XX.—*On the Absorption of Weak Reagents by Cotton, Silk, and Wool.*

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COTTON, silk, and wool are definite chemical substances, whose composition is represented by the formulæ $C_6H_{10}O_5$, $C_{24}H_{36}N_8O_6$, and $C_{42}H_{157}N_5SO_{15}$ * respectively. It has long been known that they are capable of absorbing from weak aqueous solutions the ordinary acid and alkaline reagents.

* This expression has been calculated by ourselves from the summary of analyses in *Gmelin's Handbook*, 18, 351.

The object of the following research is first the quantitative measurement of such absorption, under conditions to be subsequently indicated; and then to ascertain whether the absorption is amenable to laws already established in other fields of chemical investigation.

Our work has naturally fallen into two divisions, viz., (I), the rate and amount of absorption of individual reagents; and (II), the ratio of absorption of mixed reagents.

PART I.

A number of tall cylindrical wide-mouthed stoppered bottles, holding about 300 c.c. (12 cm. $\times$ π [3 cm.]²), were filled each with 250 c.c. of an acid or alkaline solution of known strength, and kept at a constant temperature during experiment by immersion in a current of water from the main; equal weights of the tissue (in nearly every case 3 grams) were placed in each of these bottles, and the time noted. After a suitable interval, the tissue was removed from the bottles by means of glass rods. A known volume of the liquid in the bottle from which the tissue had been removed was now taken and tested volumetrically for residual acid or alkali, phenolphthalein being the indicator. The diminution of strength gives the amount of absorption. Such determinations having been made with a series of bottles, each of which contained the tissue for a different length of time, the differences in amount of absorption in different bottles enable us to infer the rate of and total absorption.

The wool employed was fine Cashmere wool; the silk, a plain pure silk, freed from Prussian blue; the cotton, a pure calico;—all in the piece. These were all previously washed with very weak sodic hydrate, water, very weak hydric chloride, and distilled water successively in the cold. The acids and alkali we employed were hydric sulphate, hydric chloride, and sodic hydrate.

The following table comprises the results of a trial series of experiments:—

TABLE I.

Material.	Weight of the material.	Time in weeks.	Acid.	Total absorption.	Acids per c.c.	Mean temperature.
Silk	1 gram	1	Hydric sulphate	0·002863	0·00004833	16·7°
"	"	2	"	0·003063	"	16·3
"	"	2	Hydric chloride	0·000805	0·0000180	16·0
"	"	2	Hydric tartrate	0·001897	0·0001479	16·0
Wool ..	"	1	Hydric sulphate	0·004552	0·00004833	16·7
" ..	"	2	"	0·004736	"	16·3
" ..	"	2	Hydric chloride	0·001225	0·0000180	16·0
" ..	"	2	Hydric tartrate	0·004715	0·0001479	16·0

The silk employed in the above experiments contained 6·8 per cent. of moisture and an inappreciable amount of ash. The results show clearly the points intended to be ascertained, viz. (1) that wool and silk do really absorb the acids in question, and (2) that the greater part of the effect is completed, at the ordinary temperature, in a week's time.

Henceforward the following points are common to all tables:— (1) Unit of time $\frac{1}{4}$ hour; (2) volume of liquid in each bottle = 250 c.c.; (3) an equation, in which y stands for remaining absorbable reagent, and x the number of units of time.

TABLE IIa.—*Absorption of Hydric Sulphate by Wool.*

Hydric sulphate in each bottle = 0·187535 gram.

Weight of anhydrous wool 0·8728 gram (weighed hydrous with 12 per cent. of moisture: ash, 0·06 per cent.).

Equation, $y = 0·01594(0·77047)^x$.

Time.	Temp.	Sulphate absorbed.	Remaining sulphate.	Remaining sulphate calc.
0	—	—	—	0·01594
1	8·0°	0·00844	0·01350	0·01228
2	8 0	0·01087	0·01107	0·00946
3	8·0	0·01500	0·00694	0·00729
4	7·5	0·01594	0·00600	0·00562

Probable error of a single comparison, 0·00082 gram.

TABLE IIb.—*Absorption of Hydric Sulphate by Wool.*

Hydric sulphate in each bottle = 0·662575 gram.

Weight of anhydrous wool in each bottle 2·61 grams (weighed hydrous with 12·7 per cent. of water).

Ash in anhydrous wool 0·06 per cent.

Equation, $y = 0·062614(0·75432)^x$.

Time.	t° .	Sulphate absorbed.	Remaining sulphate.	Remaining sulphate calc.
—	—	—	0·06261	0·06261
1·93	4·0	0·025416	0·03720	0·03634
2	"	0·027000	0·03561	0·03563
3	"	0·037472	0·02514	0·02687
4	"	0·046131	0·01648	0·02027
6	"	0·052601	0·01001	0·01154
8	"	0·056258	0·00636	0·00656
12	"	0·058171	0·00444	0·00212
20	"	0·062165	0·00045	0·00022
28	"	0·062446	0·00019	0·00002
106	4·5	0·062614	—	—

Probable error of a single comparison, 0·00114 gram.

TABLE III.—*Absorption of Hydric Chloride by Wool.*

Hydric chloride in each bottle = 0·41810 gram.

Weight of anhydrous wool in each bottle 2·61 grams (weighed 3 grams hydrous with 12·7 per cent. of water).

Ash per cent., 0·05 per cent. in anhydrous wool.

Equation, $y = 0·038702(0·47217)^x + 0·0028703(0·93949)^x$.

t° C. corr.	Time.	Chloride absorbed.	Remaining chloride.	Remaining chloride calc.
—	—	—	0·04157	0·04157
4·0	1·93	0·026900	0·01467	0·01164
"	2	0·030568	0·01100	0·01116
"	3	0·035051	0·00652	0·00645
"	4	0·038312	0·00326	0·00416
"	6	0·039208	0·00236	0·00240
"	8	0·039738	0·00173	0·00184
"	12	0·039942	0·00163	0·00136
"	20	0·040757	0·00082	0·00082
"	28	0·041165	0·00041	0·00050
4·5	106	0·041572	—	—

Probable error of a single comparison, 0·00076 gram.

TABLE IVa.—*Absorption of Sodid Hydrate by Wool.*

The reagent consisted of standard sodid hydrate diluted to the indicated strength.

Sodid hydrate in each bottle = 0·0765449 gram.

Weight of anhydrous wool in each bottle = 0·87288 gram (weighed hydrous with 12·72 per cent. of water and 0·06 per cent. of ash).

Equation, $y = 0·013016(0·58818)^x$.

Time.	$t^{\circ}\text{C.}$	Hydrate absorbed.	Remaining hydrate.	Remaining hydrate calc.
0	—	—	0·01302	0·01302
1	7·9	0·00620	0·00682	0·00766
2	8·0	0·00860	0·00441	0·00450
3	8·2	0·00918	0·00383	0·00265
4	8·2	0·01148	0·00153	0·00156
6	8·2	0·01225	0·00077	0·00054
8	7·8	0·01302	—	0·00019

Probable error of a single experiment, 0·00048 gram.

TABLE IVb.—*Absorption of Sodid Hydrate by Wool.*

Sodic hydrate in each bottle = 0·45925 gram.

Weight of anhydrous wool 2·61 (weighed hydrous with 12·7 per cent. of water).

Ash in anhydrous wool, 0·05 per cent.

Equation, $y = 0·063086(0·31040)^x + 0·0053417(0·92340)^x$.

$t^{\circ}\text{C.}$	Time.	Hydrate absorbed.	Remaining hydrate.	Remaining hydrate calc.
—	—	—	0·06843	0·06843
4·0	1·93	0·056671	0·01176	0·01118
"	2	0·058325	0·01010	0·01063
"	3	0·060162	0·00827	0·00609
"	4	0·063147	0·00528	0·00447
"	6	0·065213	0·00322	0·00337
"	8	0·065444	0·00298	0·00283
"	12	0·066591	0·00184	0·00205
"	20	0·067142	0·00139	0·00109
"	28	0·067960	0·00046	0·00057
4 5	106	0·068428	—	—

Probable error of a single comparison, 0·00056 gram.

In the following three tables the weight of anhydrous silk in each bottle was 2·75 grams with 8·2 per cent. of moisture and 0·09 per cent. of ash.

TABLE V.—*Absorption of Hydric Sulphate by Silk.*

Hydric sulphate in each bottle, 0·562575 gram.

Equation, $y = 0·01225(0·58980)^x$.

t° C.	Time.	Sulphate absorbed.	Remaining sulphate.	Remaining sulphate calc.
—	—	—	0·01225	0·01225
6·7	2	0·007583	0·00467	0·00426
„	3	0·009901	0·00235	0·00251
„	4	0·010869	0·00136	0·00148
„	8	0·012251	—	0·00018

Probable error of a single experiment, 0·00021 gram.

TABLE VI.—*Absorption of Hydric Chloride by Silk.*

Hydric chloride in each bottle, 0·41810 gram.

Equation, $y = 0·01511(0·3134)^x$.

Time.	t° C.	Chloride absorbed.	Remaining chloride.	Remaining chloride calc.
—	—	—	0·01511	0·01511
1	4·5	0·010455	0·00466	0·00474
2	„	0·013581	0·00153	0·00148
3	„	0·014735	0·00038	0·00047
4	„	0·015114	—	0·00015

Probable error of a single experiment, 0·00008 gram.

TABLE VII.—*Absorption of Sodid Hydrate by Silk.*

Sodid hydrate in each bottle, 0·45925 gram.

Equation, $y = 0·06200(0·4595)^x$.

Time.	t° C.	Hydrate absorbed.	Remaining hydrate.	Remaining hydrate calc.
—	—	—	0·06200	0·06200
1	4·5	0·03444	0·02756	0·02849
2	„	0·04879	0·01371	0·01309
3	„	0·05603	0·00597	0·00602
4	„	0·06071	0·00129	0·00276
5	„	0·06200	—	0·00127

Probable error of a single comparison, 0·00076 gram.

The weight of cotton referred to in the following three tables was, anhydrous cotton 2·893 grams (weighed hydrous, 3 grams), with 6·9 per cent. of moisture and 0·05 per cent. of ash.

TABLE VIII.—*Absorption of Hydric Sulphate by Cotton.*

Hydric sulphate in each bottle = 0.562575 gram.

$t^{\circ} \text{C.}$	Time.	Sulphate absorbed.	Remaining sulphate.
—	0	—	0.0049506
4	1	0.0025316	0.0024190
„	2	0.0042193	0.0007313
„	3	0.0049506	—

TABLE IX.—*Absorption of Hydric Chloride by Cotton.*

Hydric chloride in each bottle = 0.41810 gram.

$t^{\circ} \text{C.}$	Time.	Chloride absorbed.	Remaining chloride.
—	—	—	0.007336
4	1	0.0048909	0.002445
„	2	0.0061136	0.001223
„	3	0.0073363	
„	4	No increase.	
„	6		
„	8		
„	10		
„	12		
„	20		
„	193		

TABLE X.—*Absorption of Sodid Hydrate by Cotton.*

Sodid hydrate in each bottle = 0.45925 gram.

Equation, $y = 0.012205(0.87837)^x + 0.016265(0.03815)^x$.

$t^{\circ} \text{C.}$	Time.	Sodid hydrate absorbed.	Remaining hydrate.	Remaining hydrate calc.
—	—	—	0.02847	—
5	1	0.01837	0.01010	0.01134
„	2	0.01903	0.00944	0.00944
„	3	0.02020	0.00827	0.00827
„	4	0.02204	0.00643	0.00727
„	6	0.02847	—	0.00561

Probable error of a single comparison, 0.00196 gram.

PART II.

The object of the following experiments is to determine the ratio of absorption of different acids by wool and silk from different mixtures of acids. For this purpose we made three mixtures of hydric sulphate and hydric chloride in the following proportions :—

	Gram per c.c.
(1.) $\text{H}_2\text{SO}_4 : \text{HCl}$	$\begin{cases} 0\cdot001563 & \text{sulphate.} \\ 0\cdot00058397 & \text{chloride.} \end{cases}$
(2.) $\text{H}_2\text{SO}_4 : 2\text{HCl}$	$\begin{cases} 0\cdot00117 & \text{sulphate.} \\ 0\cdot000876 & \text{chloride.} \end{cases}$
(3.) $\text{H}_2\text{SO}_4 : 4\text{HCl}$	$\begin{cases} 0\cdot00078 & \text{sulphate.} \\ 0\cdot001168 & \text{chloride.} \end{cases}$

These mixed acids were made from hydric sulphate and chloride (of the same strength or acidity) in the proportion of 2 : 1, 1 : 1, and 1 : 2 by volume ; so that all these mixtures have the same strength as the original or unmixed acids. The acids were of the same strength as in the previous experiments, viz. :—

	Gram per c.c.
Hydric sulphate.....	0·00234
Hydric chloride	0·0017519

The wool and silk employed were part of the samples referred to in Part I.

Our method of experiment was as follows :—

In a measured volume (250 c.c.) of mixed acids a known weight (3 grams) of silk or wool was digested in a stoppered bottle for a known length of time at a constant temperature.

After taking out the tissue from the bottle, a measured quantity (25 c.c.) of the acids in the bottle was titrated with sodic hydrate solution, phenolphthaleïn being the indicator.

The sodic hydrate solution was made to have the same strength as the acid solutions ; it had been prepared from metallic sodium, and was free from chlorine. This titration gives the total acid absorbed.

The titrated solution containing a trace of soda in excess was now carefully neutralised by adding a few drops of carbonic water (1 c.c. of which happened to correspond with 18 c.c. of soda solution).

When the faint pink colour of the solution had disappeared the solution was titrated with argentic nitrate solution, using neutral potassic chromate as an indicator.

This titration gives the amount of hydric chloride absorbed, which, when subtracted from the total amount of absorbed acid, gives the amount of hydric sulphate absorbed.

The ratios of the number of c.c. of hydric sulphate and twice that

of hydric chloride thus found, give directly the ratio of these two acids in terms of their formulæ as weights.

(α .) *Proportion of Acids, $H_2SO_4 : HCl$.*

	Units of time.	Temp. corr.	Hydric chloride absorbed, c.c.	Hydric sulphate absorbed, c.c.
Wool	0	—	—	—
Experiment No. 1	2	10·7	4·5	31·75
Wool	0	—	—	—
Experiment No. 2	3	10·9	5·8	31·7
„ „	—	—	4·6	32·9
„ „	—	—	5·0	32·5
„ „	—	—	4·6	32·9
Mean	..	..	5·0	32·5
Silk	0	—	—	—
„	3	11·8	0·87	6·63
„	—	—	0·87	6·63

Ratio of Absorption.

		Formulæ as weights.		Weight.		Volume.	
		H_2SO_4 .	HCl.	Sulphate.	Chloride.	Sulphate	Chloride.
Wool No. 1	Acid employed	100	: 100	100	: 37·24	100	: 50
Wool No. 1	Acid absorbed	100	: 28·34	100	: 10·57	100	: 14·17
Wool No. 2	—	100	: 30·8	100	: 11·5	100	: 15·4
Silk ..	—	100	: 29·3	100	: 10·91	100	: 12·98

(β .) *Proportion of Acids, $H_2SO_4 : 2HCl$.*

	Units of time.	Temp. corr.	Hydric chloride absorbed, c.c.	Hydric sulphate absorbed, c.c.
Wool	0	—	—	—
Experiment (α)	2	11·0	11·25	22·5
Wool	0	—	—	—
Experiment (β)	3	10·9	11·5	25·5
Silk	0	—	—	—
„	3	11·8	2·5	5·0
„	—	—	2·5	5·0

Ratio of Absorption.

		Formulae as weights.		Weight.		Volume.	
		H ₂ SO ₄ .	HCl.	Sulphate.	Chloride.	Sulphate.	Chloride.
Wool (a)	Acid employed	100 : 200		100 : 74·5		100 : 100	
	Acid absorbed	100 : 100		100 : 37·24		100 : 50	
Wool (b)	„	100 : 90·2		100 : 33·59		100 : 45·1	
Silk ..	„	100 : 100		100 : 37·24		100 : 50	

(γ.) Proportion of Acid, H₂SO₄ : 4HCl.

	Units of time.	Temp. corr.	Hydric chloride absorbed, c.c.	Hydric sulphate absorbed, c.c.
Wool.....	0	—	—	—
Experiment (A).....	2	10·7	Lost	Lost
Wool.....	0	—	—	—
Experiment (B).....	3	10·9	16·56	18·44
Silk	0	—	—	—
„	3	11·8	3·5	4·0

Ratio of Absorption.

		Formulae as weights.		Weight.		Volume.	
		H ₂ SO ₄ .	HCl.	Sulphate.	Chloride.	Sulphate.	Chloride.
Wool (A)	Acid employed	100 : 400		100 : 148·3		100 : 200	
	Acid absorbed	—		—		—	
Wool (B)	„	100 : 179·6		—		—	
Silk ..	„	100 : 175·0		—		—	

The above results show that although the absolute amounts of absorption are different, the ratios of absorption are the same for wool and silk.

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On account of the very small absorption by cotton of the individual acids (see Tables VIII and IX), we did not submit that material to the action of their mixtures.

SUMMARY.

TABLE XI.

Tissue.	Reagent.	Weight of reagent.	Maximum absorption per gram of anhydrous tissue.	Reference to tables.	Weight of anhydrous tissue.
		gram.	gram.		gram.
Wool...	Hydric sulphate	0.18754	0.018263	IIa.	0.8728
" ...	" "	0.66256	0.023988	IIb.	2.6100
" ...	" chloride	0.41810	0.015927	III.	2.6100
" ...	Sodic hydrate ..	0.07654	0.014913	IVa.	0.8728
" ...	" "	0.45925	0.026218	IVb.	2.6100
Silk	Hydric sulphate	0.56258	0.004455	V.	2.7500
"	" chloride	0.41810	0.005495	VI.	2.7500
"	Sodic hydrate ..	0.45925	0.022545	VII.	2.7500
Cotton..	Hydric sulphate	0.56258	0.00171	VIII.	2.893
" ..	" chloride	0.41810	0.00254	IX.	2.893
" ..	Sodic hydrate ..	0.45925	0.00984	X.	2.893

The mean probable error of a single comparison with experiment of our calculated nine equations is 0.00075 gram, or about 2 per cent. on the mean total absorption. As this is about the ordinary error of careful work with small quantities, we infer that the absorptions we have measured are amenable to laws already established in other fields of chemical investigation. Combination proceeds at first with considerable absolute rapidity, and continues with decreasing rapidity. Increase in the mass of reagent—which as a rule accelerates combination—may be counterbalanced by lowering the temperature (Tables IVa and IVb).

From the column "maximum absorption per gram" in Table XI, it is easy to calculate that the ratios of such absorption in the last six (comparable) experiments are—

	Cotton.	Silk.
Hydric sulphate	1	: 2.6
Hydric chloride	1	: 2.2
Sodic hydrate.....	1	: 2.3

numbers exhibiting a significant tendency to identity in the case of all three reagents.

Lines 5 and 8 in the same table show that wool and silk also tend to resemble each other in the weight they absorb of sodic hydrate; but

from the remainder of the table it is clear that wool takes up much more from acid solutions than is the case with silk.

The quantities 0.41810 gram hydric chloride and 0.45925 gram sodic hydrate in the same table are in the ratio $\text{HCl} : \text{NaHO}$. When wool is treated with the weak reagents severally in this proportion, the absorption is nearly in the ratio $2\text{HCl} : 3\text{NaHO}$. The corresponding results for silk and cotton are $3\text{HCl} : 10\text{NaHO}$ in both cases. There is thus a very intimate relation between silk and cotton—a relation which, whatever it may be in part, is shown by these changes to be, to a great extent, of a strictly chemical nature.

We have, in conclusion, to express the hope that our investigation, while bearing on the one hand on questions of great technical importance, may not be without its value in the profounder future study of cotton, silk, and wool—three bodies of definite chemical composition, but whose intimate constitution still remains obscure.