

Divs. on stem A.	Sp. gr.	Divs. on stem A.	Sp. gr.	Divs. on stem A.	Sp. gr.	Divs. on stem A.	Sp. gr.
7-0	0-7939	10-4	0-8004	13-8	0-8062	17-2	0-8117
7-2	0-7942	10-6	0-8009	14-0	0-8065	17-4	0-8119
7-4	0-7945	10-8	0-8012	14-2	0-8069	17-6	0-8122
7-6	0-7951	11-0	0-8015	14-4	0-8071	17-8	0-8124
7-8	0-7954	11-2	0-8017	14-6	0-8074	18-0	0-8128
8-0	0-7957	11-4	0-8022	14-8	0-8078	18-2	0-8130
8-2	0-7960	11-6	0-8025	15-0	0-8081	18-4	0-8133
8-4	0-7965	11-8	0-8028	15-2	0-8083	18-6	0-8135
8-6	0-7968	12-0	0-8031	15-4	0-8088	18-8	0-8139
8-8	0-7971	12-2	0-8036	15-6	0-8090	19-0	0-8141
9-0	0-7977	12-4	0-8039	15-8	0-8093	19-2	0-8143
9-2	0-7980	12-6	0-8041	16-0	0-8097	19-4	0-8148
9-4	0-7986	12-8	0-8046	16-2	0-8100	19-6	0-8150
9-6	0-7989	13-0	0-8049	16-4	0-8103	19-8	0-8152
9-8	0-7992	13-2	0-8052	16-6	0-8107	20-0	0-8156
10-0	0-7998	13-4	0-8057	16-8	0-8110		
10-2	0-8001	13-6	0-8059	17-0	0-8112		

Divs. on stem.	Sp. gr.	Divs. on stem.	Sp. gr.	Divs. on stem.	Sp. gr.	Divs. on stem.	Sp. gr.
0-0	0-8156	14-0	0-8390	28-0	0-8633	42-0	0-8883
0-2	0-8159	14-2	0-8392	28-2	0-8638	42-2	0-8887
0-4	0-8161	14-4	0-8396	28-4	0-8641	42-4	0-8891
0-6	0-8165	14-6	0-8400	28-6	0-8644	42-6	0-8895
0-8	0-8167	14-8	0-8404	28-8	0-8647	42-8	0-8898
1-0	0-8169	15-0	0-8407	29-0	0-8652	43-0	0-8902
1-2	0-8174	15-2	0-8411	29-2	0-8655	43-2	0-8906
1-4	0-8176	15-4	0-8413	29-4	0-8658	43-4	0-8910
1-6	0-8180	15-6	0-8417	29-6	0-8662	43-6	0-8913
1-8	0-8183	15-8	0-8421	29-8	0-8665	43-8	0-8917
2-0	0-8187	16-0	0-8424	30-0	0-8668	44-0	0-8922
2-2	0-8190	16-2	0-8428	30-2	0-8673	44-2	0-8925
2-4	0-8194	16-4	0-8432	30-4	0-8676	44-4	0-8928
2-6	0-8196	16-6	0-8434	30-6	0-8679	44-6	0-8932
2-8	0-8201	16-8	0-8437	30-8	0-8682	44-8	0-8935
3-0	0-8203	17-0	0-8441	31-0	0-8687	45-0	0-8939
3-2	0-8205	17-2	0-8444	31-2	0-8690	45-2	0-8942
3-4	0-8210	17-4	0-8448	31-4	0-8693	45-4	0-8945
3-6	0-8214	17-6	0-8451	31-6	0-8698	45-6	0-8949
3-8	0-8219	17-8	0-8455	31-8	0-8701	45-8	0-8952
4-0	0-8221	18-0	0-8458	32-0	0-8704	46-0	0-8956
4-2	0-8223	18-2	0-8462	32-2	0-8708	46-2	0-8961
4-4	0-8228	18-4	0-8465	32-4	0-8711	46-4	0-8965
4-6	0-8232	18-6	0-8469	32-6	0-8714	46-6	0-8968
4-8	0-8234	18-8	0-8472	32-8	0-8719	46-8	0-8970
5-0	0-8238	19-0	0-8477	33-0	0-8722	47-0	0-8974
5-2	0-8240	19-2	0-8480	33-2	0-8725	47-2	0-8978
5-4	0-8244	19-4	0-8483	33-4	0-8728	47-4	0-8982
5-6	0-8248	19-6	0-8486	33-6	0-8733	47-6	0-8986
5-8	0-8252	19-8	0-8490	33-8	0-8736	47-8	0-8990
6-0	0-8254	20-0	0-8494	34-0	0-8739	48-0	0-8994
6-2	0-8257	20-2	0-8497	34-2	0-8744	48-2	0-8998
6-4	0-8261	20-4	0-8501	34-4	0-8747	48-4	0-9000
6-6	0-8263	20-6	0-8504	34-6	0-8751	48-6	0-9005
6-8	0-8267	20-8	0-8508	34-8	0-8754	48-8	0-9007
7-0	0-8270	21-0	0-8511	35-0	0-8757	49-0	0-9012
7-2	0-8274	21-2	0-8515	35-2	0-8762	49-2	0-9016
7-4	0-8278	21-4	0-8518	35-4	0-8765	49-4	0-9020
7-6	0-8280	21-6	0-8522	35-6	0-8768	49-6	0-9025
7-8	0-8284	21-8	0-8525	35-8	0-8771	49-8	0-9027
8-0	0-8288	22-0	0-8529	36-0	0-8776	50-0	0-9030
8-2	0-8292	22-2	0-8532	36-2	0-8779	50-2	0-9034
8-4	0-8294	22-4	0-8535	36-4	0-8782	50-4	0-9038
8-6	0-8297	22-6	0-8538	36-6	0-8786	50-6	0-9042
8-8	0-8301	22-8	0-8542	36-8	0-8789	50-8	0-9045
9-0	0-8305	23-0	0-8545	37-0	0-8794	51-0	0-9048
9-2	0-8307	23-2	0-8550	37-2	0-8798	51-2	0-9051
9-4	0-8311	23-4	0-8553	37-4	0-8801	51-4	0-9054
9-6	0-8315	23-6	0-8556	37-6	0-8805	51-6	0-9058
9-8	0-8319	23-8	0-8560	37-8	0-8808	51-8	0-9062
10-0	0-8321	24-0	0-8563	38-0	0-8811	52-0	0-9066
10-2	0-8325	24-2	0-8566	38-2	0-8815	52-2	0-9069
10-4	0-8329	24-4	0-8571	38-4	0-8818	52-4	0-9072
10-6	0-8332	24-6	0-8574	38-6	0-8823	52-6	0-9076
10-8	0-8336	24-8	0-8577	38-8	0-8826	52-8	0-9080
11-0	0-8338	25-0	0-8581	39-0	0-8830	53-0	0-9084
11-2	0-8342	25-2	0-8585	39-2	0-8833	53-2	0-9087
11-4	0-8346	25-4	0-8588	39-4	0-8836	53-4	0-9091
11-6	0-8348	25-6	0-8592	39-6	0-8841	53-6	0-9095
11-8	0-8352	25-8	0-8595	39-8	0-8844	53-8	0-9099
12-0	0-8355	26-0	0-8599	40-0	0-8848	54-0	0-9103
12-2	0-8359	26-2	0-8602	40-2	0-8852	54-2	0-9107
12-4	0-8363	26-4	0-8605	40-4	0-8855	54-4	0-9111
12-6	0-8367	26-6	0-8609	40-6	0-8859	54-6	0-9115
12-8	0-8370	26-8	0-8612	40-8	0-8862	54-8	0-9118
13-0	0-8374	27-0	0-8615	41-0	0-8866	55-0	0-9122
13-2	0-8376	27-2	0-8618	41-2	0-8870	55-2	0-9126
13-4	0-8379	27-4	0-8622	41-4	0-8873	55-4	0-9130
13-6	0-8383	27-6	0-8627	41-6	0-8876	55-6	0-9133
13-8	0-8387	27-8	0-8630	41-8	0-8880	55-8	0-9137

Divs. on stem.	Sp. gr.	Divs. on stem.	Sp. gr.	Divs. on stem.	Sp. gr.	Divs. on stem.	Sp. gr.
56-0	0-9141	67-0	0-9351	78-0	0-9563	89-0	0-9779
56-2	0-9146	67-2	0-9354	78-2	0-9567	89-2	0-9783
56-4	0-9150	67-4	0-9359	78-4	0-9571	89-4	0-9786
56-6	0-9153	67-6	0-9362	78-6	0-9575	89-6	0-9792
56-8	0-9157	67-8	0-9366	78-8	0-9579	89-8	0-9794
57-0	0-9161	68-0	0-9369	79-0	0-9583	90-0	0-9798
57-2	0-9164	68-2	0-9374	79-2	0-9586	90-2	0-9802
57-4	0-9168	68-4	0-9378	79-4	0-9590	90-4	0-9806
57-6	0-9172	68-6	0-9381	79-6	0-9594	90-6	0-9811
57-8	0-9176	68-8	0-9384	79-8	0-9598	90-8	0-9815
58-0	0-9180	69-0	0-9388	80-0	0-9602	91-0	0-9819
58-2	0-9184	69-2	0-9393	80-2	0-9608	91-2	0-9823
58-4	0-9187	69-4	0-9397	80-4	0-9610	91-4	0-9827
58-6	0-9191	69-6	0-9400	80-6	0-9613	91-6	0-9831
58-8	0-9194	69-8	0-9403	80-8	0-9617	91-8	0-9834
59-0	0-9198	70-0	0-9407	81-0	0-9621	92-0	0-9839
59-2	0-9202	70-2	0-9411	81-2	0-9626	92-2	0-9842
59-4	0-9206	70-4	0-9416	81-4	0-9629	92-4	0-9846
59-6	0-9210	70-6	0-9419	81-6	0-9633	92-6	0-9850
59-8	0-9213	70-8	0-9422	81-8	0-9637	92-8	0-9854
60-0	0-9217	71-0	0-9426	82-0	0-9642	93-0	0-9859
60-2	0-9221	71-2	0-9430	82-2	0-9646	93-2	0-9863
60-4	0-9224	71-4	0-9433	82-4	0-9650	93-4	0-9867
60-6	0-9228	71-6	0-9437	82-6	0-9654	93-6	0-9871
60-8	0-9232	71-8	0-9441	82-8	0-9657	93-8	0-9874
61-0	0-9235	72-0	0-9445	83-0	0-9661	94-0	0-9878
61-2	0-9239	72-2	0-9448	83-2	0-9665	94-2	0-9882
61-4	0-9243	72-4	0-9452	83-4	0-9669	94-4	0-9886
61-6	0-9246	72-6	0-9456	83-6	0-9673	94-6	0-9890
61-8	0-9250	72-8	0-9459	83-8	0-9676	94-8	0-9894
62-0	0-9255	73-0	0-9463	84-0	0-9680	95-0	0-9898
62-2	0-9258	73-2	0-9467	84-2	0-9684	95-2	0-9900
62-4	0-9262	73-4	0-9471	84-4	0-9688	95-4	0-9907
62-6	0-9266	73-6	0-9475	84-6	0-9693	95-6	0-9911
62-8	0-9269	73-8	0-9479	84-8	0-9696	95-8	0-9915
63-0	0-9273	74-0	0-9483	85-0	0-9700	96-0	0-9919
63-2	0-9278	74-2	0-9487	85-2	0-9704	96-2	0-9924
63-4	0-9281	74-4	0-9491	85-4	0-9708	96-4	0-9928
63-6	0-9285	74-6	0-9496	85-6	0-9712	96-6	0-9933
63-8	0-9289	74-8	0-9500	85-8	0-9716	96-8	0-9937
64-0	0-9292	75-0	0-9504	86-0	0-9720	97-0	0-9941
64-2	0-9297	75-2	0-9509	86-2	0-9724	97-2	0-9945
64-4	0-9300	75-4	0-9513	86-4	0-9727	97-4	0-9949
64-6	0-9304	75-6	0-9516	86-6	0-9732	97-6	0-9953
64-8	0-9308	75-8	0-9520	86-8	0-9735	97-8	0-9958
65-0	0-9311	76-0	0-9523	87-0	0-9739	98-0	0-9962
65-2	0-9315	76-2	0-9527	87-2	0-9743	98-2	0-9966
65-4	0-9319	76-4	0-9531	87-4	0-9748	98-4	0-9970
65-6	0-9323	76-6	0-9535	87-6	0-9752	98-6	0-9974
65-8	0-9327	76-8	0-9539	87-8	0-9756	98-8	0-9979
66-0	0-9331	77-0	0-9543	88-0	0-9760	99-0	0-9983
66-2	0-9334	77-2	0-9547	88-2	0-9764	99-2	0-9987
66-4	0-9339	77-4	0-9551	88-4	0-9768	99-4	0-9991
66-6	0-9342	77-6	0-9555	88-6	0-9771	99-6	0-9996</

rubber goods has a definite standard of quality. He can make reliable determinations of the strength of different samples of rubber and upon them base his valuation. On the other hand, little or no reliable information is available as to what these qualities depend upon or with what they are directly associated. Consequently the planter is still at a loss to know why his rubber is inferior in strength to the native Fine Hard Para and what means he may adopt to improve it. At the present prices* of Fine Hard Para and plantation rubber, 3s. 2d. and 2s. 3d. respectively, the superiority of the former, considering its 15 to 20 per cent. impurity, is equivalent to an increased value in the caoutchouc of 75 per cent. as compared with the plantation product.

Though some authorities do not admit the existence of any superiority in Brazilian rubber, nevertheless many theories have been put forward to account for it. Numerous empirical methods of preparing rubber have been devised, more or less in imitation of the Amazonian smoking method, but none except direct imitations of this method have been proved equal to it, and these, unfortunately, are not adaptable to plantation conditions. Samples of rubber have been prepared at the Botanical Gardens, Singapore, by the smoking method of coagulation, and after vulcanisation gave physical tests equal to those of Fine Hard Para.† Many estates also claim to have produced superior samples of rubber, but, as Eaton has already pointed out, these results are not the outcome of scientific experiment, but of fortunate methods adopted by careful managers and factory superintendents. In 1907 Beadle and Stevens conducted experiments to show that plantation rubber was superior to Fine Hard Para and obtained results accordingly. Results so undoubtedly exceptional are of little value unless fully interpreted in relation to the methods of coagulation employed and the subsequent treatment of the rubber.

Now the Amazonian smoking method consists essentially in coagulating successive films of latex on a stick rotating in a jet of smoke produced by the slow combustion of certain palm nuts. The influences to which the latex is subjected in such a process are increase of temperature, action of smoke, action of volatile organic acids, evaporation of water and consequent concentration of serum.

The use of acetic acid as a coagulant, now generally adopted by most estates in the East, was suggested by its occurrence in the distillation products of wood and in Brazilian rubber, and the practice of smoking sheet rubber in drying sheds is believed to improve the quality of plantation rubber on the supposition that Brazilian rubber owes its superior strength to the action of smoke and other distillation products of wood.

The effect of temperature on coagulation and the quality of the rubber has not been worked out. Henri observed that the "Brownian movement" of the globules of caoutchouc increases with rise of temperature and the caoutchouc becomes less viscous. The writer found that coagulation takes place more readily as the temperature is increased up to 70° or 80° C., but that at higher temperatures it is more difficult to obtain. This result is in agreement with Whitby's suggestion as to the existence of a coagulating enzyme in latex.

The evaporation of water and the consequent increase in concentration of the serum as a factor influencing coagulation, appear to have been entirely neglected by previous workers—a negligence which is all the more surprising when we consider the recent progress in the study of colloidal proteins and their behaviour in salt solutions of various concentrations. This attitude towards such an obviously important factor is no doubt due to the prevailing ideas concerning the part played by the protein in the coagulation of the latex and the quality of the final product. The manufacturer's appreciation of the obvious merits of a clean rubber has encouraged the planter to produce rubber which is almost chemically pure caoutchouc, on the supposition that quality was dependent on purity. The inferior physical properties of synthetic rubber and of caoutchouc prepared from raw rubber do not support such a supposition. Besides,

Lock and Bamber have shown that the breaking strains of a number of samples of plantation rubber vary inversely as the percentages of caoutchouc contained in the samples; while Beadle and Stevens, working on the insoluble nitrogenous constituents left after solution of the caoutchouc hydrocarbon in benzene, have shown that their removal from a sample of rubber results in a deterioration of the sample. The nitrogenous constituent would thus appear to exercise a greater influence on the quality of rubber than is generally supposed.

Biffen and Weber both held the view that the proteins play an important part in coagulation, forming a clot which entangles the caoutchouc globules, and that variations in coagulation are dependent on the qualities of the particular albuminoids present in the latex. Frank also supported this view by his experiments on the latex of *Hevea* and *Kickxia*. On the other hand, De Jong and Tromp de Haas obtained coagulation of the latex of *Castilloa elastica* after removal of the proteins by means of alcohol. Spence obtained similar results with *Kickxia*, and Crossley obtained coagulation of *Hevea* latex after considerable dilution with water. Gardner removed the protein from the latices of *Hevea*, *Castilloa*, and *Micrandia* by dialysis after digestion with papain, and obtained coagulation in each case. Henri, as a result of microscopic examination, concluded that protein was not essential to coagulation, but he, along with Weber, drew a distinction between coagulation and coalescence or mere fusion of the caoutchouc globules. Zimmermann observes that coagulation can take place in the absence of protein, but believes that the protein in the latex tends to promote coagulation.

The writer examined the behaviour of *Hevea* latex microscopically and found that agglutination and coalescence of the caoutchouc globules is possible without any change taking place in the condition of the protein solution, and that small clots of caoutchouc are formed in this way. This process he considers to be quite independent of true or complete coagulation, in which the caoutchouc globules are embedded in a matrix of coagulated protein. Fusion of the globules and protein with formation of a homogeneous structure takes place when pressure is applied.

Considering these facts, it seemed to the writer that a study of the colloidal properties of latex under different conditions might afford interesting information likely to lead to a better understanding of the process of coagulation and to a clearer conception of strength in rubber. A considerable amount of work on the coagulation of *Hevea* latex by acids and salts has already been done by various workers, notably Parkin, Crossley, Eaton, Whitby, and others, but with little consistency in the results; while apparently no one, except perhaps Whitby, has attempted a quantitative comparison of the effects of different concentrations of the same and of different reagents.

Accordingly, with this object in view, the writer carried out the following experiments on the coagulation of fresh *Hevea* latex in solutions of varying concentration of acid and salt. The experiments were conducted by methods similar to those of Wood in his work on the strength of wheat gluten.

Concentration of Salt.	N/2	51	52	53	54	55	56	57	58	59	60
	N/5	41	42	43	44	45	46	47	48	49	50
	N/10	31	32	33	34	35	36	37	38	39	40
	N/25	21	22	23	24	25	26	27	28	29	30
	N/50	11	12	13	14	15	16	17	18	19	20
	N/100	1	2	3	4	5	6	7	8	9	10

N/500 N/250 N/100 N/50 N/25 N/10 N/5 N/2 N 2N
Concentration of Acid.

* India Rubber Journal, Nov. 15, 1913.

† L. Wray in Bulletin of Straits Settlements, Vol. X.

In the absence of facilities for dialysing the latex, the following mode of procedure was found most suitable. A number of large test-tubes were each marked at 50 c.c. and numbered from 1 to 60. Standard solutions of acid and salt were run in from a burette in sufficient quantities to make the required strengths, as shown in the above table. One half c.c. of clean fresh latex was then added to each tube, and the liquid thoroughly stirred to effect complete diffusion of the latex throughout. The tubes were placed in racks and allowed to stand for 24 hours to ensure equilibrium between the colloid and its solution. A comparative examination of the tubes was then made. The numbers of all the tubes in which coagulation was just short of completeness were indicated in the table as shown above. The points thus obtained were plotted on squared paper with concentrations of acids as abscissae and concentrations of salt as ordinates. Such a graph shows the coagulating effect of varying concentrations of salt as measured against the disintegrating effect of varying concentrations of acid. The method of working and the appearance of the latex in varying concentrations of sodium chloride and hydrochloric acid is shown in Plate I. The curves obtained for various acids and salts are given in Plates II., III. and IV.

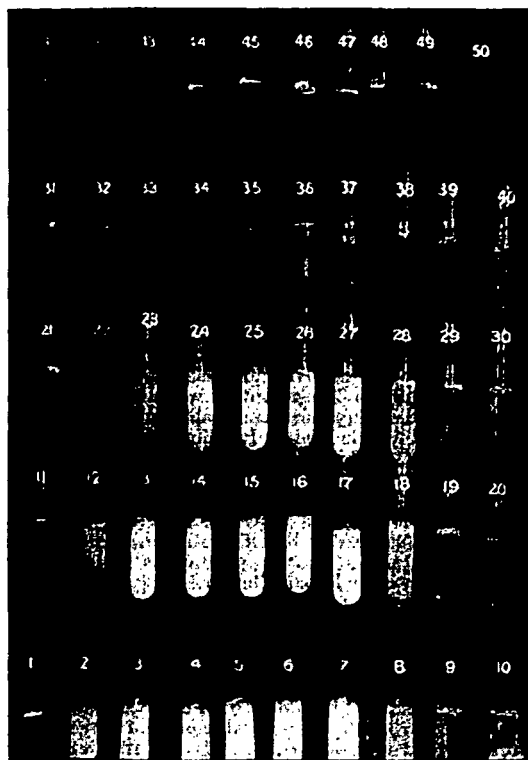
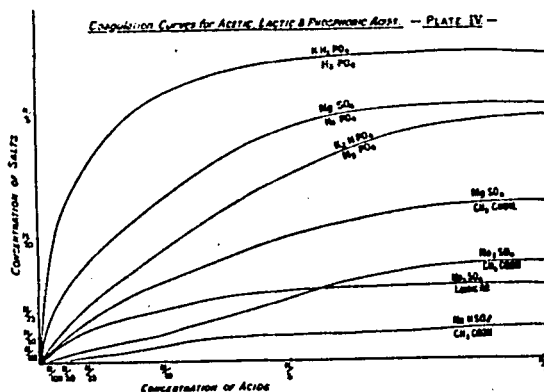
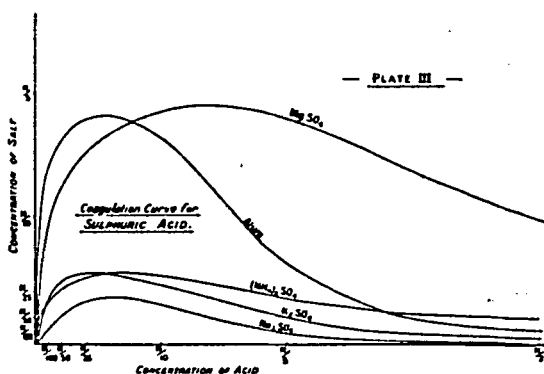
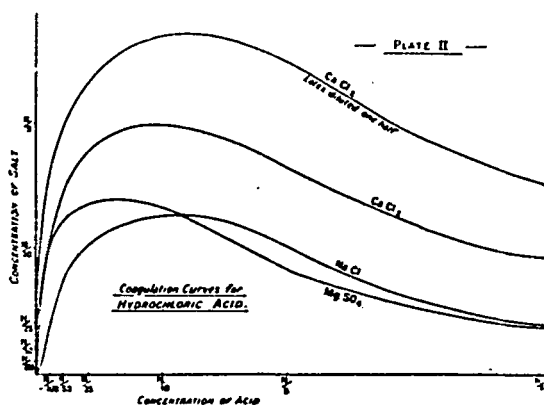


PLATE I.

At concentrations of acid and salt corresponding to any point within the curve coagulation does not take place and the solution remains permanently milky, though a thin skin or coagulum, due to the creaming of the larger caoutchouc globules, may form at the surface. Examination of the opaque serum after several days shows the presence of caoutchouc globules in a state of Brownian movement.

At concentrations of acid and salt corresponding to any point outside the curve coagulation is complete, and no caoutchouc globules are to be found in the serum which is quite clear. Proceeding from any point of concentration inside the curve in a vertical direction, as the concentration of the salt increases, the degree of coagulation increases, becoming complete on reaching a point outside the curve and increasing in intensity the further we get from it.

The difference in intensity of the coagulation between points remote from the curve and points adjacent to it was distinctly perceptible in all experiments. The coagula formed by high concentration of salt at points distant from the curve were tougher and stronger in texture, while those formed at low concentration of salt were soft and spongy. Thus one could easily arrange a number of samples of coagula according to their position with respect to the curve. On rolling the samples, however, these differences were much less obvious.



The water-absorbing capacity of the protein in the different samples was determined as follows. The clots from a vertical series of tubes were first washed thoroughly in running water, and dried between sheets of blotting paper and in the open for 24 hours. They were then weighed and afterwards dried to a constant weight in a steam oven. The results were as follows:—

Loss of water on heating rubber to 100° C.

Sample.	Initial weight.	Dry weight.	Difference.	Percentage loss.	Concentration of Salt.	Acid.
1	3.55	3.16	0.39	10.9	N	N/50
2	3.10	2.76	0.34	10.9	N/2	N/50
3	3.17	2.90	0.27	8.5	N/5	N/50
4	2.70	2.54	0.16	5.9	N/10	N/50
5	2.05	1.92	0.13	6.3	—	2N

thus showing that the water-absorbing capacity of the coagulum varies inversely as the concentration of salt in the serum.

Examination of the curves shows that the inhibiting effect of acids on coagulation increases with increase of concentration of acid up to a certain maximum. Beyond that, in the case of hydrochloric and sulphuric acids, the inhibiting effect begins to diminish with increasing concentration of the acid, until at a concentration of N/2 coagulation takes place without the addition of salt. With acetic, lactic, and phosphoric acids, further increase in concentration has no effect, and these acids are unable to produce coagulation at any concentration in the absence of salt. Small differences in the concentration of the organic acids have very little influence on the degree of coagulation produced by salts. Particularly is this the case with acetic acid in the presence of sodium sulphate or bisulphite. This accounts for the fact that acetic acid as used on plantations allows considerable variation in the strength required for coagulation.

Sulphuric acid in the presence of sodium salts behaves similarly but in a less degree. At concentrations of sodium salts above N/25 coagulation is produced at all concentrations of acid. Eaton, using undiluted latex, found that coagulation was produced at all concentrations of sulphuric acid. It follows, therefore, that the concentration of salts in latex corresponds to at least N/25 sodium sulphate. Comparison of the coagulating effect of various salts shows that the valency of the radicles does not appear to exert much influence. Considering the curves for sodium salts, the sulphate is more powerful than the phosphates or chloride, and comparing the effects of the basic radicles, arranged in order of effectiveness they form a series thus: Na, K, NH₄, Al, Mg. These results do not agree with those of Wood, who found that with wheat gluten the coagulating effect of salts was related to the valency of the kations. They agree, however, with Hofmeister's series, and probably represent the comparative water-drawing capacities of the salts.

Chick and Martin, experimenting with egg albumen, found that the precipitation of protein was analogous to the salting out of alcohol. The first effect of concentrated salt is to withdraw water from the protein aggregates. When precipitation is about to take place, the anion or kation of the electrolyte present can complete the process by neutralising the charges of the particles. Thus in studying the total effect of the concentration of salt on coagulation, the influence of the ions of the electrolytes must be regarded as subsidiary to the dehydrating effect of the salt as a whole. It would appear that coagulation of latex is analogous to the salting-out of proteins like casein and egg-albumen. On this supposition, the addition of salts like sodium and magnesium sulphate to latex causes a separation into two phases, one protein-rich and the other protein-poor, whatever the charge upon the protein aggregates, if enough salt be added. Such phase-separation would be facilitated if the particles were positively charged, that is, in solutions more acid than the isoelectric point. With negatively charged particles in an alkaline solution, the charge cannot be neutralised by the more potent SO₄⁻, which, if adsorbed, would still further increase the negative charge. Thus the addition of the proper quantity of acid to latex, normally alkaline, gives the particles a positive charge, and enables the salts in the latex to effect coagulation.

The system on separating into two phases attains equilibrium, and any alteration in the amount of any one of their three components is followed by a change both in their composition and volume. Thus increase in concentration of salt or of protein is followed by a corresponding increase in the protein-rich phase (precipitate). This influence of the quantity of protein on coagulation is seen in the curves for HCl and CaCl₂, showing that latex diluted until it contains half the quantity of protein requires more salt to effect coagulation. Eaton also gives analytical results in support of this theory as follows:—

Sample.	Vol. of latex.	Vol. of water added.	Vol. of acetic acid, 1 per cent.	Composition of Coagulum.	
				Protein, per cent.	Ash, per cent.
1	c.c. 100	c.c. 200	c.c. 10	2.2	0.13
2	100	100	10	2.4	0.10
3	100	50	10	2.5	0.12
4	100	—	10	2.6	0.12

The influence of the increase in the concentration of salt on the physical properties of the coagulum has already been shown. It also affects the composition, but to a less degree. Increase in the salt component is divided proportionally between the two phases, so that most of it remains in the watery phase and only a small quantity enters into the protein-rich phase, which loses a certain quantity of its water. Chick and Martin found this to be the case with egg-albumen and in the above analysis of rubber there is very little difference, if any, in the salt content of the coagulum formed at different concentrations of the latex. In Eaton's analysis this increase was so small as to be imperceptible. His results show little or no difference in the salt content on diluting the latex.

The foregoing results support the theory of Riffen-Weber and others that the protein constituents play a most important part in coagulation and determine to a considerable degree the physical properties of the resulting rubber coagulum.

According to the analysis of Seeligmann, *Hevea* latex from Brazil contains 55 per cent. of water and 9 per cent. of mineral salts, chiefly sodium and calcium, in combination with complex organic acids. It follows therefore that in the Amazonian smoking method, coagulation of the latex takes place at a concentration of salt higher than 18 per cent. It seems very probable that the high concentration of salt and protein in this process is a factor determining the superior qualities of Brazilian rubber, and that the dilution of latex on Eastern plantations by the direct addition of water and acid solution is largely responsible for the inferiority of plantation rubber. If this be the case, then those substances (the protein and ash), hitherto regarded as undesirable impurities in the rubber, are just the factors upon which the quality of the product depends.

This theory would account for the variability which exists among plantation rubbers even from the same estate. Tapping experiments in several countries have shown that the yield and composition of the latex vary considerably with respect to the percentages of caoutchouc, protein and ash, according to the length of tapping, age of trees and rainfall. This variation in composition, in addition to that directly due to artificial dilution of the latex in the factory, will result in considerable variation in the quality of the rubber produced from day to day. The standardisation of plantation rubber therefore involves testing the daily output of the factories, since, if the method of preparation were standardised, the natural variation in the composition of latex itself would cause daily variation in the quantity of rubber produced. If, then, dilution of the latex lowers the quality of the rubber, it should be possible to improve it by increasing the concentration of salts or protein in the latex. The writer has prepared samples of rubber by coagulation in the presence of varying concentrations of salt, but before expressing an opinion on the value of this method, manufacturers' tests of these samples are being obtained. As such tests, however, require a considerable time, the

results so far obtained were considered sufficiently suggestive to warrant publication by themselves. The results of these vulcanising tests will be published as soon as available.

Spence, as a result of microscopic examination of Para rubber, attributes the superior qualities of Fine Hard Para to the presence of tough protein fibres. He does not account for the differences in the degree of toughness of the fibres of different rubbers, nor does he attempt to correlate the existence of such fibrous material running through the caoutchouc with the physical properties of rubber. The writer has not been able to detect the presence of fibres in raw rubber. Observation of the process of coagulation under the microscope showed that the caoutchouc globules are embedded in the protein rather than *vice versa*, and that on pressing the coagulum beneath the coverslip coalescence of the caoutchouc and protein takes place with formation of what appears to be a solid solution of the two constituents.

The part played by caoutchouc globules during coagulation also requires consideration. Since they exist in the latex in a state of Brownian movement which is considerably affected by changes in concentration of salt and acid, it is very probable that their physical properties in the final product are also affected by these changes. Schidrowitz has shown that the viscosities of rubber solutions in benzene vary according to the quality of the rubber. In preparing such solutions, the clear liquid is decanted off from the insoluble nitrogenous constituent. It follows therefore that the properties of the protein in the rubber have no influence on the viscosity determination and that the condition of the caoutchouc itself varies according to the method of preparation of the sample. Further, if the quality of a sample of rubber is dependent on the properties both of the caoutchouc and of the protein, and these properties may vary in different directions at the same time, it is possible that a given sample of rubber may be inferior in general physical properties to another sample after vulcanisation, but superior to it in the viscosity test. This is found to be the case in actual practice, and as a result much doubt has been thrown on the value of viscosity tests.

The problem that remains to be solved, therefore, is what conditions determine the physical properties of the caoutchouc in rubber. The writer leaves further discussion of this question until the above-mentioned vulcanisation tests are available.

Before concluding I wish to express my indebtedness to Mr. Sharples, A.R.C.Sc., of the Mycological Department, Fed. Malay States, who conducted experiments in conjunction with these on the effect of varying salt concentrations on the growth of organisms causing the spotting of plantation rubber, results of which will appear elsewhere; also to Mr. Lambourne, F.R.H.S., Superintendent of Government Plantations, for assistance in many other ways.

SUMMARY.

It is shown that the physical properties of the coagula of *Hevea* latex depend on the concentration of acid and salts in the serum at the time of coagulation, and it is suggested that these have an important bearing on the difference in quality between rubber produced by different methods, notably Fine Hard Para and plantation rubber.

Suggestions are made for improving the plantation methods of coagulation and the difficulties of standardisation are shown.

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POWER AND HEAT COSTS IN CHEMICAL WORKS.

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At the Annual Dinner of the Manchester Section, a speaker expressed the view that the future of British chemical industries was assured if the horse-power could be obtained at a cost of 30s. per annum. This suggested to the author that it might be of value to set forth the true position in regard to power costs in chemical works.

There is hardly an industry in the country in which chemistry is not associated with engineering in the production of saleable commodities, therefore one must perforce deal with the above subject on broad and general lines. In chemical works economy "power" and "heat" costs seem to be inseparable, but to vary in relation to one another in a marked degree. For example, in two different works, of each 100 tons of coal consumed, one will require 20 tons for motive power and 80 tons for heating, whilst the other will have these conditions reversed. The substitution of more economical engines for power purposes in the two works will have very different significance. This may perhaps be best illustrated by a recent case in my own experience. A firm consulted me upon a proposal to pull out several small and wasteful steam engines and to substitute two gas engines with suction gas plants. They had good boiler plant, but in bad condition and inefficiently worked. Though the engines were wasteful, the bulk of the steam generated seemed to be utilised for heating and boiling, and the boiler efficiency seemed to be low.

Simple tests confirmed these suspicions. The boiler efficiency was only about 50 per cent. and only 20 per cent. of the steam generated went for motive power. Upon the basis of burning 100 tons of coal, 20 tons of this would go for power. The installation of the gas plant would reduce this amount say to 5 tons, or the whole consumption to 85 tons. The alternative suggested was to spend half the money the gas plants would have cost on boiler house improvements so as to bring its efficiency up to 70 per cent. Thus without any alteration within the works the 100 tons of coal would be reduced to about 72 tons. The first proposal, taking capital charges into account, showed 15 per cent. on its outlay involved, the second 50 per cent. on its outlay, obviously the better proposition from every point of view.

The chemist is by his training eminently qualified to analyse such cases. He generally knows more of the theory of combustion and evaporation than the engineer, but often fails apparently to turn his knowledge to practical account. He may for example install an automatic carbon dioxide recorder, spend much time in keeping it in