4	13.0	1	12.75
5	13.0		Recovery Read Up

Actino- plus thermo- electric effects.

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	14	14	14			
25	12.5	12.5	12.5	-0.6	-0.6	-0.6
50	12.5	12.5	12.5	-4.6	-4.6	-4.6
75	8.0	8.0	8.0	-4.4	-4.6	-4.5
100	3.75	3.75	3.75	-2.8	-2.8	-2.8
125	2.5	2.5	2.5	-1.6	-1.6	-1.6
150	2.5	2.5	2.5	-1.1	-1.1	-1.1
175	-2.1	-2.1	-2.1	-1.5	-1.3	-1.4
200	-4.2	-4.4	-4.3	-2.3	-2.7	-2.5
225	-7.1	-7.1	-7.1	-6.5	-5.9	-6.2
250	-10.5	-11.5	-11.0	-9.6	-9.6	-9.6
275	-17.0	-17.1	-17.15	-16.1	-16.1	-16.1
300	-21.1	-20.9	-21.0			Recovery Read Up

Sample 12 ³⁷



A = Actino-effect

B = Actino + Thermo-effects

Fig. 14

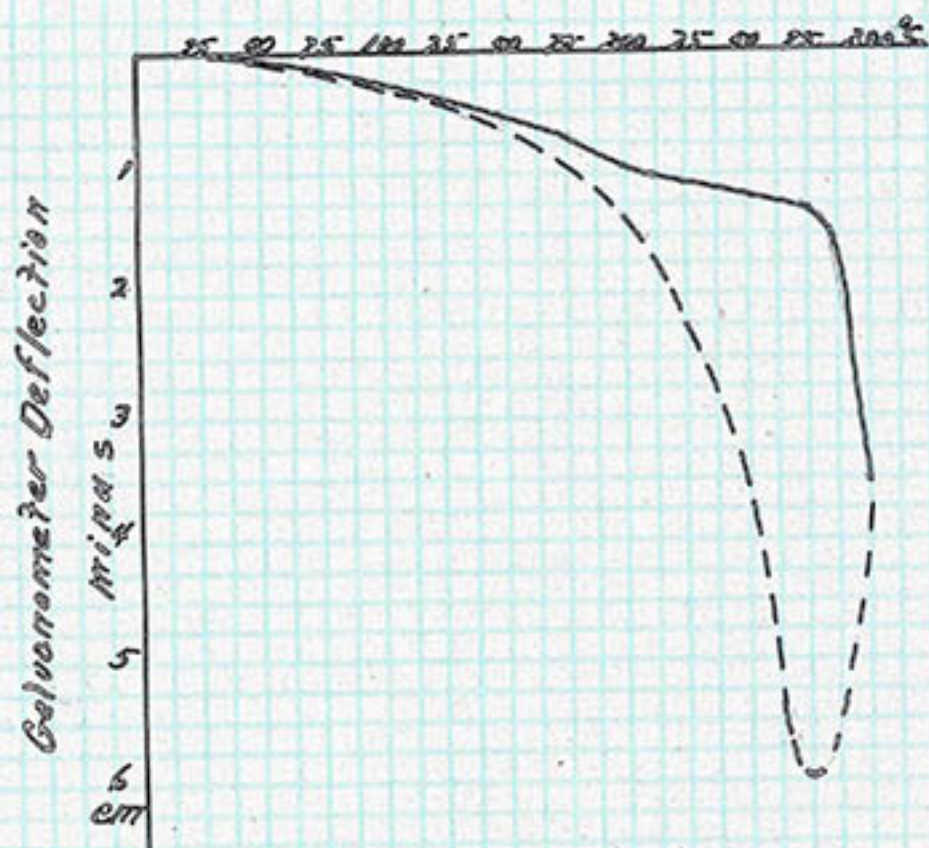
Sample 12

Thermo-electric Effect

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	0.	0.	0.	0.	0.	0.
50	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
75	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
100	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
125	-0.35	-0.35	-0.35	-0.4	-0.4	-0.4
150	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
175	-0.7	-0.7	-0.7	-0.9	-0.9	-0.9
200	-0.9	-0.9	-0.9	-1.4	-1.4	-1.4
225	-1.1	-1.1	-1.1	-2.45	-2.15	-2.3
250	-1.2	-1.2	-1.2	-3.45	-3.5	-3.475
275	-1.3	-1.3	-1.3	-6.1	-5.8	-5.95
300	-3.4	-3.4	-3.4	Recovery Read Up		

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Sample 12



Thermo-effect

Fig. 15

Sample 12

This sample gave a deflection of 16.6 cm under the influence of the e.m.f. at room temperature.

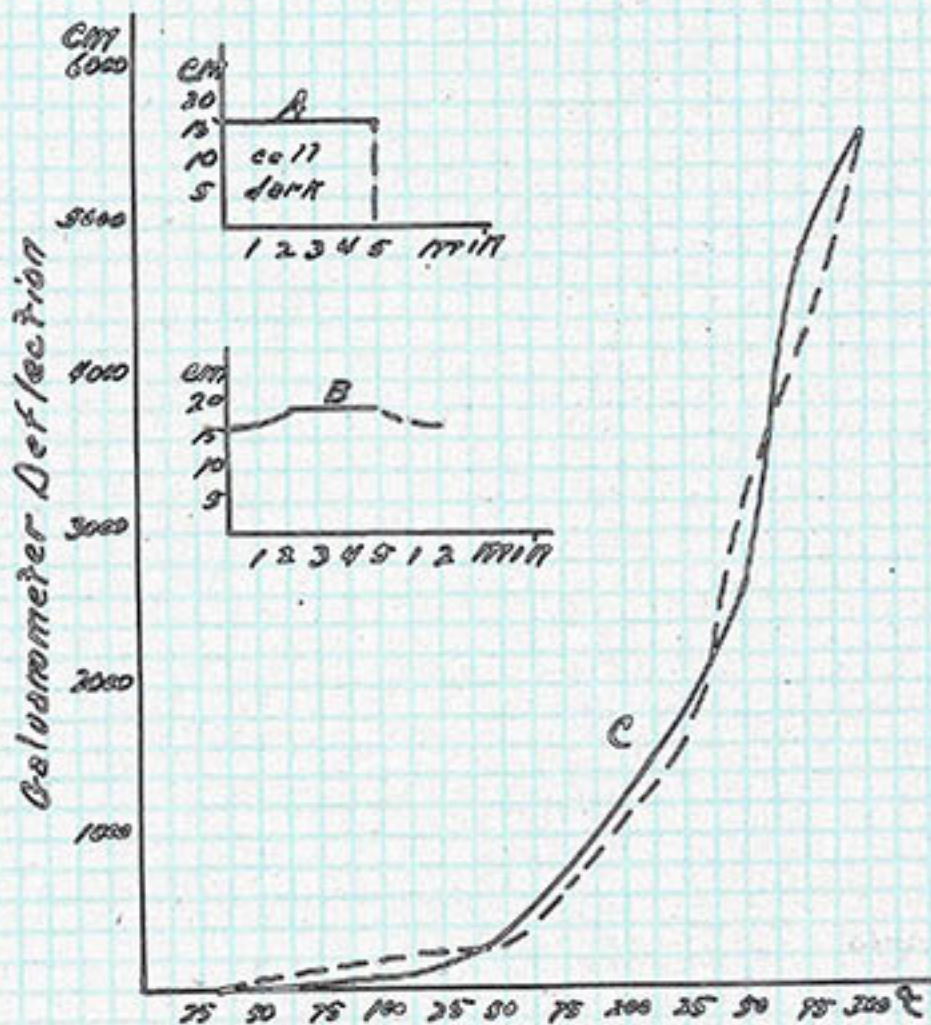
The effect of light and e.m.f.

Time	Galvanometer Deflection in centimeters	Time	Galvanometer Deflection in centimeters
1 min	18		
2	20		
3	20	2 min	18 cm
4	20	1	19
5	20	Recovery Read Up	

The effect of e.m.f., light, and heat.

Temp °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	20	20	20			
25	20	20	20	21	21	21
50	12	12	12	29	29	29
75	8	8	8	52	52	52
100	57	57	57	112	124	128
125	120	120	120	232	216	224
150	420	420	420	330	410	395
175	890	900	890	740	720	730
200	1210	1190	1200	1140	1190	1175
225	1780	1800	1790	1690	1660	1675
250	2580	2620	2600	3000	3100	3050
275	4600	4800	4700	4300	4300	4300
300	5500	5500	5500	Recovery Read Up		

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Sample 12



A = Conductivity due to e.m.f.

B = Conductivity due to e.m.f.
and light.

C = Conductivity due to e.m.f.
light and heat.

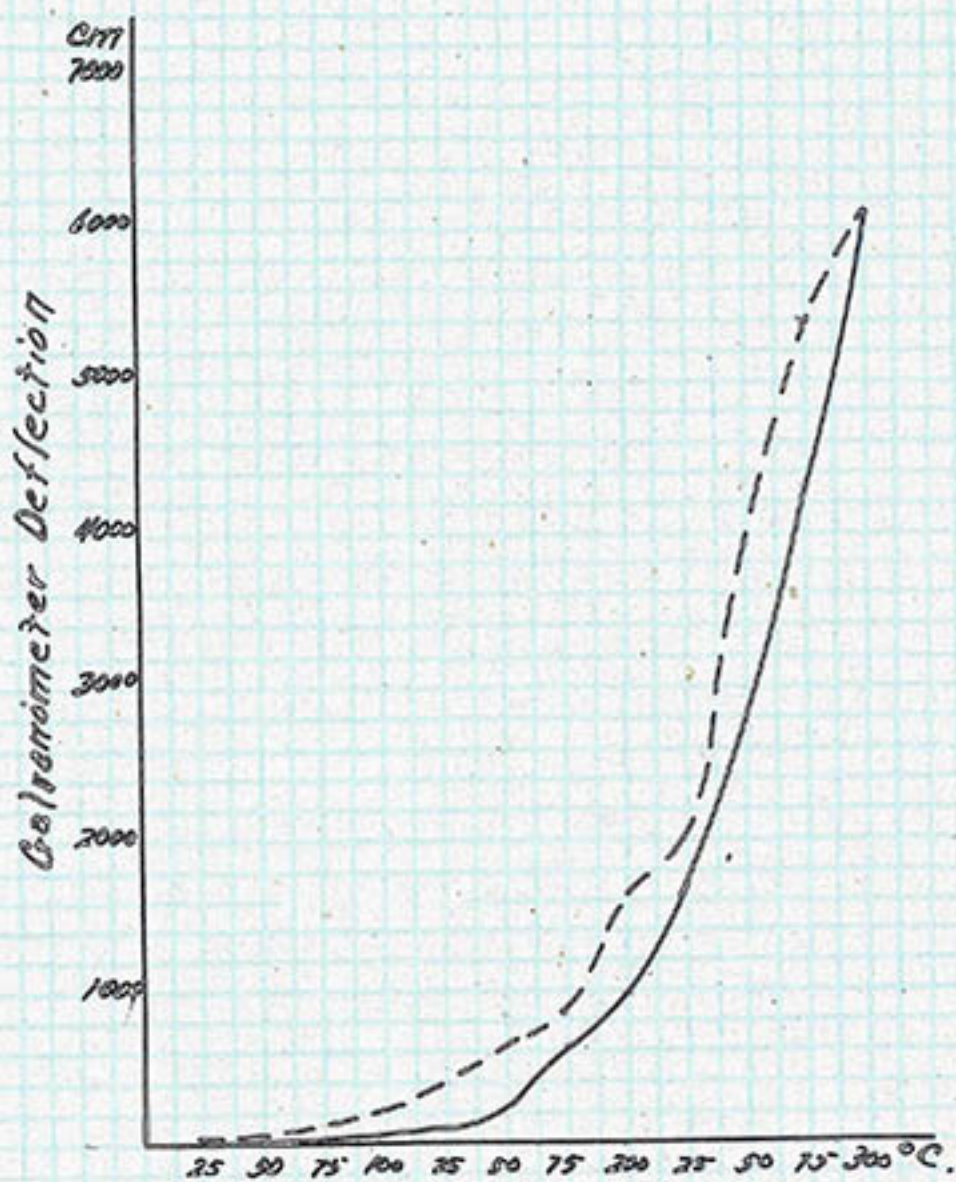
Fig. 16

Sample 12

The effect of e.m.f. and heat

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	13	13	13			
25	13	13	13	18	18	18
50	15	15	15	81	81	81
75	32	32	32	160	160	160
100	51	51	51	250	250	250
125	120	120	120	400	400	400
150	220	220	220	670	670	670
175	660	660	660	990	990	990
200	960	960	960	1370	1370	1370
225	1760	1760	1760	1940	1940	1940
250	2710	2730	2720	3800	3900	3850
275	4300	4400	4350	5400	5400	5400
300	6100	6100	6100	Recovery Read Up		

Sample 12



conductivity due to e.m.f.
and heat.

Fig. 17

Sample 13

This sample was found to be very actino- active at room temperature, but upon applying heat it was observed that the current decreased to zero at near 110° . Beyond this temperature the current increased but in a negative direction until at 300° the deflection was -346 cm. In testing the thermo- reaction it was discovered that the deflection was only -22.55 cm at 300° and negative to that of the actino- effect at room temperature. Figs. 18 and 19 illustrate the above results. Upon testing these same phases at ice temperature it was found that the sample was not actino- active and the thermo- effect gave a deflection of only -0.8 cm.

Fig. 20 will show that the sample was slightly photo- sensitive at room temperature. Under the influence of heat the photo- reaction gave a deflection of 64,400 cm at 300° . Testing the sample under the influence of heat and e.m.f. gave a deflection of 65,200 cm at 300° as shown by Fig. 21. These results were not altered upon reducing the temperature to that of ice

Sample 13

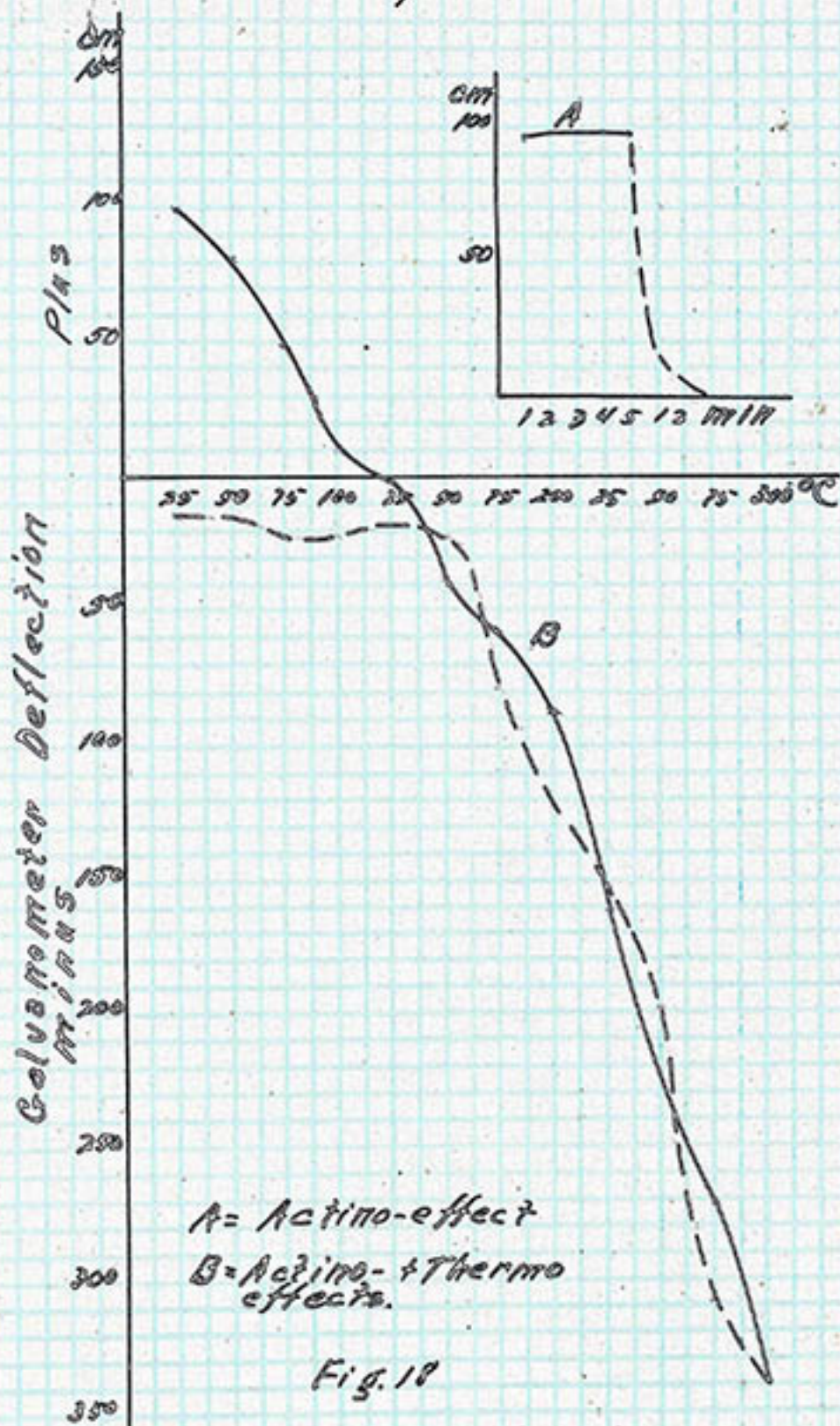
Actino-electric effect

Time	Galvanometer Deflection	Time	Galvanometer Deflection
1 min	97 cm		
2	100		
3	100	2 min	0.25
4	100	1	12.00
5	100	Recovery Read Up	

Actino- plus thermo- electric effects

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	97	97	97	-12.5	-12.5	-12.5
50	82	82	82	-12.5	-12.5	-12.5
75	50	50	50	-20.0	-20.0	-20.0
100	7.25	7.25	7.25	-22.0	-22.0	-22.0
125	-2.5	-2.5	-2.5	-17.0	-17.0	-17.0
150	-35.0	-34.7	-34.85	-25.0	-27.0	-26.0
175	-55.0	-56.0	-55.0	-77.0	-77.0	-77.0
200	-87.0	-87.0	-87.0	-130.0	-142.0	-136.0
225	-162.0	-162.0	-162.0	-155.0	-157.0	-156.0
250	-222.0	-222.0	-222.0	-195.0	-202.0	-198.5
275	-272.0	-272.0	-272.0	-312.0	-305.0	-308.5
300	-347.0	-345.0	-346.0	Recovery Read Up.		

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Sample 13



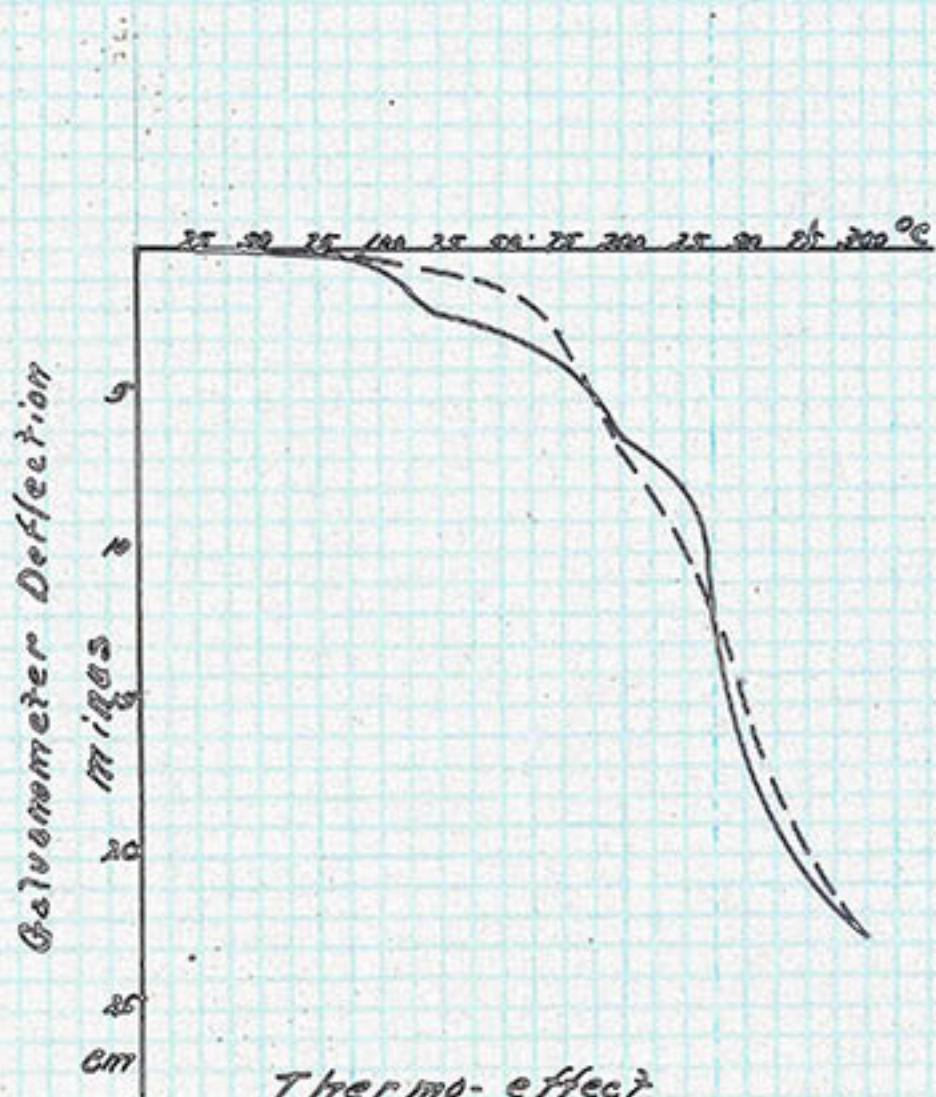
Sample 13

Thermo-electric effect

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	-0.8	-0.8	-0.8			
25	0	0	0	0	0	0
50	-0.1	-0.1	-0.1	0	0	0
75	-0.4	-0.4	-0.4	-0.1	-0.1	-0.1
100	-0.3	-0.3	-0.3	-0.35	-0.3	-0.325
125	-2.2	-2.6	-2.4	-0.9	-0.9	-0.9
150	-3.0	-2.95	-2.975	-1.2	-1.2	-1.2
175	-4.9	-4.9	-4.9	-3.7	-3.7	-3.7
200	-6.0	-6.0	-6.0	-7.1	-6.7	-6.9
225	-8.0	-7.9	-7.95	-9.6	-9.9	-9.75
250	-16.2	-16.5	-16.35	-14.3	-14.1	-14.2
275	-20.9	-20.8	-20.85	-19.6	-20.8	-20.2
300	-22.5	-22.6	-22.55	Recovery Read Up		

48

Sample 13



Thermo-effect
Fig. 19

Sample 15

This sample gave a deflection of 12 cm due to e.m.f. at room temperature.

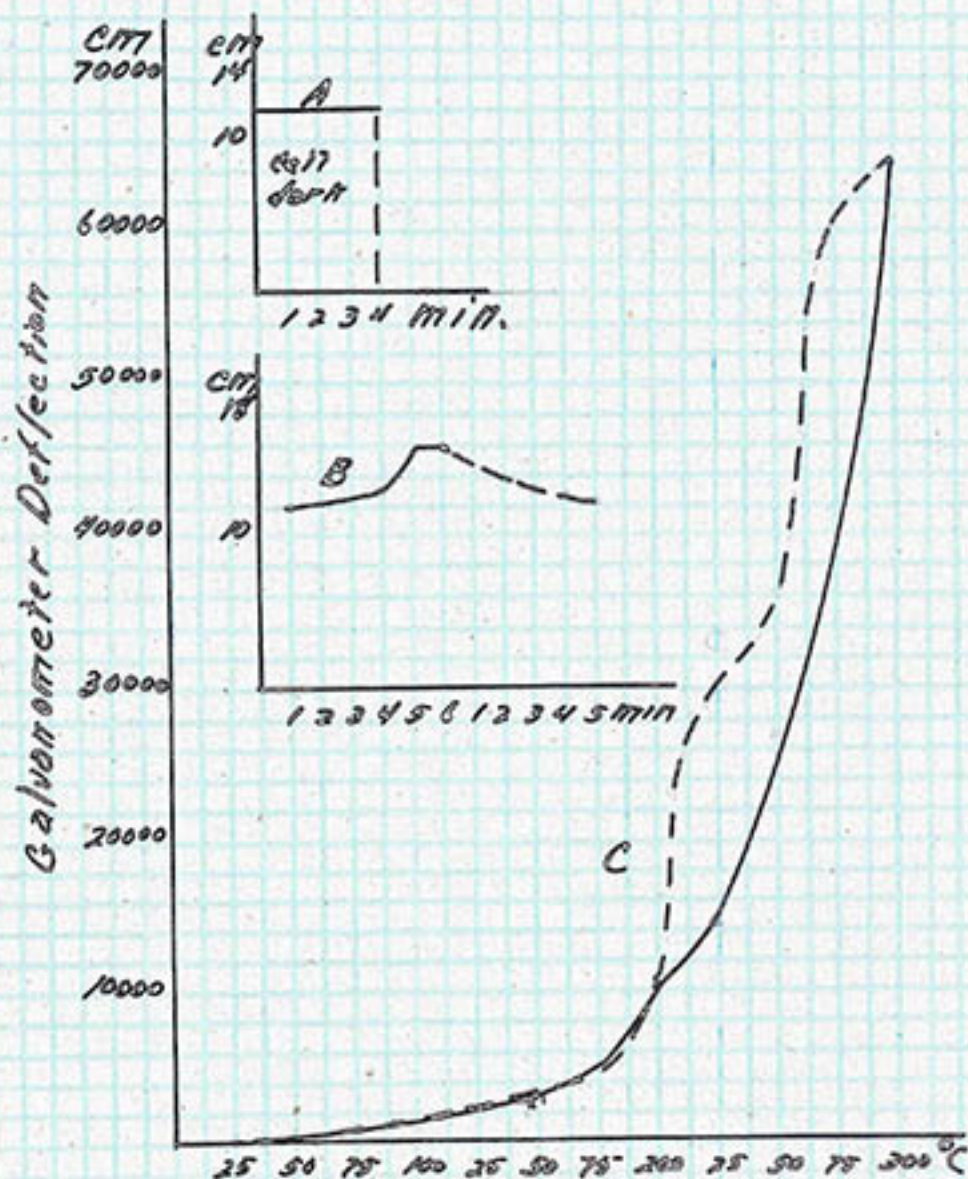
The effect of e.m.f. and light

Time	Galvanometer Deflection	Time	Galvanometer Deflection
1 min	12.5 cm		
2	13.3	3 min	12.8
3	12.6	2	15.2
4	12.8	1	15.6
5	16.8	Recovery Read Up	

The effect of e.m.f., light, and heat.

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	16.8	16.8	16.8			
25	16.8	16.8	16.8	100	102	101
50	20.0	20.	20.	164	164	164
75	39.	38.	38.5	450	450	450
100	172.	176.	174.	580	590	585
125	380.	377.	378.5	2000	2000	2000
150	1820.	1840.	1835.	3100	3100	3100
175	4600.	4600.	4600.	4950	5100	5025
200	11800.	11800.	11800.	10500	10500	10500
225	14400.	14200.	14300.	30500	30500	30500
250	27100.	27100.	27100.	27100	27100	27100
275	39440.	38640.	39040.	60375	60375	60375
300	64400.	64400.	64400.	Recovery Read Up		

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Sample 13



A = Conductivity due to e.m.f.

B = Conductivity due to e.m.f.
and light.

C = Conductivity due to e.m.f.
light and heat.

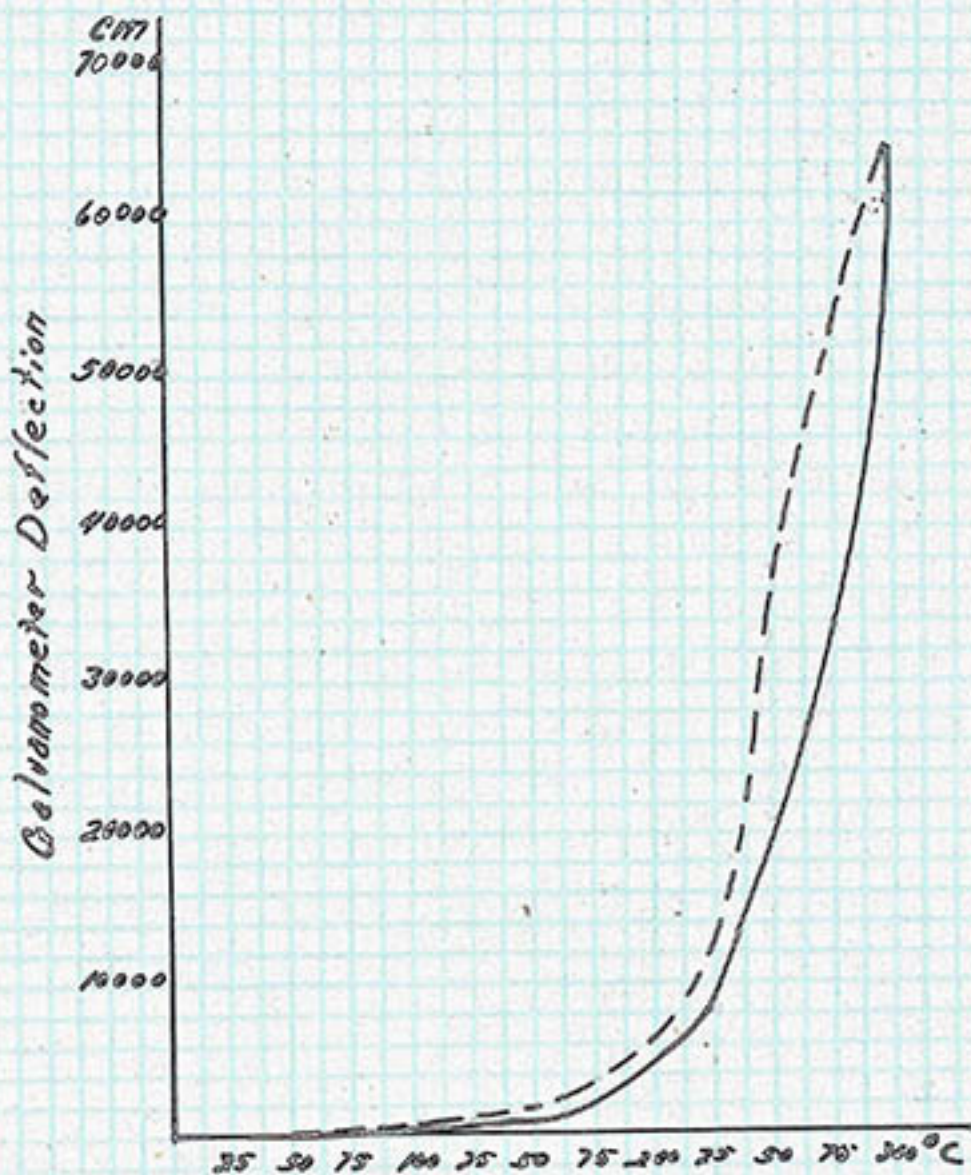
Fig. 20

Sample 13

The effect of e.m.f. and heat

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	11.2	11.2	11.2			
25	11.2	11.2	11.2	56.	56	56
50	13.6	13.6	13.6	296	296	296
75	23	23	23	304	300	302
100	103	103	103	530	530	530
125	250	250	250	840	840	840
150	540	540	540	1580	1580	1580
175	1520	1520	1520	3240	3240	3240
200	5200	5400	5300	6300	6300	6300
225	9900	10200	10050	12800	12600	12700
250	20800	20800	20800	37000	37000	37000
275	33390	33390	33390	52300	52300	52300
300	65200	65200	65200	Recovery Read Up		

52
Sample 13



Conductivity due to e.m.f.
and heat.

Fig. 21

Sample 14

This sample was not actino- active at room temperature but under the influence of heat it was noticed that the current changed from positive to negative and back to positive between the ranges of room temperature and 300° . This test was made several times and the results would always bear out these observations. Fig. 22 shows this reaction. This sample was slightly thermo- active at room temperature and showed a deflection of 15.75 cm at 300° . Reference is made to Fig. 23 for this curve. This sample showed neither actino- nor thermo- sensitivity at ice temperature.

This sample was not photo-sensitive at room temperature but showed a deflection of 3475 cm at 300° . Fig. 24 is referred to for this graph. Upon testing the sample under the influence of heat and e.m.f. it was observed that the deflection was 4100 cm at 300° . Fig. 25 shows this reaction. These results were not altered at ice temperature.

Sample 14

Actino- plus thermo- electric effects

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	0.2	0.2	0.2	0.2	0.2	0.2
50	0.2	0.2	0.2	0.2	0.2	0.2
75	0.5	0.5	0.5	0.6	0.6	0.6
100	0.25	0.25	0.25	-0.1	-0.1	-0.1
125	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2
150	-0.2	-0.2	-0.2	-0.7	-0.7	-0.7
175	0.2	0.2	0.2	-0.3	-0.2	-0.25
200	1.4	1.4	1.4	1.3	1.3	1.3
225	1.1	1.1	1.1	1.9	1.9	1.9
250	0.5	0.5	0.5	1.6	1.4	1.5
275	-0.15	-0.05	-0.1	1.2	1.2	1.2
300	0.5	0.5	0.5	Recovery Read Up		

55
Sample 14

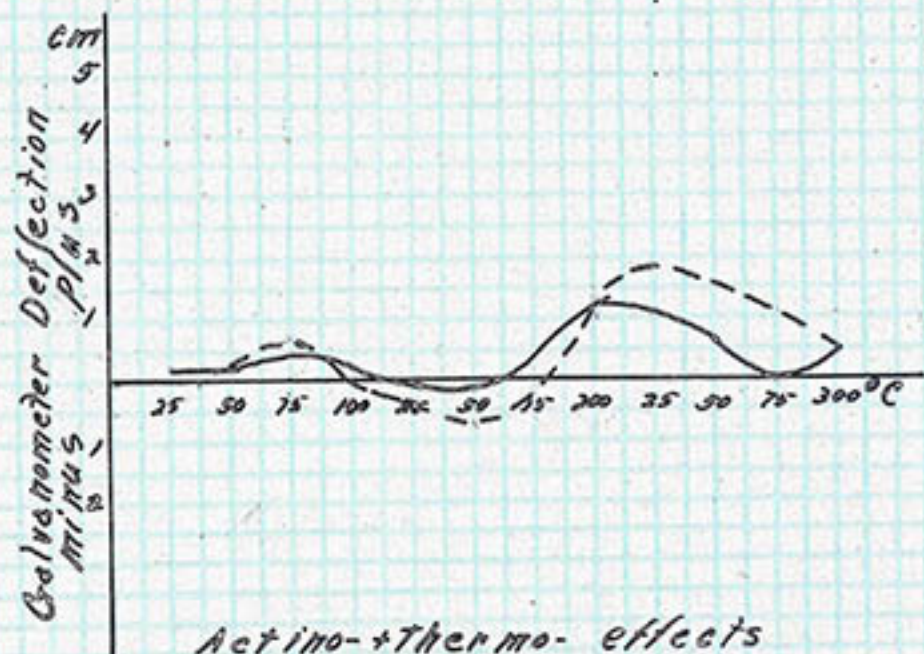


Fig. 22

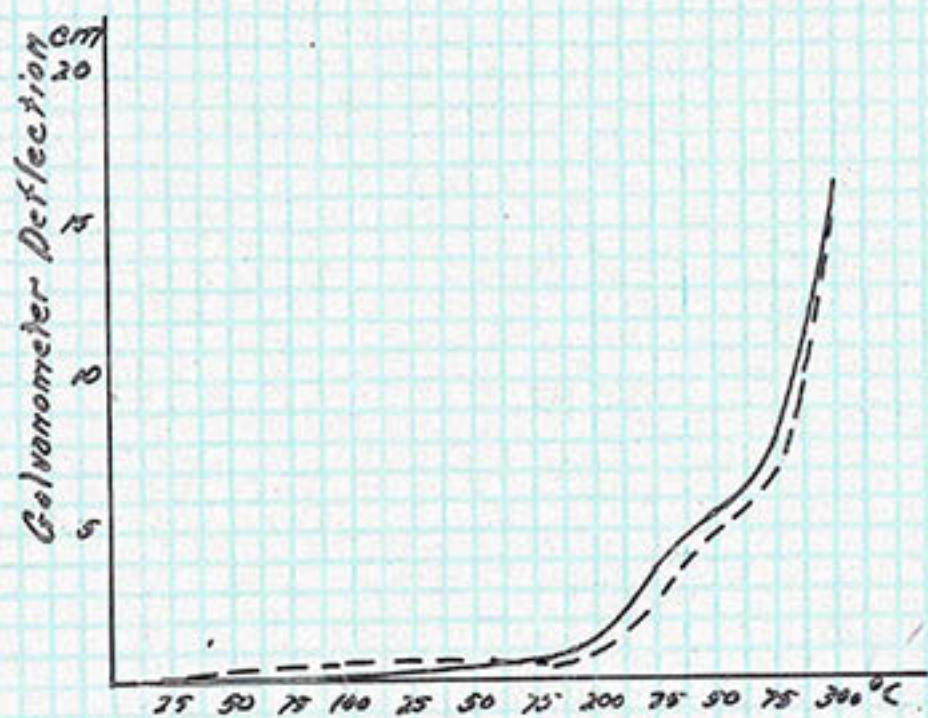
Sample 14

Thermo-electric effect

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	0	0	0			
25	0.1	0.1	0.1	0.1	0.05	0.75
50	0.1	0.1	0.1	0.1	0.1	0.1
75	0.15	0.15	0.15	0.2	0.25	0.225
100	0.15	0.2	0.175	0.2	0.25	0.225
125	0.25	0.25	0.25	0.3	0.4	0.35
150	0.5	0.5	0.5	0.25	0.3	0.275
175	0.85	0.8	0.825	0.5	0.5	0.5
200	1.1	1.2	1.15	0.8	0.8	0.8
225	3.4	3.6	3.5	2.4	2.6	2.5
250	5.6	5.6	5.6	5.7	5.2	5.45
275	8.9	8.6	8.75	8.2	8.7	8.45
300	15.5	16.0	15.75	Recovery Read Up		

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sample 14



Thermo-effect.

Fig. 28

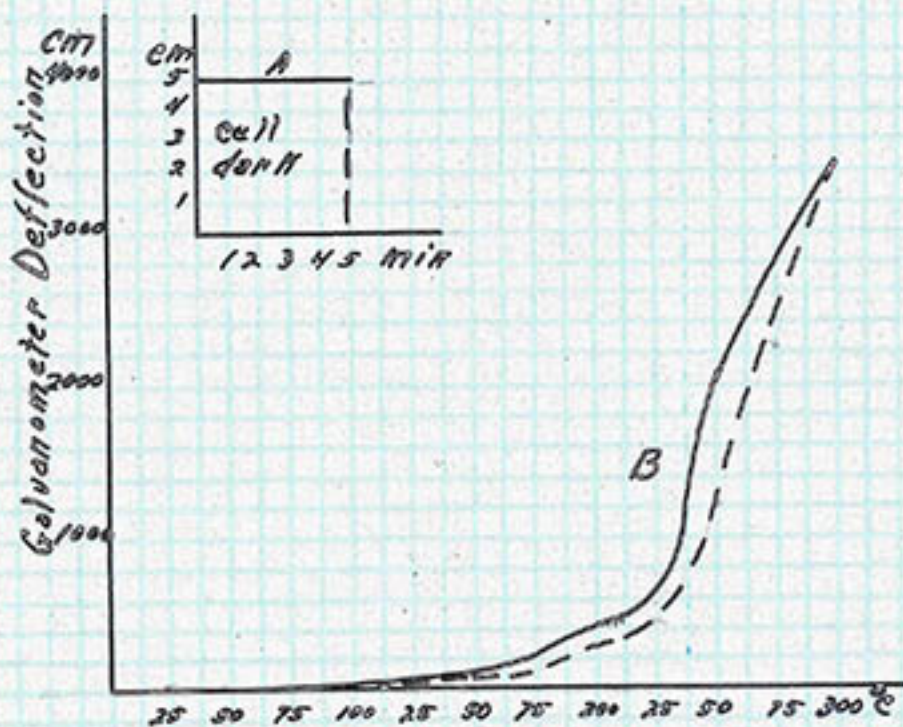
Sample 14

This sample gave a deflection of 5 cm with the e.m.f. in series but was not photo-resistant at room temperature

The effect of e.m.f., light, and heat

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	5	5	5			
25	5	5	5	6	6	6
50	12	12	12	9	9	9
75	25	25.6	25.3	18	18	18
100	36.5	35.8	36.1	26	26	26
125	91	93	92	81	81	81
150	141	143.5	142.2	124	124	124
175	201	201	201	163	163	163
200	432	425	424	330	340	335
225	562	597	579	465	540	500
250	2210	2300	2255	1240	1180	1210
275	2320	2900	2360	2410	2350	2380
300	3450	3500	3475	Recovery Read Up		

59
Sample 14



A = Conductivity due to e.m.f.

B = Conductivity due to e.m.f.
light and heat.

Fig. 24

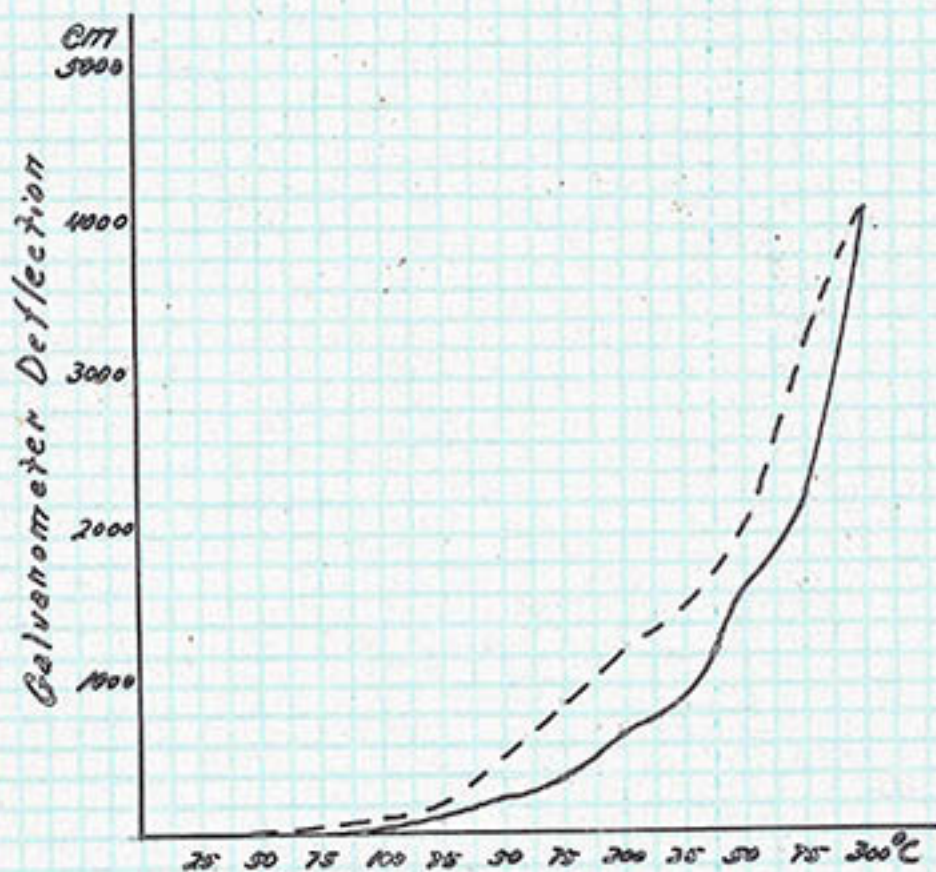
Sample 14

The effect of e.m.f. and heat

Temp. °C	Galvanometer Deflection in centimeters			Galvanometer Deflection in centimeters		
	Direct	Reverse	Average	Direct	Reverse	Average
0	11	11	11			
25	11	11	11	16	16	16
50	12	12	12	16	16	16
75	25	25	25	28	28	28
100	33	33	33	60	60	60
125	55	55	55	150	150	150
150	240	240	240	530	530	530
175	370	370	370	920	920	920
200	700	700	700	1330	1330	1330
225	830	830	830	1570	1590	1580
250	1630	1650	1640	2120	2120	2120
275	2320	2380	2350	3280	3280	3280
300	4100	4100	4100	Recovery Read Up		

61

Sample 14



Conductivity due to emf.
and heat.

Fig. 25

Summary

1. It has been found that the thermo-electric power of molybdenite may be positive (or negative) to that of the actino-effect and always increases with a rise in temperature.

2. The actino-electric reaction is found in samples of both low and high resistances, but the intrinsic value seems to be greater in samples of low resistance, a fact which is born out by an investigation by Coblenz¹¹. From the data at hand it seems that the actino-electric reaction is affected by the application of intense heat. Coblenz¹² found, for temperatures below 70° (the melting point of Wood's metal), the actino-electric phenomena to be independent of any agencies.

3. The photo-resistant effect of molybdenite is not affected by an increase in temperature. This statement was verified by turning off the light at different temperatures and noticing the deflection. Coblenz¹³ found that reducing the temperature did not affect the photo-resistant reaction.

11. Coblenz, W. W. "Some New Thermoelectric and Actino-electric Properties of Molybdenite". B. S. Bul. No. 486, p. 418. 1924.

12. Loc. Cit.

13. Loc. Cit.

4. The resistance of the samples was greatly reduced at high temperature. This is in accordance with an investigation conducted by Coblantz ¹⁴ in that he found the resistance to be increased with a decrease in temperature.

5. There is a slight variation in the readings for different effects of the same sample which may be attributed to a fatigue within the samples. Sample 14 was tested several times for the same phase and the readings were slightly less each time, but the general shape of the curves was the same for each test.

-
14. Coblantz, W. W. "Some Optical and Photoelectric Properties of Molybdenite". B. S. Bul. No. 338 p. 146. 1919.

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