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The First Step in the Swelling of Gelatin with Water. V

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By the aid of a simple model of the constitution of the interference plate it is possible to calculate the thickness of the silver bromide layer and the swelling factor of the gelatin.

In the preceding paper of this series [1] it was shown that the amount of silver bromide which was taken up during the aftertreatment of the interference plate was due to two sources, namely 1) the adsorbed amount of silver ions, and 2) the solution of silver nitrate.

When the original chromated gelatin plate, after exposure, is bathed in the solution of silver nitrate (25:100) a certain amount of silver ions are directly adsorbed [2], and at the same time the solution is filling the network of gelatin molecules for which reason the said amount is determined by 1) the swelling factor f, and 2) the percentage by volume of unhardened gelatin, G′.

1. THE ADSORPTION.

As shown before [3], the adsorption is expressed by the formula

$$\text{ads.} = 0.64 \frac{G'}{2d_G} \tag{1}$$

where d_G is the diameter of the gelatin molecule.

Table 1 contains, 1) the numbers of the plates, 2) the mean values of v_A, the percentage by volume of silver bromide, for the upper (I) and the lower (II) edge of the broad band. No. 47 comprises 10 cases, No. 196 9, No. 212 5 and No. 216 5 cases. The values of d_G are known from an earlier paper [4], the mean values of G′ are taken as 31.4 and 22.2, respectively [5]. The third column contains the calculated amount of adsorbed silver bromide (ads) and the fourth column the quotients ads:v_A.

From previous measurements [6] it is possible to calculate this quotient for different values of G′, which are taken from Table 7 of the paper just quoted. Table 2 contains the results for three different values of G′, which correspond to the three last values in the said Table 7.

Table 1.

Plate No.	v_A	ads.	ads:v_A	exp.
47 I	27.7	10.9	0.39	0.32
47 II	18.4	7.7	0.42	0.38
196 I	24.7	8.7	0.35	0.32
196 II	16.0	6.2	0.39	0.38
212 I	35.1	9.0	0.26	0.32
212 II	23.6	6.3	0.37	0.38
216 I	30.4	10.4	0.39	0.32
216 II	21.2	7.3	0.42	0.38

The first column shows the number of days which have passed between the coating and the exposure of the plate, the second and the third column show the adsorbed and the total amounts of silver nitrate, and the fourth column the quotient ads: total.

It appears that the behaviour of the plates which have remained only 2 days before the exposure is different from that of plates which have remained 4, 7 or 11 days before the exposure. For these three groups of plates the quotient for each individual value of G′ is nearly constant and markedly greater than for the plates which have had 2 days rest.

All the newly examined plates have only remained 2 days between coating and exposure. It is therefore possible to interpolate graphically the values for $G' = 31.4$ and 22.2. These values are shown in Table 1, column 5 under the desingnation exp.

Table 3 contains the corresponding values for the older plates [7].

As the same sort of gelatin (Stoess hard) was used as for No. 212, the value 1.12 for d_G was used for the calculation.

Both Tables 1 and 3 show that the calculated and the experimentally found values of the quotient agree well.

Table 2.

	G′								
	53.0			28.3			3.2		
Days	ads.	total	ads : total	ads.	total	ads : total	ads.	total	ads : total
2	2.4	11.6	0.21	2.9	8.3	0.35	3.3	7.0	0.47
4	3.5	10.6	0.33	3.8	8.3	0.46	4.4	7.7	0.57
7	3.5	10.4	0.34	3.5	8.2	0.43	3.9	7.1	0.55
11	4.8	11.2	0.43	2.7	8.4	0.49	4.3	7.6	0.57
			0.37			0.44			0.56

Table 3.

Plate No.	Days	v_A	G′	ads.	ads : v_A	exp.
14a I	2	26.4	30.2	8.6	0.33	0.34
14a II	2	17.3	22.2	6.3	0.37	0.38
2 I	3	27.0	30.6	8.7	0.32	0.33
2 II	3	17.3	22.2	6.3	0.36	0.38
9 I	9	22.9	30.9	8.8	0.39	0.44
9 II	9	14.9	22.2	6.3	0.42	0.48
28 I	9	23.3	34.2	9.8	0.42	0.43
28 II	9	14.2	21.9	6.2	0.44	0.48

2. THE ABSORPTION OF SILVER NITRATE SOLUTION

In order to calculate the amount of silver nitrate solution which is absorbed by the exposed chromated gelatin plate it is necessary to know the swelling factor f. Earlier measurements [8] have been interpreted under the assumption that — for each sort of gelatin — f should be a constant, independent of the exposure, when it was calculated for 100 % unhardened gelatin. By closer examination of the results this assumption does not seem to hold good. On the contrary, there seems to be an approximate proportionality between f and the amount of swelling water, so that $f = 0.093$ V. It appears from this, that the value of f must be higher at the upper than at the lower edge of the broad band.

The formula for the absorption is now

$$((f - v_o)\frac{G'}{100} + v_o) \times 0.0422$$

or

$$\left[f\frac{G'}{100} + v_o\left(1 - \frac{G'}{100}\right)\right] \times 0.0422 \tag{2}$$

where v_o is the volume which is filled momentarily with water (or solution), and 0.0422 the volume of silver bromide which corresponds to one volume of silver nitrate solution 25:100.

The experimentally found values of the quotient ads:v_A are only valid for a certain sort of gelatin. They cannot therefore be used for calculating v_A for plates made with other sorts of gelatin. The only possible expedient therefore is to use the experimentally found values of v_A and from them calculate the values of f with the aid of the formulae (1) and (2). Table 4 contains the results for the mean values of the new plates, and Table 5 for the previously examined plates.

3. THE THICKNESS OF THE SILVER BROMIDE LAYER

The silver bromide v_A has one of its surfaces in common with half of the unhardened gelatin G′. Therefore

$$\frac{G'}{2d_G} = \frac{V_A}{d_{AgBr}}$$

Table 4.

Plate No.	v_A	v_O	d_G	ads.	diff.	G′	f
47 I	27.7	61	0.92	10.9	16.8	31.4	11.4
47 II	18.4	61	0.92	7.7	10.7	22.2	9.3
196 I	24.7	90	1.15	8.7	16.0	31.4	10.2
196 II	16.0	90	1.15	6.2	9.8	22.2	7.3
212 I	35.1	106	1.12	9.0	26.1	31.4	17.5
212 II	23.6	106	1.12	6.3	17.3	22.2	14.8
216 I	30.4	75	0.97	10.4	20.0	31.4	13.5
216 II	21.2	75	0.97	7.3	13.9	22.2	12.3

Table 5.

$v_O = 64 \quad d_G = 1.12$					
Plate No.	v_A	ads.	diff.	G′	f
14a I	26.4	8.6	17.8	30.2	12.5
14a II	17.3	6.3	11.0	22.2	9.5
2 I	27.0	8.7	18.3	30.6	12.7
2 II	17.3	6.3	11.0	22.2	9.5
9 I	22.9	8.8	14.1	30.9	9.4
9 II	14.9	6.3	8.6	22.2	7.0
28 I	23.3	9.8	13.5	34.2	8.4
28 II	14.2	6.2	8.0	21.9	6.4

where d_{AgBr} is the thickness of the silver bromide layer. The thicknesses d_G of the gelatin molecule are taken from Table 12 in the previous paper in this series [9]. The results are collected in Table 6.

All the values of dAgBr for the lower edge of the broad band are lower than for the upper edge. This is explained by the fact [10] that during the drying of the plate after bathing in silver nitrate solution some of the silver nitrate diffuses deeper into the coating where it constitutes the fringes. This loss is of course greater at the lower than at the upper edge.

4. THE PREPARATION OF THE INTERFERENCE PLATE

This preparation has been thoroughly described in a previous paper [11]. Through the results of the latest experiments it is possible to give some further hints about the procedure.

1. The gelatin should be characterised by the greatest possible swelling factor.

2. After coating the plate should be laid on a plate glass which can be cooled by cold water.

3. The time between the coating and the exposure should not exceed 2 days.

Table 6.

Plate No.	v_A	d_G	G′	d_{AgBr}
47 I	27.7	0.92	31.4	1.62
47 II	18.4	0.92	22.2	1.52
196 I	24.7	1.15	31.4	1.82
196 II	16.6	1.15	22.2	1.66
212 I	35.1	1.12	31.4	2.52
212 II	23.6	1.12	22.2	2.38
216 I	30.4	0.97	31.4	1.88
216 II	22.2	0.97	22.2	1.84

4. The drying of the plate treated with silver nitrate should be accelerated as much as the coating can stand without melting.

5. The treatment with the potassium bromide solution (20:100) which takes about 10—15 sec should be prolonged until the plate shows faint signs of opacity.

5. CONCLUSIONS

1. A scheme for the adsorption and absorption of silver nitrate in the exposed chromated gelatin plate is proposed.

2. The swelling factor f is nearly proportional to the amount of water taken up by the chromated gelatin plate.

3. The calculated values of the quotient ads:v_A agree very well with the experimentally found values.

4. When v_0, the amount of water momentarily absorbed, and d_G, the diameter of the gelatin molecule, are known, it is possible to calculate the swelling factor f.

5. The calculated values of f are smaller when the plate is stored longer than two days between coating and exposure.

6. From the values of unhardened gelatin G′ and of the thickness of the gelatin molecule it is possible to calculate the thickness ofthe silver bromide layer.

7. The results of the new experiments can give some hints about the preparation of the interference plates.

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