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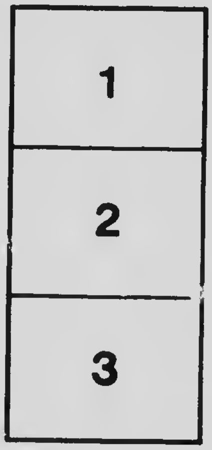

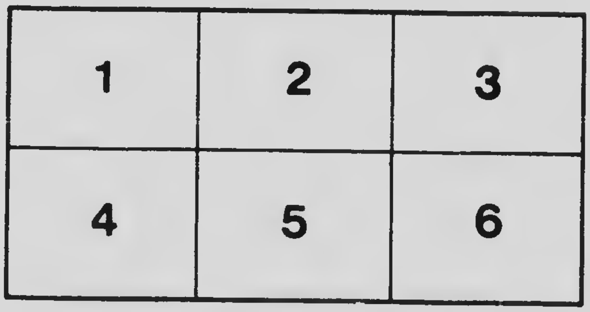

UNIVERSITY OF TORONTO STUDIES

PAPERS FROM THE PHYSICAL LABORATORIES

No. 72: ABSORPTION OF LIGHT BY THIN FILMS OF RUBBER, BY E. R. I. PRATT

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Absorption of Light by Thin Films of Rubber

By E. R. I. PRATT, M.A., UNIVERSITY OF TORONTO

Presented by E. F. BURTON, F.R.S.C.

(Read May Meeting, 1919.)

Considerable work on the influence of light on rubber has been done by Victor Henry. In his investigations he experimented with pure unvulcanized rubber, and with vulcanized rubber cured in different ways.

The pure rubber as obtained from Para sheets was exposed to the rays of a mercury vapour lamp for several hours. The samples exposed in this manner showed considerable change in colour and lost their elasticity, being readily torn. The change in the rubber appeared to depend on the colour of the original sheet, the dark brown sample being altered at the surface only, while the "yellow plantation" was changed through a considerable thickness. The vulcanized samples had to be left for a much longer period than that of the unvulcanized before any apparent change was noted.

An effort was also made to determine what particular part of the spectrum was most injurious to the rubber. He arrived at the conclusion that the rays below 3000 A. are the most active in this respect. Some of the rays between 4000 and 3000 A. were strongly absorbed, but the most refrangible rays are the particular agents which alter the rubber, the unvulcanized samples being altered most.

The foregoing results were confirmed during the course of the preliminary work in the present investigation, and prove conclusively that light has a very great influence on rubber and that certain wave lengths are more active than others in this respect. Beyond ascertaining the effect of light on rubber in changing its appearance, elasticity and general physical properties, no attempt was made, by previous investigators, to obtain in a quantitative way the absorption of light for different parts of the spectrum.

The purpose of this investigation was to ascertain in a quantitative manner the amount of light absorbed by rubber and how it varied for different wave lengths.

Pure Para rubber sheets were obtained, light brown in colour and several millimetres thick. Efforts were made to cut the sheets into thinner ones, for this purpose a microtome being used, but owing to the great elasticity of the rubber this method had to be abandoned as also an attempt made with a freezing microtome Thin slices were ultimately obtained by freezing the rubber in liquid air and then cutting it with a sharp knife or razor. Slices obtained in this way were still too thick for satisfactory work and it was necessary to obtain sheets which had been rolled out by mechanical means. These were quite thin and could be readily used in all experimental work.

Preliminary tests were made to determine whether there were any absorption bands produced in a continuous spectrum. A quartz uviol spectrograph was used for this determination. As a source of light, a Nernst lamp was used, and also an arc in which different metals could be inserted as terminals. A photograph of the spectrum produced by the Nernst was first obtained and directly below it a photograph of the spectrum after it had passed through a thin sheet of rubber mounted directly in front of the slit of the spectrograph. In this way the two spectra could be readily compared and their characteristics noted.

The photographs obtained show that rubber absorbs light and that the more refrangible rays are more readily absorbed, so that any change or alteration in the characteristics of the rubber must be due principally to these rays. These results are, however, not sufficiently quantitative in nature to warrant any definite assumption as to the amount of light that is being actually absorbed.

The second stage of the experimental work was undertaken with the object of determining more definitely in a quantitative way a measure of this absorption. A suitable method of investigation is afforded by the photo-electric cell. The cell used in this work was of the round bulb type, about 5 cm. in diameter and made of glass. The arrangement of the apparatus was as shown in the following diagram. (Fig. 1.)

The source of illumination (A) was a Nernst lamp, the filament of which was focused by a quartz lens (L) on the slit of a monochromatic illuminator (M). The light on emerging from (M) fell on the photo-electric cell (C), the silvered surface being charged to a potential of 6 volts by a battery (B). The filament of the cell was joined through insulated connections to one pair of quadrants of a quadrant electrometer (Q), the other pair of quadrants being earthed. The quadrants joined to the cell could be earthed by the earthing needle (N). The needle of the electrometer was charged to a constant high potential by a Tucker Hydroscopic Battery (H). The electrometer when adjusted had a sensibility of 330 divisions per volt. The sensibility curve is shown in Fig. 2.

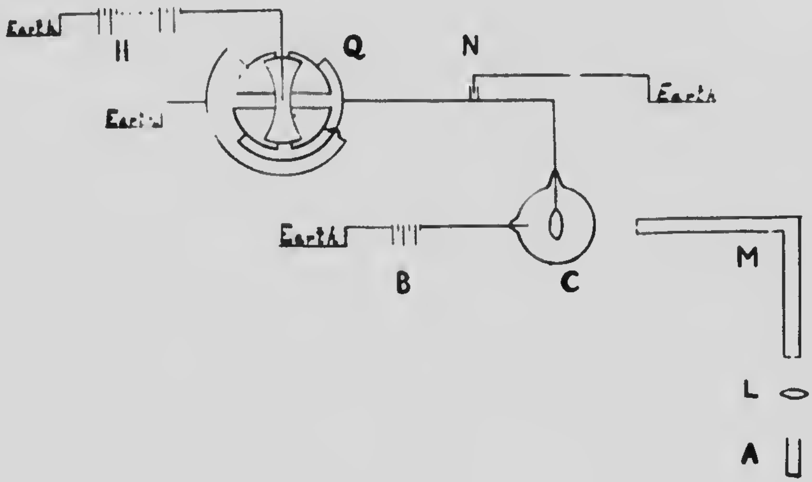

Figure 1

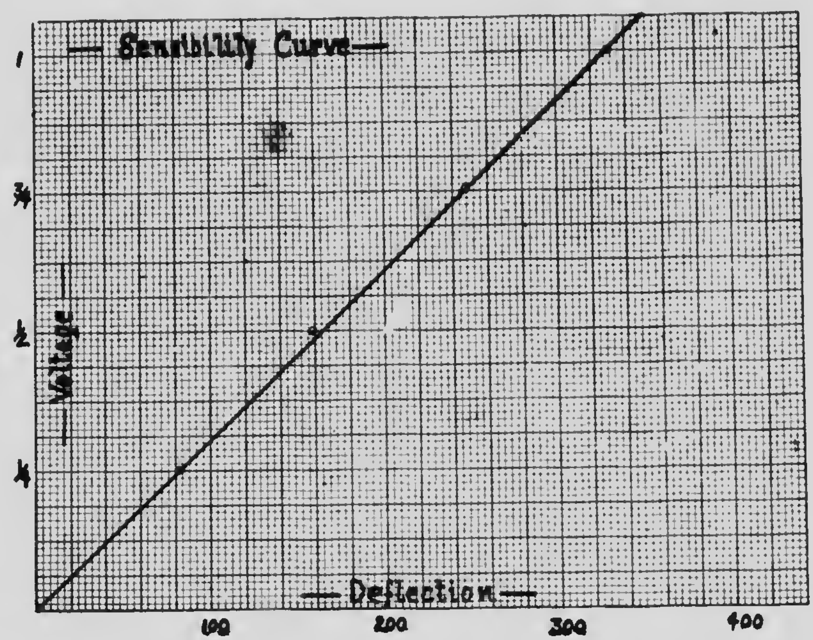

Figure 2

Light of any desired wave length could be introduced into the cell and the rate of drift of the needle noted on a scale suitably mounted in front of the electrometer. The wave length of the light introduced into the cell was altered from 7260 A.U. to 3140 A.U., by successive stages, and the rate of drift taken for each particular stage. This was repeated for each set of readings taken. The intensity curve for the variation of the deflection with the wave length for the different sets of readings varied but slightly, a typical curve being that shown in Fig. 3. In this curve we see that the maximum drift was obtained at

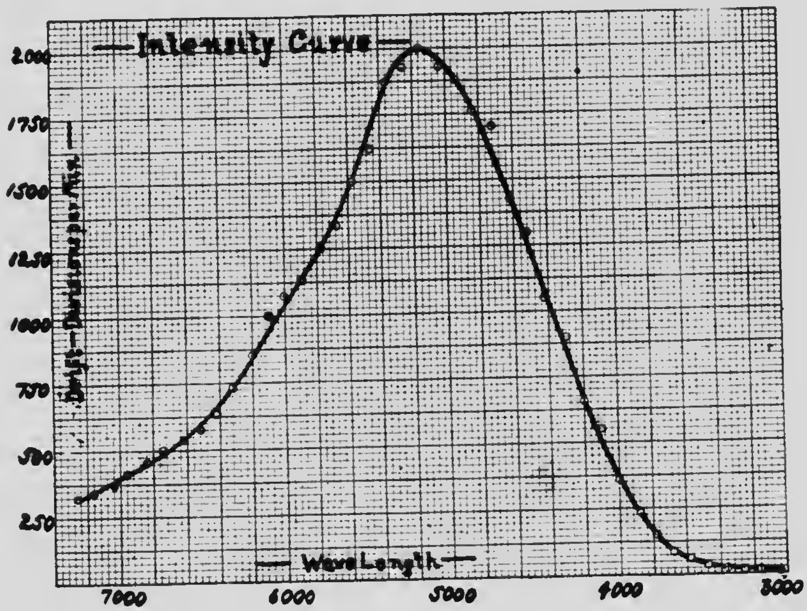

Figure 3

a wave length of 5160 A. After a set of readings as indicated were taken the rubber was placed directly in front of the slit of the spectrograph. The thin sheet of rubber was held between brass plates about 8 cm. by 5 cm., in the centre of which had been cut a small rectangular opening about 1 cm. long and ·3 cm. wide. The brass plate cut out all the extraneous light and only that passing through the rectangular opening where the rubber was exposed, was permitted to fall on the slit of the instrument. Readings for the rate of drift of the needle were again noted. In this way two sets of readings were obtained for any particular wave length, the first due to the effect of the light direct, the second due to the effect of the light after passing through the rubber, from which the percentage absorption can be readily calculated.

The following tables show the results obtained from four sets of readings. Table V shows the percentage absorption as obtained in each of the four separate sets and an average of the four sets is shown in Column No. 5 of Table V, from which an average curve was plotted and is shown in Fig. 4.

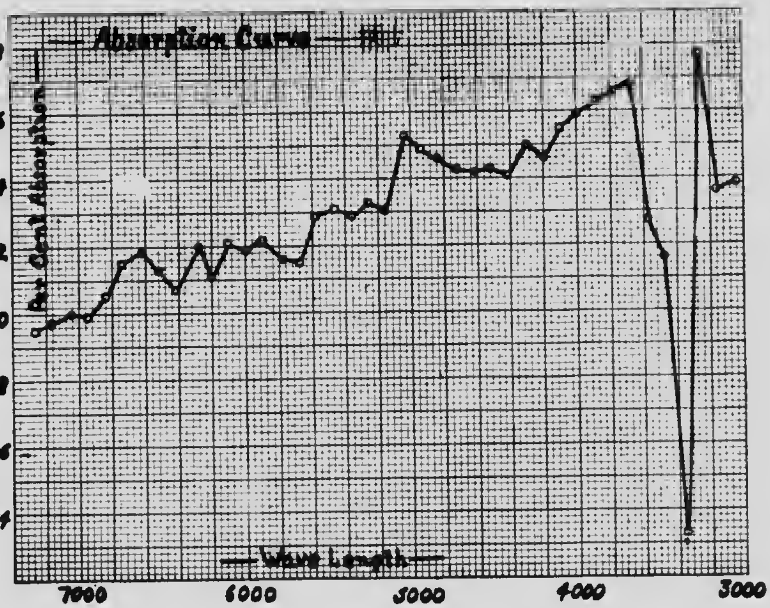

Figure 4

In each of the following tables, Column No. 1 gives the wave length in Angstrom Units; Column No. 2 gives rate of drift, light falling direct; Column No. 3 gives rate of drift, light passing through rubber; Column No. 4 gives percentage absorption.

TABLE I

1 Wave Length	2 Rate of Drift (Direct)	3 Rate of Drift (through rubber)	4 Absorption
7260	304	70·5	76·8
7160	331	76·2	77·1
7050	364	79·2	78·2
6950	426	88·4	79·2
6840	460	99·3	78·4
6740	515	112·0	78·2
6620	598	120·0	79·9
6520	611	132·0	78·4
6420	665	158·2	76·2
6320	855	174·5	79·6
6200	822	206·1	76·6
6100	1032	234·2	77·4
6000	1089	268·1	75·4
5900	1198	298·0	75·0
5780	1361	330·6	75·8
5680	1427	366·0	74·4
5580	1620	382·4	76·4
5460	1716	398·0	76·8
5360	1620	398·3	75·4
5260	1765	398·0	77·4
5160	1620	372·5	76·0
5040	1578	279·5	82·3
4940	1461	298·0	79·8
4840	1275	281·0	78·0
4720	1175	269·4	77·2
4620	1019	222·7	78·6
4520	855	176·6	79·4
4420	644	133·6	79·4
4300	506	96·1	81·0
4200	378	68·3	81·9
4100	273	47·3	82·7
4000	181	29·8	83·5
3880	121	18·6	84·6
3780	74·5	12·2	83·6
3680	45·6	7·5	83·5
3580	31·2	4·6	85·3
3480	20·8	3·5	83·2
3360	14·8	2·6	82·6
3260	11·3	1·8	84·0
3160	8·4	1·6	80·9
3040	5·9	1·2	79·6

TABLE II

1 Wave Length	2 Rate of Drift (Direct)	3 Rate of Drift (through rubber)	4 Absorption
7260	344	52·3	84·8
7160	379	57·6	84·8
7050	422	63·0	85·1
6950	461	68·0	85·3
6840	492	75·4	84·7
6740	535	82·6	84·6
6620	600	93·0	84·5
6520	660	102·8	84·4
6420	760	118·2	84·4
6320	870	135·4	84·4
6200	984	150·0	84·7
6100	1090	168·7	84·6
6000	1175	190·2	83·9
5900	1305	211·3	83·9
5780	1500	231·5	84·6
5680	1875	255·6	86·4
5580	2000	274·4	86·3
5960	2075	292·0	85·6
5360	2212	325·3	85·3
5260	2212	328·6	85·2
5160	2310	325·4	85·9
5040	2400	325·4	86·5
4940	2400	332·4	86·2
4840	2212	310·1	86·1
4720	2000	299·2	85·1
4620	1875	271·8	85·5
4520	1430	230·0	83·9
4420	1200	201·6	83·3
4300	1015	162·2	84·1
4200	845	128·5	84·8
4100	618	98·6	84·1
4000	462	69·8	84·8
3880	312	45·1	85·6
3780	208	27·3	86·8
3680	126	16·0	87·3
3580	79·6	9·4	88·3
3480	50·3	5·8	88·7
3360	34·1	4·1	88·3
3260	24·2	3·1	87·6
3160	18·6	3·0	83·9
3040	14·0	2·0	85·7

TABLE III

1 Wave Length	2 Rate of Drift (Direct)	3 Rate of Drift (Through Rubber)	4 Absorption
7260	242	70·0	71·1
7160	254	77·4	71·5
7050	292	83·5	71·4
6950	300	91·4	69·6
6840	364	96·2	73·6
6740	426	100·3	76·5
6620	463	110·0	76·4
6520	500	122·8	75·5
6420	548	134·7	75·6
6320	635	148·5	76·5
6200	665	166·3	75·1
6100	756	173·1	77·1
6000	935	190·0	79·7
5900	1070	209·1	81·2
5780	1000	230·4	77·0
5680	1090	241·6	76·2
5580	1200	249·9	79·2
5460	1250	250·2	80·0
5360	1300	261·0	79·8
5260	1330	278·0	78·9
5160	1330	300·0	77·4
5040	1460	278·0	81·0
4940	1460	263·0	82·0
4840	1430	241·6	83·0
4720	1330	220·0	83·3
4620	1110	205·0	81·9
4520	1090	179·6	83·7
4420	951	160·0	83·2
4300	782	130·0	83·4
4200	553	103·0	81·4
4100	453	74·0	83·6
4000	333	53·0	84·1
3800	238	39·0	83·6
3780	162	25·0	84·6
3680	94·1	14·0	85·1
3580	54·4	19·0	65·2
3480	32·5	11·8	63·4
3360	12·0	8·3	31·0

Table IV

1 Wave Length	2 Rate of Drift	3 Rate of Drift (Through Rubber)	4 Absorption
7260	320	47·6	85·2
7160	339	50·0	85·3
7050	364	53·1	85·4
6950	413	60·0	85·5
6840	455	60·8	85·3
6740	500	65·9	85·8
6620	533	71·3	86·6
6520	575	76·4	86·7
6420	637	84·6	86·7
6320	730	91·3	87·5
6200	855	101·0	88·2
6100	1000	108·7	89·2
6000	1070	121·1	88·7
5900	1130	129·2	88·6
5780	1250	138·9	88·9
5680	1332	150·0	88·8
5580	1550	155·0	88·7
5460	1620	160·2	90·1
5360	1872	162·2	91·3
5260	1936	165·9	91·5
5160	2000	168·9	91·6
5040	1936	168·0	91·4
4940	1872	162·2	91·4
4840	1764	152·2	91·5
4720	1712	143·3	91·7
4620	1428	130·2	90·4
2520	1200	115·3	90·4
4420	1051	100·0	90·7
4300	907	80·0	91·4
4200	665	65·0	90·2
4100	554	48·0	91·8
4000	363	34·0	91·3
3880	242	23·5	91·4
3780	155	16·0	91·3
3680	88·4	10·0	91·4
3580	57·2	7·0	91·9
3480	34·8	5·5	91·2
3360	24·0	4·5	91·2
3260	19·0	4·0	91·5
3160	15·0	4·5	86·0
3040	13·0	4·4	86·2

TABLE V

Wave Length	No. 1	No. 2	No. 3	No. 4	No. 5
7260	76·8	84·8	71·1	85·2	79·5
7160	77·1	84·8	71·5	85·3	79·7
7050	78·2	85·1	71·4	85·4	80·0
6950	79·2	85·3	69·6	85·5	79·9
6840	78·4	84·7	73·6	85·3	80·5
6740	78·2	84·6	76·5	86·8	81·5
6620	79·9	84·5	76·4	86·6	81·8
6520	78·4	84·4	75·5	86·7	81·3
6420	76·2	84·4	75·6	86·7	80·7
6320	79·6	84·4	76·5	87·5	82·0
6200	76·6	84·7	75·1	88·2	81·1
6100	77·4	84·6	77·1	89·2	82·1
6000	75·4	83·9	79·1	88·7	81·9
5900	75·0	83·9	81·2	88·6	82·2
5780	75·8	84·6	77·0	88·9	81·6
5680	74·4	86·4	76·2	88·8	81·5
5580	76·4	86·3	79·2	88·7	82·9
5460	76·8	85·6	80·0	90·1	83·1
5360	75·4	85·3	79·8	91·3	82·9
5260	77·4	85·2	78·9	91·5	83·3
5160	76·0	85·9	77·4	91·6	83·0
5040	82·3	86·5	81·0	91·4	85·3
4940	79·8	86·2	82·0	91·4	84·9
4840	78·0	86·1	83·0	91·5	84·6
4720	77·2	85·1	83·3	91·7	84·3
4620	78·6	85·5	81·9	90·4	84·2
4520	79·4	83·9	83·7	90·4	84·3
4420	79·4	83·3	83·2	90·7	84·1
4300	81·0	84·1	83·4	91·4	85·0
4200	81·9	84·8	81·4	90·2	84·6
4100	82·7	84·1	83·6	91·8	85·5
4000	83·5	84·8	84·1	91·3	85·9
3880	84·6	85·6	83·6	91·4	86·3
3780	83·6	86·8	85·1	91·3	86·6
3680	83·6	87·3	65·2	91·4	86·8
3580	85·3	88·3	63·4	91·9	82·7
3480	83·2	88·7	31·0	91·2	81·6
3360	82·6	88·3		91·2	73·3
3260	84·0	87·6		91·6	87·7
3160	80·9	83·9		86·0	83·6
3040	79·6	85·7		86·2	83·8

On examining the intensity curve (Fig. 3), it will be noted that for wave lengths in the region of 6500 A. and all above that wave length the instrument is not very sensitive, similarly, for very short wave lengths (from 4000 A. down) it is much less sensitive, so that for the two ends of the spectrum the results will not be as accurate as for the region about 5000 A. in which the rate of drift is fairly rapid.

The absorption curve (Fig. 4) indicates that we were wrong in assuming that very little light was being absorbed in the red region. Even if the results are not reliable above 6500 A. we see that there is a large percentage of the light being absorbed which increases as the wave length decreases, but does not become complete at any point as we were led to suppose in our first investigation. The points group themselves in a more or less regular curve with an abrupt change in the percentage absorption. This abrupt change is characteristic of all the curves for the particular wave length at which the change occurs. The curve becomes very irregular as the wave length decreases, owing to the rate of drift being very slow, hence accurate or reliable results are difficult to obtain. Throughout the visible part of the spectrum the proportion of light absorbed is a large fraction of the incident light and increases as the wave lengths decreases till about 3800 A. is reached. Beyond this point nothing definite can be concluded since the glass of which the photo-electric cell is made may be absorbing an appreciable amount of the ultra-violet rays that are emitted by the Nernst lamp and so their action is not recorded by the apparatus.

This work was done under the direction of Professor E. F. Burton.