REFLECTION AND TRANSMISSION OF ULTRA-VIOLET LIGHT BY SODIUM AND POTASSIUM.

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SYNOPSIS.

Reflecting power of K and Na, for wavelengths from 0.25 to 0.55 μ. (1) *Normal incidence* (10°). *Opaque mirrors* in contact with fused quartz were tested with monochromatic light from a mercury arc. A sodium photoelectric cell was used to compare the intensities of incident and reflected beams. It was found that sodium maintains a remarkably high reflecting power throughout the ultra-violet, increasing slightly from a flat minimum near 3600A to 80 per cent. at 2536A. The reflecting power of potassium on the contrary decreases rapidly with the wavelength, reaching the very low value of 11 per cent. at 2536A. *A thin film of potassium* deposited and kept at $-190°$ C. gave a curve of the same form. Among the metals so far investigated in the ultra-violet, therefore, sodium and potassium have respectively the highest and lowest reflecting powers. (2) *Polarized light at 45° incidence.* The ratio of the reflecting powers for light polarized with the electric vector respectively parallel and perpendicular to the plane of incidence, was found for both sodium and potassium to have a maximum value near 3650A. There is also a common minimum at about 3341A which is far more pronounced in the case of sodium.

Transmitting power of K and Na films for wave-lengths from 0.25 to 0.55 μ. Films deposited on quartz and on glass at liquid-air temperatures were studied while still cold by the use of a special apparatus and compared with the ordinary colloidal films prepared at room temperature. The results are shown graphically. Under comparable conditions, the transmitting power of potassium is considerably greater than that of sodium.

Thin films of K and Na deposited at $-190°$ C. on quartz have a metallic *appearance;* on being warmed a thin film becomes peppered with holes and an opaque film loses its luster.

CONTENTS.

A STUDY of the reflecting power of the alkali metals in the ultra-violet is of special interest in connection with the selective photoelectric effect. Since this property of metals probably points to a resonance phenomenon, it seems possible that a knowledge of the optical properties may throw some light on the mechanism of this effect. The relation between the electron emission and the light absorption in the selective effect does not appear to be a direct linear one, such as seems to exist in the normal effect for a given wave-length.

The alkali metals, especially sodium and potassium, are highly reflecting in the visible spectrum, with large extinction coefficients and extremely small refractive indices. Drude's[1] values of the index of refraction of sodium and of the extinction coefficient, obtained by analyzing the state of polarization of yellow light reflected from the surface of the molten metal, were the only data available until the work of R. W. and R. C. Duncan[2] who, using Drude's method, determined the optical properties of both sodium and potassium as a function of the wave-length in the visible region. The metals were used in the solid form backed by glass. The first direct method for the determination of the reflecting powers of these metals was used by Nathanson[3] for sodium, potassium and rubidium, with white light and monochromatic polarized light for the region 6409–4546 Å. He also used the solid metal backed by glass. The intensity of the light was measured by means of a photoelectric cell, connected to an electrometer.

The well-known "selective effect" of the alkali metals and a few other metals offers a particularly promising field of research for the relations existing between the ejected electrons and the atoms. It was with the hope of throwing some light on this subject that this investigation of the reflecting powers of sodium and potassium through the regions in which the selective effect occurs has been attempted. Elster and Geitel[4] were the first to show that the selective effect is directly concerned with the position which the electric vector in the incident light has relative to the metallic surface; that is, the photoelectric current is a maximum when the plane of polarization is perpendicular to the plane of incidence (*i.e.*, the electric vector is in the plane of incidence), and is a minimum when these planes are parallel (*i.e.*, the electric vector is at right angles to the plane of incidence). Pohl and Pringsheim[5] have

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[1] Drude, Annalen der Physik, 64, 159, 1898.

[2] R. W. and R. C. Duncan, Physical Review, 36, 294, 1913.

[3] Nathanson, Astrophysical Journal, 44, 137, 1916.

[4] Elster and Geitel, Annalen der Physik, 52, 540, 1894; 55, 684, 1895; 61, 445, 1897.

[5] Pohl, Physikalische Zeitschrift, 10, 542, 1909. Pohl, Deutsche Physikalische Gesellshaft, 11, 339 and 609, 1909. Pohl and Pringsheim, Deutsche Physikalische Gesellshaft, 12, 215 and 349, 1910.

determined the photoelectric current as a function of the wave-length, both for $E_{||}$ and $E_{\perp}$, as well as for unpolarized light incident at some angle different from zero (corresponding to $E_{||}$). These results have been embodied in the familiar diagram reproduced here.

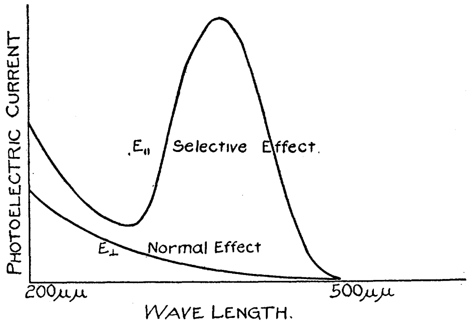

Fig. 1.

The ordinates represent the amount of electron emission for equal amounts of energy in the exciting light.

The ratio $E_{||}/E_{\perp}$ gives a curve similar to $E_{||}$ and yields the same value of λ for the maximum of the selective effect.

The conclusion from their work and that of others is that when the electric vector in the incident light has a component perpendicular to the metal surface illuminated, the resulting electron emission, called the selective effect, increases enormously for a number of elements, the maximum values occurring at definite values of λ. For sodium and potassium these values are as follows:

Na: λ = 340 μμ (Pohl and Pringsheim)[1]
360 μμ (Richardson and Compton)[2]
K: 436 μμ (Pohl and Pringsheim)[3]
440 μμ (Braun)[4]

A study of the velocities of the electrons emitted in the normal and selective effects was made by Hughes,[4] but these values proved to be only slightly different from each other. The difference in the mechanism of the normal and selective effects is still left undetermined—beyond the fact that the former suggests an action of free electrons, the latter of electrons in the atoms, of frequencies characteristic of the metal.

The work of Richardson and Compton[7] has shown a maximum photo-

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[1] Pohl and Pringsheim, Deutsche Physikalische Gesellshaft, 14, 49, 1912.

[2] Richardson and Compton, Philosophical Magazine, 26, 549, 1913.

[3] Braun, Dissertation, Bonn, 1906.

[4] Hughes, Philosophical Magazine, 31, 100, 1916.

electric current to exist even for the normal effect, that for sodium for instance occurring at 227 $\mu\mu$. The photoelectric activity of metals is evidently a complicated phenomenon. Investigation of the optical properties of metals for wave-lengths covering these " normal " maxima would also be of interest.

Preparation of the Mirrors, and Means of Support.

The metal surfaces used were of two kinds: those of the solid metal in a lump against quartz, such as had been used by R. W. and R. C. Duncan and by Nathanson; and thin films of the metal deposited on quartz by evaporation at the temperature of liquid air. The arrangement for making mirrors of the first kind is shown in Fig. 2. Pieces of sodium or potassium are placed in a small tube and slipped into the end A, which is then sealed off. The apparatus is heated locally with a Bunsen flame to drive off water vapor and gases, particularly from the plate Q which is of fused quartz. Crystalline quartz is very likely to crack when the hot metal is poured over. The pump is kept in action until the pressure has become fairly low and perfectly steady. Parts A and B are now placed inside a can and heated slowly, and the gas evolved is pumped off. In time the metal distils over into C, where it collects in a small pool. After the apparatus is sealed off from the pump the molten metal is poured over into D and brought into contact with the quartz plate. If the cooling of the metal takes place slowly and uniformly, and if the quartz is clean, the metal shows little tendency to withdraw from the quartz surface and the resulting mirror presents a fairly large area free from blemishes. Mirrors that are dotted over with small holes result from too rapid or non-uniform cooling. Bulb D is cracked open, the quartz plate with the metal adhering to it is removed, and " half and half " is quickly applied until the metal is made air-tight. Mirrors of sodium and potassium made in this way kept very well during many weeks, apparently without any deterioration. During the damp days of spring the metals showed a tendency to oxidize around the edges, hence special precautions are necessary to preserve them.

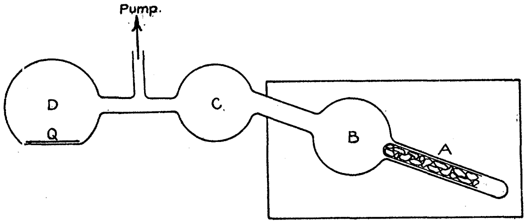

Fig. 2.

For purposes of support, a glass plate is sealed on parallel with *Q*. The mirror is supported vertically (see Fig. 3) against a brass plate, held rigidly, in which had been drilled a hole 5 mm. in diameter.

The mirror was pressed against three pins in the brass plate, by a tight spring surrounding a brass rod that touched the glass plate. With this arrangement the mirrors could be replaced with great accuracy in the same position relative to the hole, which was very essential for readings that could be reproduced. The front side of the brass support was blackened with soot. The light was incident on the mirror at an angle of 10°.

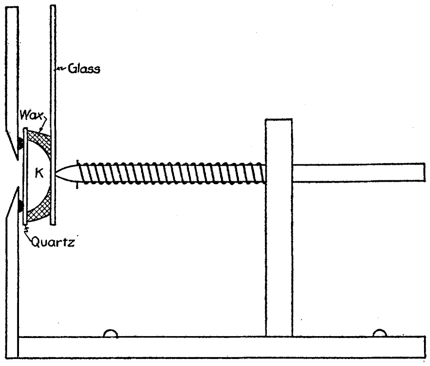

Fig. 3.

The making of metallic films of sodium and potassium by cooling the glass or quartz surface to the temperature of liquid air was suggested by Prof. R. W. Wood.[1] A small amount of metal is distilled over on to the surface of a bulb, similarly to the method already described (see Fig. 2), except that *A* is heated locally, driving the metal to *B*, and is then sealed off from the apparatus. *B* is then heated sending the metal to *C*, and is also sealed off. Two distillations are usually sufficient. The quartz plate is now placed in *C*. The apparatus is now removed from the pump, and bulb *D*, of various shapes and sizes according to the nature of the experiment, is cooled down to $-190°$ C, as is also the lower part of *C*, containing *Q*. A small flame is then applied to the upper part of *C*, thus vaporizing the metal, some of which deposits on the cold quartz plate below. When conditions are favorable the resulting film has a truly metallic appearance, quite different from the colloidal film formed at ordinary temperatures. On warming up to room temperature, a thin film becomes peppered with holes and appears to evaporate; an opaque film loses its luster.

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[1] R. W. Wood, Philosophical Magazine, 38, 98, 1919.

Measurement of Intensity.

As in Hulbert's[1] and in Nathanson's[3] work, the intensity of the reflected light was measured directly by means of a photoelectric cell. This was a bulb coated with sodium, with a short tube about 1 cm. in diameter carrying a fluorite window. This cell, which was used by Dr. E. O. Hulburt, in his research on reflecting power of metals, obeys the law of direct proportionality between the light intensity and the photoelectric current, through a range of intensities far exceeding those used in the present work. This was tested by varying the distance between the cell and a tungsten lamp. A later test for monochromatic light (4358 Å. and 3130 Å.) gave the same result. Except at the anode and window the cell was covered with tinfoil, which served very well to remove charges from the surface of the glass. It was found advisable to keep the cell in a box in order to make the "dark leak" small. The anode, which was connected to a sensitive electroscope, was charged to 110 volts; the cathode and case of electroscope were earthed. In the winter the dark leak took 20 to 30 minutes, while many of the actual readings for the intensity of the reflected light occupied 10 to 20 seconds. In the spring the dark leak was greater. It is measured by taking the rate of motion of the gold leaf when the mirror is removed from the brass support (see Fig. 4 below).

Normal Incidence.

Arrangement of Apparatus.—This is shown in the following diagram. The apparatus was set up in a dark room, and suitable screens were used to protect the mirror M from all light except that passing through S_2. The source of light was a mercury arc in quartz, designed by Dr. A. H. Pfund, and run on storage batteries at 120 volts. This lamp runs very steadily for hours, giving light of constant intensity. The light is passed through a quartz spectrograph so designed (by Dr. Pfund[2]) that the different wave-lengths were brought into focus at the slit by a single rack and pinion adjustment. The first slit (towards the arc) was 1 mm. in width, the second slit was .6 mm.; these were kept the same throughout. The intensities of the lines in the arc differ greatly. The more intense lines were cut down by the use of suitable screens in front of S_1; narrowing S_1 failed to give reproducible results.

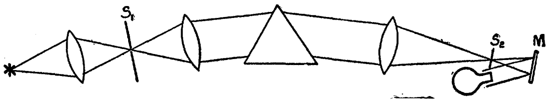

Fig. 4.

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[1] Hulburt, Astrophysical Journal, 42, 205, 1915.

[2] Pfund, Physical Review, 7, 29, 1916.

Since the reflecting power of mercury against quartz has been determined with accuracy by Hulburt[1] in the ultra-violet, using a direct method with a photoelectric cell, and by Meier[2] in the visible spectrum and partly in the ultra-violet using the katoptric method, a comparison method with mercury was decided upon for the present investigation. The procedure is to place the mirrors in succession—say mercury, sodium, potassium, mercury—in the brass support at M, reading for each the rate of fall of the gold leaf. The second setting of the mercury mirror serves as a check on the constancy of the incident light. The readings obtained for a given set of mirrors for different sets of observations differed by not more than 6 per cent.

COMPUTATION[13] AND RESULTS.

If r is the reflecting power of quartz,

R_q is the reflecting power of sodium or potassium in contact with quartz,

R' is the reflecting power of the whole mercury mirror,

i is the photoelectric current due to the light reflected by the whole sodium or potassium mirror,

i' is the photoelectric current due to the light reflected by the whole mercury mirror,

then, to a fair approximation,

$$R_q = \frac{\frac{i}{i'}R' - r}{(1 - r)^2}.$$

The value of r is computed from Fresnel's formula $\left(\frac{n-1}{n+1}\right)^2$; the appropriate values of n, the refractive index of quartz, are interpolated from those determined by Martens.[15] The values of i and i' are inversely proportional to the rate of leak of the electroscope (corrected when necessary for the dark leak).

Some of the results are shown in Table I., where i_{Na}/i'_{Hg} is the ratio of the intensities of the reflected light from the whole sodium mirror and the whole mercury mirror respectively. The number of seconds given in parentheses is the original reading, not corrected for the dark leak. The corrected reading is the one directly below. R_q is the reflecting power of the metal in contact with quartz. The reflecting power of the metal alone, found by Ingersoll's[4] method, is only a few per cent.

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[1] Hulburt, Astrophysical Journal, 46, 1, 1917.

[2] Meier, Annalen der Physik, 31, 1017, 1910.

[3] Martens, Annalen der Physik, 6, 603, 1911.

[4] Ingersoll, PHYSICAL REVIEW, 29, 392, 1903.

higher. The results given here are not of sufficient accuracy to warrant its use. R_q' is the value R_q (for potassium) assumes when multiplied by a suitable factor. This factor is obtained by comparing the value of R_q for λ 5461 Å. with that given by Nathanson[3] for normal incidence.

The graphs shown in Fig. 5 represent the average values of R_q for the two metals taken from many sets of observations. It is interesting

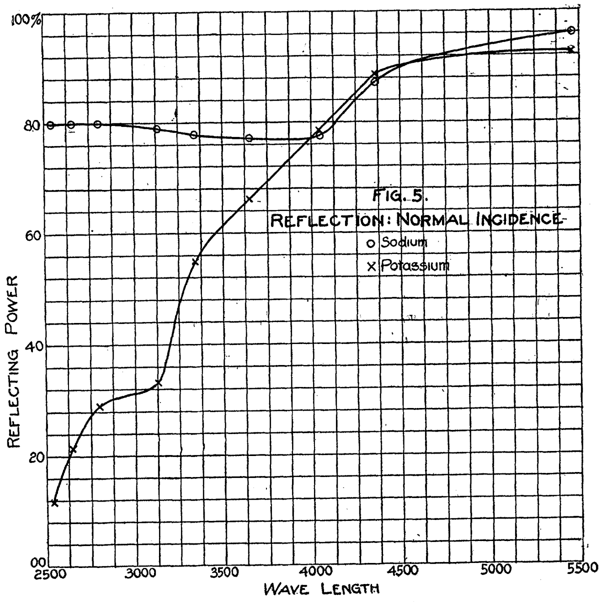

Fig. 5.

that the reflecting power of sodium shows a minimum in the region in which the maximum of the selective effect occurs. Although the angle of incidence was small, the electric vector had a small component perpendicular to the surface of the mirror. Since a greater energy of emission in the form of electrons suggests a greater absorption of light for this wave-length, a diminution in the reflecting power of sodium might be expected. A second point worthy of notice is the high reflecting power of sodium in the ultra-violet—nearly 80 per cent.; this is higher than for any other substance that has been investigated.

The curve for potassium on the other hand shows a rapid decrease in the reflecting power with wave-length, the decrease setting in rapidly below 4358 Å. the wave-length at which the maximum of the selective effect for potassium occurs. The abrupt decrease at 3130 Å. and slight decrease at 2804 Å. may possibly mean that a maximum photoelectric current for the normal effect is to be expected in the vicinity of 3130 Å.

TABLE I.

Wave-length.	Reflection from Sodium. No. of Seconds. Hg.	Na.	$\frac{i_{Na}}{i'_{Hg}}$.	R'.	R_q.	Reflection from Potassium. No. of Seconds. Hg.	K.	$\frac{i_K}{i'_{Hg}}$.	R_q.	R'_q.
5461	21.2	15.2	1.40	66	96.0	21.2	19.4	1.10	73.4	92.5
	21.4	15.2				21.4	19.4			
	(35.6)	(26.0)	1.39			(35.6)	(33.7)	1.06		
	37.1	26.8				37.1	35.1			
4358	14.2	10.6	1.35	62	87.5	14.2	12.6	1.12	69.7	88.0
	13.8	10.2				13.8	12.4			
	13.0	9.5	1.37			13.0	12.0	1.08		
4047	14.2	10.5	1.35	57	80.5	14.2	12.9	1.10	62.7	79.0
	13.2	9.6	1.38			13.2	12.3	1.07		
3650	20.2	14.0	1.40	55	78.5	20.2	18.6	1.08	59.5	74.0
	20.4	14.8				20.4	18.8			
	15.4	11.2	1.37			15.4	14.4	1.06		
	14.8	10.8				14.8	14.2			
	15.2					15.2				
3341	13.8	10.0	1.38	55	78.0	13.8	16.0	.86	46.0	58.0
	13.6	9.8				13.6	16.0			
	15.2	10.6	1.37			15.2	18.0	.84		
	15.0	11.0				15.0	18.0			
		11.0								
3130	22.0	16.0	1.38	55	78.0	(22.0	(40.2	.54	26.4	33.2
	22.0	15.8				22.0)	39.8)			
						22.6	41.7			
	18.0	12.8	1.40			(18.0	(34.4	.51		
	17.8	12.8				17.8)	34.4)			
						18.2	35.8			
2804	(173)	(127)	1.44	55	80.0	(173)	(318)	.43	20.0	25.2
	215	149				215	503			
	(324)	(273)	1.36			(324)	(466)	.40		
	629	464				629	550			
2653	(173)	(129)	1.43	55	81.0	(173)	(388)	.32	14.0	17.6
	215	150				215	675			
	(167)	(124)	1.42			(167)	(369)	.33		
	204	144				204	622			
2536	(63.2	(47.2	1.38	55	78.0	(63.2	(213	.25	8.4	10.6
	64.0)	46.8)				64.0)	213)			
	68.5	49.5				68.5	278			
	(65.0	(48.6	1.35			(65.0	(231)	.22		
	64.4)	49.0)				64.4)				
	69.5	51.5				69.5	309			

However, line 2804 A. has a very low intensity and perhaps not much importance can be attached to this value.

A second set of sodium and potassium mirrors backed by the same quartz plates gave similar curves with the exception of the minimum of sodium, which occurs slightly farther towards the short wave-lengths.

No other change was made in the apparatus except for the hole in the brass support, which was enlarged to 8 mm.

Oblique Incidence: Polarized Light.

A Rochon prism, one part of which was quartz and the other part calcite, cemented with glycerine, was used as polarizer. In the path of the light from S_2 was placed a quartz lens, following this the Rochon prism, finally the mirror at the focus of the lens in such a position as to receive only one image. The angle of incidence used was 45°. Since the quartz plates backing the metals are fused, and nothing is interposed between the Rochon prism and the mirror, the state of polarization of the light is known as the metal-quartz surface. The ordinary ray was used, with the electric vector either in the plane of incidence or perpendicular to it, effected by turning the prism through 90°. The extraordinary ray fell beyond the mirror on the soot-blackened surface of the brass support. The intensity of the ordinary ray when polarized so that the electric vector is in the plane of incidence was not the same as when it was polarized so that the electric vector is perpendicular to the plane of incidence, except for two of the lines used. The ratio of the two was found by removing the brass support and placing the photoelectric cell in the direct beam of light. Two methods were used (see Fig. 6); that of focussing the light just within the window of the cell, so that the cell receives practically the whole beam of light; and that of placing the window of the cell in the diverging beam so that the central part of the image is on the window. The two methods agreed within 5 per cent., which is as accurate as could be expected. Because of deficiencies of the Rochon prism, the image shifts sidewise and downward when the prism is turned; the mirror (8 mm. diameter) is sufficiently large to accommodate this shift, but the reflected image travels away from the window of the cell. Hence it became necessary to adjust the cell for each adjustment of the Rochon prism. Lines 3341 Å. and 3130 Å. lose greatly in intensity on passage through the prism; hence the difficulty of setting the cell accurately for the reflected images of these lines became very great. A large number of observations have been made, but not much accuracy can be claimed for the values obtained. An error of 10 per cent. or even more is highly probable.

Fig. 6.

The wave-lengths below 3130 Å. were absorbed by the prism.

Whether the cell is used for the direct beam or the reflected beam, the direction of the electric vector relative to the sodium surface of the cell remains the same, because of the spherical shape of the cell.

The ratio of the intensities of the reflected beams $E_{\parallel}/E_{\perp}$ was investigated as a function of the wave-length. The sodium or potassium mirror having been adjusted in the brass support and the spectrograph set for a given wave-length, the rate of leak of the electroscope was found for each component. This ratio, when plotted against the wave-lengths, should yield the information desired in relation to the photoelectric effect, if any marked change in the reflection occurs: that is, such a curve would correspond to the $E_{\parallel}/E_{\perp}$-photoelectric current curve referred to on page 2?

Some of the data are shown in Table II. The first numbers in the seventh column are obtained by taking the inverse ratio of the rates of leak in columns two and three; and similarly for the eighth, fourth and fifth columns.

TABLE II.

Wave Length.	Polarized Light. Angle of Incidence 45°.						
	Time in Seconds.				Ratio of Intensities $E_{\parallel}/E_{\perp}$.		
	Na.		K.		Incident Light.	Reflected Light Na.	Reflected Light K.
	$E_{\parallel}$.	$E_{\perp}$.	$E_{\parallel}$.	$E_{\perp}$.			
5461	29	24	17.0	12.6	.91	.83 ÷ .91 = .91	.74 ÷ .91 = .81
	30	25	17.2	12.6			
4358	10.6	9.6	21.6	17	.93	.90 ÷ .93 = .97	.79 ÷ .93 = .85
	10.8	9.6					
4047	9.6	8.8	27	24	1.03	.92 ÷ 1.03 = .89	.9 ÷ 1.03 = .88
	9.8	9.0	26	24			
3650	7.6	9.2	18	19.4	1.0	1.21 ÷ 1 = 1.21	1.09 ÷ 1 = 1.09
			17.8	19.6			
3341	(49)	(38)	29.8	23			
	(50)	(37)	30	23.6	1.0	.73 ÷ 1 = .73	.78 ÷ 1 = .78
	56	41					
3130	17	14.2	15	10	.77	.82 ÷ .77 = 1.06	.68 ÷ .77 = .88
	17.2	14	14.6	10			

The graphs of Fig. 7 represent the average of a number of observations. The maximum in the neighborhood of 3650 Å., common to both metals, is rather striking, but undoubtedly is due to the metals and not the quartz, the reflection of which for unpolarized light is less than 6 per cent. at 45°. It cannot be due to a "selective effect" from the cathode of the cell, for the reason given above. The minimum for sodium in the neighborhood of 3341 Å. together with the maximum at 3650 Å. shows a decided change in the reflecting power for the two beams polarized at right angles, through the range of wave-lengths in which the maximum of the selective effect occurs. When the electric vector is so directed that it has a component perpendicular to the illuminated surface of the metal, it appears that at the critical wave-length of the selective effect less light energy is reflected by the metal, hence more is absorbed. This is not what might have been expected from the usual point of view, that the selective effect is due to a large absorption of energy near the surface—that is, the extinction coefficient becomes large, from which a higher reflecting power is expected. According to Nathanson's data the ratio $E_{\|}/E_{\perp}$ is less than unity in the visible spectrum for 45° incidence, although his value for potassium is considerably higher than the one given here.

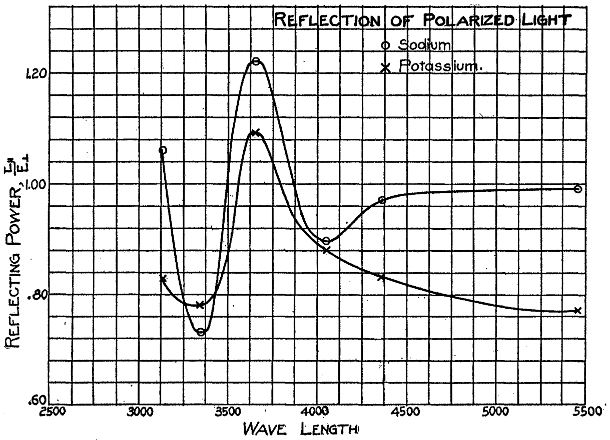

Fig. 7.

Potassium again fails to show any marked deviation at 4358 Å., but this may possibly be due to the absence of data in the interval 4358–5461 Å. Without this corresponding minimum for potassium it is hardly possible to draw any conclusions as to whether there is or is not a direct connection between the reflecting powers of the metals and the selective effect. This work must be regarded only as a preliminary attempt.

Films Deposited at Low Temperatures.

An attempt has also been made to get the reflecting power of potassium, and the transmitting power of potassium and sodium, using films of the metals deposited on quartz plates and glass plates at low temperatures. The apparatus for the reflection is represented in Fig. 8. Bulb A is coated with potassium which has been distilled over from tubes similar to those shown in Fig. 2. In the bottom of this bulb is a piece of glass half of which is plated with nickel (deposited by cathode sputtering). This half is covered by a piece of metal C which rests on M, but can readily be shaken off. On the lower side of M is attached a piece of iron, by means of which M can be manipulated with a magnet. In the bulb B is a piece of brass with a groove in which M can slide back and forth. Q is a quartz window. The lower half of B and the lower part of A are placed in vessels containing liquid air. When sufficient time has elapsed to allow the cooling to take place, by means of a small flame the potassium is driven down from the top of A on to the uncovered part of M. Opaque films only were used. M is now brought quickly over into B, which is kept in liquid air throughout this experiment.

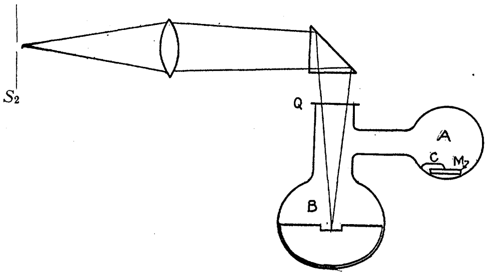

Fig. 8.

The light from S_2 (see Fig. 8) was passed through a quartz lens, then by means of a right-angled quartz prism was directed downward, almost vertically, through Q on to M, which is now in the groove in B. By means of a magnet the nickel surface and the potassium surface were in turn brought into the center of the groove, and reflected back the light through Q, into the photoelectric cell. In this case nickel served as the comparison mirror. The values of the reflecting power of nickel are taken from those given by Hagen and Rubens[1] in the visible spectrum, and by Hulburt[11] in the ultra-violet spectrum. The reflecting powers of the two metals are approximately inversely proportional to the rates of leak of the electroscope. Due to the presence of gases or impurities on the glass M these mirrors were somewhat cloudy. The reflection curves in general follow the one shown for potassium in Fig. 5, but the values are somewhat low.

For the transmitting power, a form of apparatus such as is shown in Fig. 9 was used. A glass tube with two quartz windows Q_1, Q_2 contained a metal partition P with a hole H. The part of the tube at P was kept

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[1] Hagen and Rubens, Annalen der Physik, 1, 352, 1900.

cold by means of cotton batting soaked with liquid air. Part of bulb *A*, containing the quartz plate *Q*, was cooled in liquid air, and as before the potassium was driven on to *Q* by heating *A* gently with a small flame. (Bulb *B* contains the sodium.) *Q* was then brought quickly into the main tube up against *P* so that *H* was completely covered. The tube was so supported that it could readily be moved into the beam of light or out of it. Thus the cell received in turn the transmitted beam and the direct beam. It is also a simple matter to remove the film of metal from *Q* and to measure the loss of intensity of the incident light due to Q_1, Q_2 and *Q*; and by removing *Q* the loss of intensity due to Q_1 and Q_2. The transmitting power of the film is then readily computed.

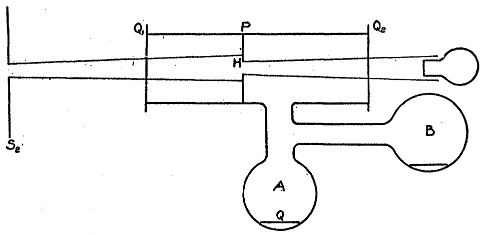

Fig. 9.

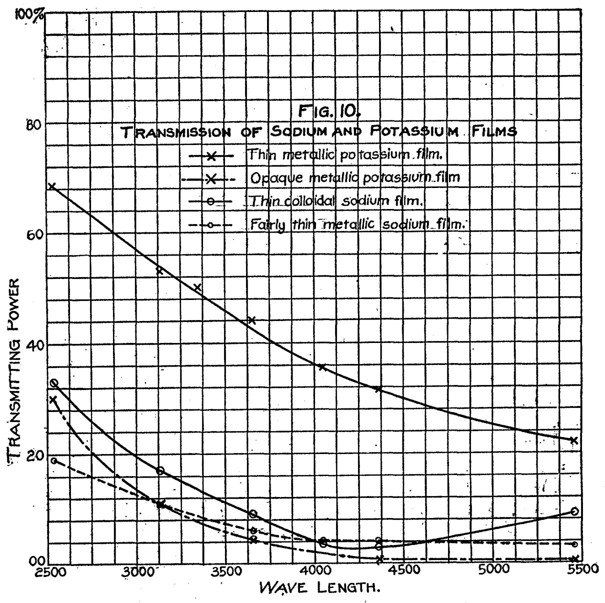

Fig. 10.

The results are shown for a few films in the graphs of Fig. 10. The divergence of the curves for the metallic and colloidal films is noticeable, particularly in the visible region. The most striking fact is the greater transmitting power of potassium.

SUMMARY.

1. The reflecting powers of sodium and potassium surfaces backed by quartz have been determined directly for normal incidence (10°), as a function of the wave-length, for the range of wave-lengths 5461 Å.–2536 Å. Sodium is the best reflector known in the ultra-violet region, giving 80 per cent. at 2536 Å.; potassium is the worst reflector in the ultra-violet, giving 11 per cent. at 2536 Å. In the case of sodium, there is evidence of a flat minimum in the neighborhood of 3300 Å–3600 Å.

2. The reflecting power of these surfaces for polarized light has been measured in the region 5461 Å.–3130 Å. by a determination of the ratio $E_{\|}/E_{\perp}$ as a function of the wave-length ($E_{\|}$ is the intensity of the reflected light when the electric vector of the incident light is parallel to the plane of incidence, $E_{\perp}$ the intensity of the reflected light when the electri-vector of the incident light is perpendicular to the plane of incidence); Both metals show a maximum value of this ratio in the vicinity of 3650 Å.. sodium shows a decided minimum in the vicinity of 3341 Å.

3. Metallic films of the two metals have been deposited at low temperac tures, and the reflecting and transmitting powers of these films examined. This promises to be a fruitful field of research, as the photoelectric current and optical properties can be examined as a function of the thickness of the film.

The transmitting power of potassium is decidedly higher than that of sodium.

It gives me great pleasure to express my gratitude to Professor Ames for his interest throughout the course of this work, and to Professor Pfund, who proposed the problems taken up, and whose assistance and helpful suggestions have made the execution of the work possible.

BIOGRAPHICAL NOTE.

Mabel Katherine Frehafer, daughter of Charles Milton Frehafer and Caroline (Ball) Frehafer, was born in Philadelphia on July 7, 1886. Her early training was received in Philadelphia. In 1904 she entered Bryn Mawr College, and in 1908 received the degree of Bachelor of Arts. She held a scholarship at Bryn Mawr from the City of Philadelphia for the years 1904–8. During the year 1908–9 she was a graduate student in physics and mathematics at the University of Wisconsin, and in 1909 received the degree of Master of Arts. She was appointed fellow in physics at Bryn Mawr College for the year 1909–10. From 1910–14 she was demonstrator in physics at Bryn Mawr College. She was enrolled as a student of physics and mathematics in the summer school of Wisconsin in 1914. During the year 1914–15 she was half time assistant and student at the University of Wisconsin. For the first semester of 1915–16 she was full time assistant at Wisconsin, and for the second semester teacher of physics in the Germantown High School for girls, Philadelphia. For two years beginning 1916 she was instructor in physics at Mt. Holyoke College. She entered Johns Hopkins University as a graduate student in October, 1918, making physics the principal subject, mathematics the first subordinate, and chemistry the second subordinate. She attended courses in physics and mathematics given by Professor Ames and Dr. Murnaghan.