

freed from air by pumping, gave a specific gravity of 5.335 but a powdered portion gave 5.60. There thus appears no evidence of the existence of a second solid form of cadmium iodide, even at higher temperatures.

Summary.

1. By crystallizing cadmium iodide from solutions in hydriodic acid, products of low specific gravity, in all respects similar to the so-called " β -cadmium iodide," were obtained. On analysis these were found to contain hydriodic acid and water in addition to cadmium iodide.

2. A critical examination of Clarke and Kebler's work leads to the conclusion that there is no valid evidence of the existence of a form of cadmium iodide of lower specific gravity than 5.6.

SOME REACTIONS DURING WATER TREATMENT.¹

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The necessity for a treatment to improve the University of Illinois Water Supply is shown by a variety of unsatisfactory features viz: turbidity forming on exposure to the air; sediment varying in color from black to red according as the amount of oxidation of the iron salts varies; trouble from crenothrix in the mains; soft scale, clogging the feed pipes of boilers and trouble in dairying and photography. The Champaign and Urbana city water which is drawn from the same geological formation, has the same drawbacks and also causes incrustation in tea-kettles and the clogging of water backs in ranges and furnaces.

In attempting to improve the water by removing the carbonates of calcium and magnesium, the amounts removed did not correspond to our calculations. Analysis of the water had been made gravimetrically and also by the briefer methods suggested by the American Public Health Association. The results of the former analysis are as follows.

ANALYSIS OF WATER FROM UNIVERSITY OF ILLINOIS WATER SUPPLY.

Ions	Parts per Million	Hypothetical Combinations	Parts Per Million	Grains Per U. S. Gallon
Potassium, K	2.6	Potassium nitrate, KNO ₃	1.1	0.06
Sodium, Na	29.0	Potassium chloride, KCl	2.9	0.17
Ammonium, NH ₄	2.3	Sodium chloride, NaCl	3.5	0.20
Magnesium, Mg.	34.9	Sodium sulphate, Na ₂ SO ₄	3.6	0.21
Calcium, Ca	70.1	Sodium carbonate, Na ₂ CO ₃	60.5	3.52
Iron, Fe	1.0	Ammonium carbonate, (NH ₄) ₂ CO ₃	6.1	0.36
Aluminium, Al	1.3	Magnesium carbonate, MgCO ₃	121.2	7.07
Nitrate, NO ₃	.7	Calcium carbonate, CaCO ₃	175.2	10.22
Chlorine, Cl	3.5	Iron carbonate, FeCO ₃	2.1	0.12
Sulphate, SO ₄	2.3	Alumina, Al ₂ O ₃	2.5	0.15
Silica, SiO ₂	18.9	Silica, SiO ₂	18.9	1.10
		Total,	397.6	23.18

¹ Read at the Toronto Meeting of the American Chemical Society.

From the results of these analyses we calculated the amount of lime necessary to react with the acid carbonates of calcium and magnesium, and treated the water accordingly.

An analysis of the water after treatment showed that the reduction in alkalinity was less than expected. The use of varying amounts of dry water-slacked lime made apparently no change in the speed of the reaction nor in the reduction of the alkalinity. On the supposition that the reaction would be more rapid and more complete if lime water was used, varying amounts were tried but without satisfactory results.

With a view to explaining the difficulty and determining just what reactions occur on each addition of lime, (calcium hydroxide) a series of tests was planned. A liter of water was measured into each of 19 two-liter glass stoppered bottles. Varying portions of a saturated solution of lime water, 10 cc. of which were equivalent to 23 milligrams of calcium carbonate were added to each of the 19 samples. The varying amounts of lime water used, with the equivalent in terms of calcium carbonate, are shown in Table 1. Since previous experiments had shown that the reaction was practically complete at the end of six hours, the precipitate formed in each bottle was filtered off at the end of that time. In the filtrate the alkalinity to phenolphthalein and methyl orange and the content of magnesium and calcium were determined. The results of these determinations are shown in Table 1 and a diagrammatic representation is given on Plate 1.

TABLE 1

TREATMENT OF THE UNIVERSITY OF ILLINOIS WATER SUPPLY WITH LIME

No.	Lime Water cc.	Amount of Lime Used Milligrams as CaCO ₃	Alkalinity to Phenolphthalein		Alkalinity to Methyl Orange		Calcium		Magnesium as MgCO ₃	
			Fillrate Parts per million	Cor. for volume Parts per million	Filtrate Parts per million	Cor. for volume Parts per million	in 250 cc. volume Parts per million	Cor. for 200 cc. from volume Parts per million	Mg ₂ P ₂ O ₇ Milligrs.	Cor. for. Parts per million
1	0	0	0	0	387.5	387.5	26.5	188.7	33.1	124.4
2	10	23	11.5	11.7	378.0	381.8	27.5	198.6	33.2	126.0
3	20	46	10.5	10.7	354.9	361.9	25.8	187.5	33.8	118.0
4	40	92	16.8	17.5	312.9	325.4	18.0	133.9	36.0	131.6
5	60	138	18.9	20.1	270.9	287.1	12.9	97.4	40.5	126.0
6	70	161	12.6	13.5	256.2	274.1	10.8	82.3	39.4	126.0
7	80	184	12.6	13.6	241.5	260.8	9.0	69.0	37.3	121.6
8	100	230	18.9	20.8	222.6	244.9	7.1	54.9	34.2	113.6
9	120	276	31.5	35.3	212.1	237.6	6.6	52.6	34.5	116.0
10	140	322	42.0	47.9	203.7	232.2	5.3	43.2	32.7	112.0
11	160	368	52.5	60.9	200.5	232.6	5.7	46.2	31.9	110.8
12	170	391	65.1	76.2	193.2	226.0	5.7	46.7	30.4	105.2
13	180	414	66.3	78.2	184.8	218.1	5.7	48.4	27.8	99.6
14	200	460	65.1	78.1	163.8	196.6	5.5	46.7	23.4	84.4
15	220	506	58.8	71.7	138.6	169.1	5.1	43.9	5.3	19.2
16	240	552	58.8	72.9	111.3	138.0	4.5	39.7	5.2	19.2
17	260	598	52.5	63.3	98.7	124.4	4.4	38.9	7.7	27.6
18	280	644	50.4	64.5	98.7	126.3	7.0	63.9	5.0	19.2
19	300	690	48.3	62.8	94.5	122.3	6.3	58.4	4.8	19.2

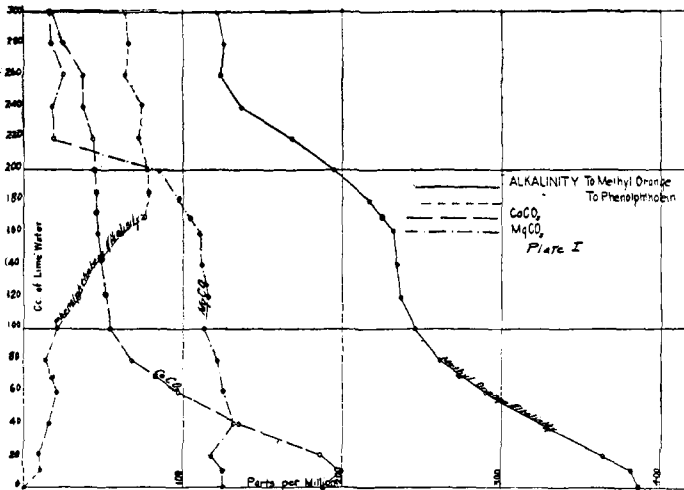


PLATE I.—Water Containing Bicarbonates of Alkalies and Alkaline Earths Treated With Lime.

The reactions with a water of this class apparently take place in four stages. During the first stage, the reaction is between the calcium hydroxide and the free carbon dioxide, during which the alkalinity to phenolphthalein remains negative, the alkalinity to methyl orange and the calcium content increases, and the magnesium content is unaffected.

During the second stage, the calcium hydroxide reacts with the calcium acid carbonate. The calcium content and the alkalinity to methyl orange decrease at equal rates; the magnesium content and the alkalinity to phenolphthalein are practically constant.

During the third stage, the calcium hydroxide reacts with the sodium bicarbonate, the alkalinity to methyl orange is unchanged, the alkalinity to phenolphthalein is increased, while the content of calcium and magnesium are constant.

During the fourth stage, the calcium hydroxide reacts with the magnesium bicarbonate with the formation of magnesium hydroxide and calcium carbonate accompanied by a decrease of the alkalinity to both methyl orange and phenolphthalein and decrease in the content of magnesium.

A fifth stage might be noted when an excess of calcium hydroxide has been added. The calcium, and the alkalinity to both methyl orange and phenolphthalein increase.

The formulas illustrating the reactions during the various stages are as follows :

1. $\text{Ca}(\text{OH})_2 + 2\text{CO}_2 = \text{CaCO}_3 + \text{H}_2\text{CO}_3$.
2. $\text{Ca}(\text{OH})_2 + \text{CaCO}_3 + \text{H}_2\text{CO}_3 = 2\text{CaCO}_3 + 2\text{H}_2\text{O}$.
3. $\text{Ca}(\text{OH})_2 + 2\text{NaHCO}_3 = \text{CaCO}_3 + \text{Na}_2\text{CO}_3$.
4. $2\text{Ca}(\text{OH})_2 + \text{MgCO}_3 + \text{H}_2\text{CO}_3 = 2\text{CaCO}_3 + \text{Mg}(\text{OH})_2 + 2\text{H}_2\text{O}$.

Under the conditions of the experiment we would not wish to imply that these reactions take place in entirely the order named. There is evidently some overlapping, but the diagrammatic representation shows that the principal part of the reactions takes place in this order.

In order to confirm our results a second water was chosen from the well of the Illinois Hotel Company, at Bloomington, Illinois. An analysis of this water is as follows:

ANALYSIS OF WATER FROM ILLINOIS HOTEL CO., BLOOMINGTON, ILL.

Ions	Parts Per Million	Hypothetical Combinations		Parts Per Million	Grains Per Gallon
Potassium, K	4.9	Potassium nitrate,	KNO_3	0.6	0.03
Sodium, Na	84.4	Potassium chloride,	KCl	9.0	0.52
Ammonium, NH_4	10.8	Sodium chloride,	NaCl	15.2	0.89
Magnesium, Mg	30.1	Sodium sulphate,	Na_2SO_4	4.4	0.26
Calcium, Ca	55.9	Sodium carbonate,	Na_2CO_3	177.2	10.35
Iron, Fe	6.6	Ammonium carbonate,	$(\text{NH}_4)_2\text{CO}_3$	28.7	1.67
Alumina, Al_2O_3	1.4	Magnesium carbonate	MgCO_3	104.2	6.07
Nitrite, NO_3	0.4	Calcium carbonate,	CaCO_3	139.5	8.13
Chlorine, Cl	13.5	Iron carbonate,	FeCO_3	13.7	0.80
Sulphate, SO_4	3.0	Alumina,	Al_2O_3	1.4	0.08
Silica, SiO_2	17.7	Silica,	SiO_2	17.7	1.03
Bases	.6	Bases,	---	0.6	0.03
		Total	---	512.2	29.84

This is shown to contain a larger proportion of sodium bicarbonate, but smaller amounts of the bicarbonates of calcium and magnesium. The other constituents are about the same as in the University of Illinois water supply.

Portions of this water were treated with lime water as in the previous experiment. The results of the treatment are shown in Table 2 and represented diagrammatically on Plate 2. It will be noted that the methyl orange alkalinity curve corresponding to the reaction between calcium hydroxide and calcium bicarbonate is shorter. The line denoting the reaction between calcium hydroxide and sodium bicarbonate is longer, while the curve where magnesium is reacted upon is shorter, indicating the truth of our hypothesis as to the order of reaction.

Precipitation with Sodium Hydroxide.—A series of tests using sodium hydroxide instead of calcium hydroxide was next carried on. The University water supply was treated. The analytical results are shown in Table 3 and a diagrammatic representation is seen on Plate 3.

Comparing Plates 1 and 3 it will be noted that the stages of the re-

actions with sodium hydroxide correspond to those with lime. The first stage, indicated by the increase in alkalinity to methyl orange and the very slight decrease in the amount of calcium, shows reaction between the sodium hydroxide and free carbon dioxide. The second stage, indicated by the decrease in the calcium content and of the alkalinity to methyl orange, shows the reaction taking place between the sodium hydroxide and calcium bicarbonate. It will be noted that the calcium bicarbonate is removed with one-half the equivalent of sodium hydroxide. The third stage, indicated by a constant amount of calcium and magnesium implies a reaction between the sodium bicarbonate and sodium hydroxide. The fourth stage, indicated by a reduction of magnesium shows a reaction between the magnesium bicarbonate and sodium hydroxide. Here it is noted that the magnesium decreases much more slowly than when calcium hydroxide is used, and does not reach a minimum until a larger amount of sodium hydroxide has been added. The reactions during the different stages may be written as follows :

1. $2\text{NaOH} + 2\text{CO}_2 = 2\text{NaHCO}_3$.
2. (A) $2\text{NaOH} + \text{CaCO}_3\text{H}_2\text{CO}_3 = \text{Na}_2\text{CO}_3 + \text{CaCO}_3$.
2. (B) $\text{Na}_2\text{CO}_3 + \text{CaCO}_3\text{H}_2\text{CO}_3 = \text{CaCO}_3 + 2\text{NaHCO}_3 + 2\text{H}_2\text{O}$.
3. $\text{NaOH} + \text{NaHCO}_3 = \text{Na}_2\text{CO}_3 + \text{H}_2\text{O}$.
4. $4\text{NaOH} + \text{MgCO}_3\text{H}_2\text{CO}_3 = \text{Mg}(\text{OH})_2 + 2\text{Na}_2\text{CO}_3 + 2\text{H}_2\text{O}$.

TABLE 2.

TREATMENT OF WATER FROM DEEP WELL OF ILLINOIS HOTEL, CO.,
BLOOMINGTON, ILLINOIS, WITH LIME

No.	Lime		Alkalinity to Phenolphthalein		Alkalinity to Methyl Orange		Calcium		Magnesium	
	Water cubic centimetres	Amount of Lime Used Milligrams as CaCO ₃ .	Filtrate parts per million	Cor. for volume parts per million	Filtrate parts per million	Cor. for volume parts per million	CaO in 200 cc. Milli-grams	CaCO ₃ Cor. for volume Parts per million	Mg ₂ F ₂ O ₇ from 200 cc. milligrs.	as MgCO ₃ Cor. for volume parts per million
1	0	0	0	0	423	423	13.2	118.1	27.5	104.2
2	5	44	25	26	378	386				
3	10	88	38	39	343	357				
4	15	132	52	56	309	327	5.5	49.9	24.4	93.8
5	20	176	48	52	287	310				
6	30	264	69	78	261	292	3.4	33.9	20.1	85.2
7	35	308	90	103	256	292				
8	40	352	122	141	254	295	3.0	30.9	18.8	82.4
9	45	396	118	139	245	290				
10	50	440	108	129	239	287	3.0	31.9	14.9	67.2
11	60	528	109	135	192	237	2.2	24.2	6.2	29.1
12	65	572	118	148	179	225				
13	70	616	104	133	162	207	—	—	2.4	14.5
14	75	660	124	161	162	210				
15	80	704	147	194	178	236				
16	85	748	166	222	194	259	7.8	92.	1.8	9.0
17	90	792	178	243	202	274				
18	100	880	242	338	267	373				

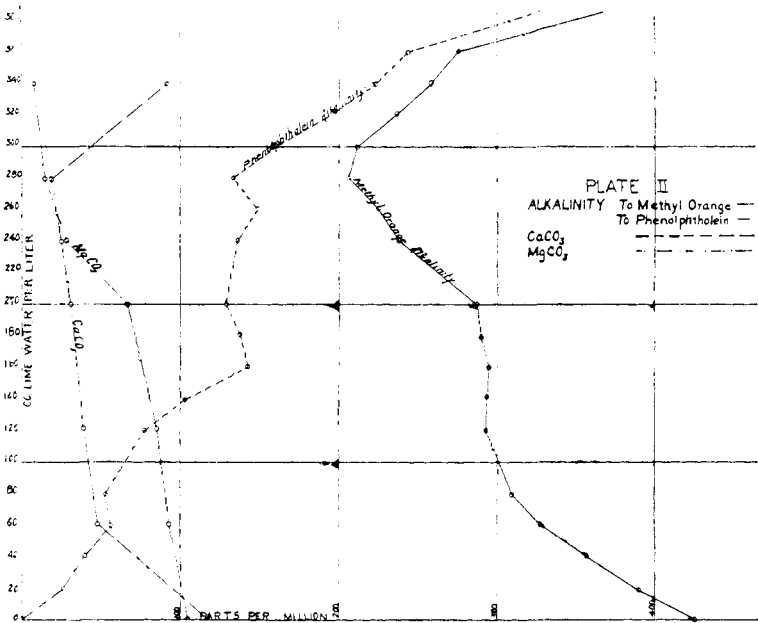


PLATE II.—Water Containing Bicarbonates of Alkalies and Alkaline Earths Treated With Lime.

TABLE 3
TREATMENT OF THE UNIVERSITY OF ILLINOIS WATER SUPPLY WITH SODIUM HYDROXIDE.

No.	Sodium Hydroxide Solution cc.	Amount of Sodium Hydroxide Used milligrams	Alkalinity to Phenolphthalein parts per million	Alkalinity to Methyl Orange parts per million	Calcium		Magnesium	
					CaO in 250 cc. milligrs.	CaCO ₃ Cor. for volume parts per million	Mg ₂ P ₂ O ₇ from 250 cc. milligrams	MgCO ₃ Corrected for Volume parts per million
1	0	0	0	386	26.5	189.1	39.7	120.5
2	1	17	0	405	26.0	185.5	39.8	120.5
3	2	34	22	403	22.1	157.8	38.3	118.8
4	4	68	26	388	12.8	91.3	38.1	118.4
5	6	102	50	388	7.2	50.4	37.4	113.2
6	7	119	72	406				
7	8	136	90	426	5.4	38.4	36.1	109.4
8	10	170	139	468				
9	12	204	147	511				
10	14	238	198	555				
11	16	272	248	589				
12	17	299	270	609	5.4	38.4	28.5	86.2
13	18	316	266	622	4.5	32.0	25.3	76.5
14	20	340	307	650				
15	22	374	334	673	3.0	21.2	15.8	47.8
16	24	408	369	702				
17	26	442	393	728	2.9	20.5	6.8	20.4
18	28	476	417	780				
19	30	510	463	813	2.1	15.0	3.2	9.7
20	32	544	518	845				
21	34	578	549	893	.8	5.5	2.2	6.6

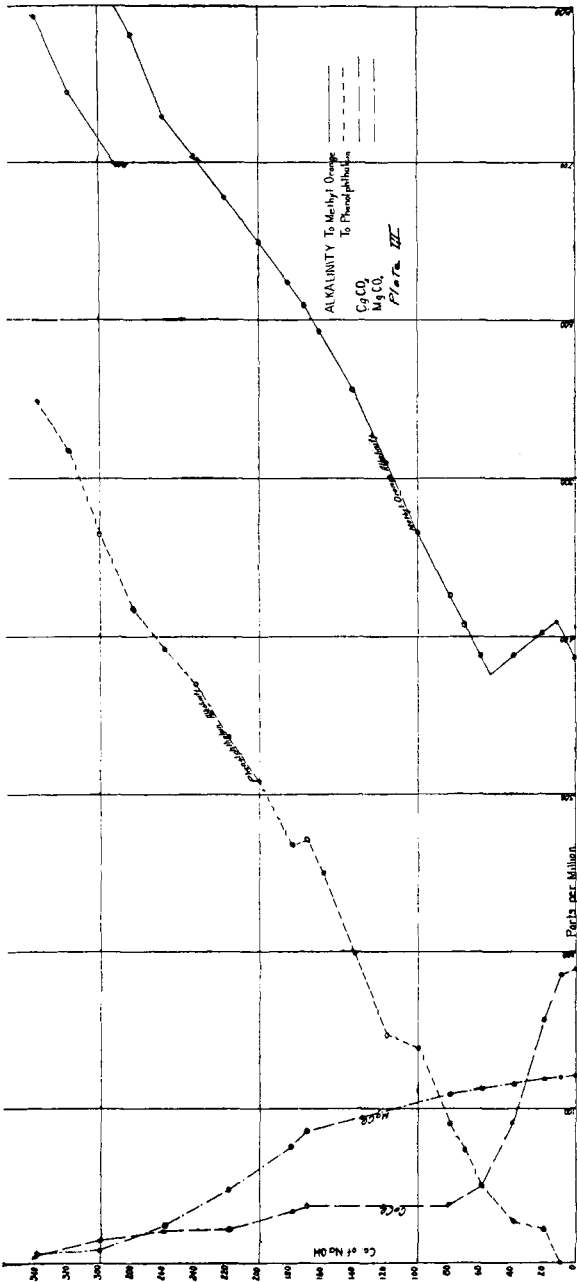


PLATE III. Water Containing Bicarbonates of Alkalies and Alkaline Earths Treated with Caustic Soda.

In order to try the effect of treatment of a water containing no sodium bicarbonate, the water from a shallow well in Champaign, Illinois, was chosen for experiment.

Analysis showed the following mineral content :

ANALYSIS OF SHALLOW WELL OF DEAN-BODE MFG. CO. CHAMPAIGN, ILL.

Parts per million	Hypothetical Contributions	parts per million	grains per gallon
Sodium, Na	Sodium nitrate, NaNO_3	1.6	0.09
Magnesium, Mg	Sodium chloride, NaCl	39.9	2.31
Calcium, Ca	Sodium sulphate, Na_2SO_4	53.7	3.13
Oxides of Iron and Alumina,	Magnesium sulphate, MgSO_4	143.7	8.49
Nitrate, NO_3	Magnesium carbonate, MgCO_3	36.4	2.12
Chloride, Cl	Calcium carbonate, CaCO_3	266.8	15.56
Sulphate, SO_4	Oxides of iron and alumina $\text{Fe}_2\text{O}_3 - \text{Al}_2\text{O}_3$	2.2	0.13
Silica, SiO_2	SiO_2	11.0	0.64
Bases,	Bases, with silica	3.0	0.17
Total Mineral Matter,		560.	32.64

Portions of this water were treated with lime as in the preceding experiments. The results of the analysis of the water after treatment including determination of incrustants according to method of the Am. Pub. Health Ass'n, are shown in Table 4 and a diagrammatic representation is shown on Plate 4. The reactions in this case are also in stages. The first and second correspond to the first and second stages of the preceding experiments. During the third stage no change is evident. Further data is necessary for explanation. The fourth stage shows a removal of the magnesium bicarbonate, with a corresponding decrease of alkalinity to methyl orange and phenolphthalein. The final stage where calcium hydroxide was added in excess, shows increase of the calcium

TABLE 4
TREATMENT OF WATER FROM SHALLOW WELL, CHAMPAIGN, ILLINOIS,
WITH LIME.

No.	Lime Water Used cc.	Amt of Lime Used milligrams	Alkalinity to Phenolphthalein.		Alkalinity to Methyl Orange		Calcium		Magnesium		Incrustants as CaCO_3 parts per million
			Rate per million	Cor. per million	Rate per million	Cor. per million	CaO in cc. milli-grams	CaCO_3 Cor. for volume per million	from Mg_2FeO_4 as MgCO_3 cc. milli-grams	Cor. for volume per million	
1	0	0	0	0	332	332	37.4	266.4	173.1	103.9	57.1
2	20	41	0	0	345	351	42.3	307.7	174.5		56.5
3	40	82	0	0	279	290					
4	60	124	0	0	236	255	24.0	181.6	174.5	91.7	53.6
5	80	165	0	0	209	228					
6	100	206	0	0	191	214					
7	120	247	6.4	7.4	169	191	14.4	114.8	93.0	48.8	164.8
8	140	288	11.9	13.6	118	137	8.5	68.8	157.9	94.6	45.6
9	160	330	25.7	31.0	110	129	8.6	70.8	148.2	85.4	42.2
10	180	371	29.4	35.	108	128	10.4	86.8	146.8	102.0	41.3
11	200	412	25.7	31.	94	118	11.1	93.8	137.1	104.0	38.1
12	220	453	18.3	22.	53	64	9.5	82.8	90.0	89.8	24.1
13	240	494	16.5	20.	51	64					
14	260	536	23.0	29.	39	48	11.3	99.6	63.6	95.0	15.8
15	280	577	31.2	40.	42	54					
16	300	618	41.	54.	66	86					
17	320	659	62.4	85.	83	104					
18	340	700	82.6	110.	101	133	29.62	82.5	5.5	91.2	1.3

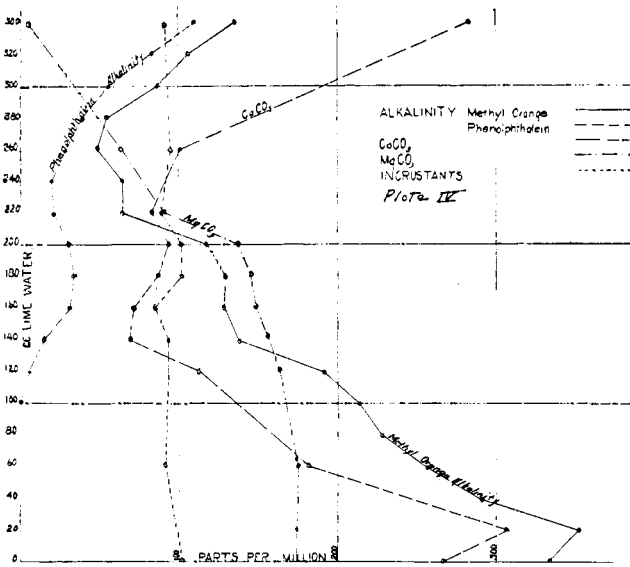


PLATE IV.—Water Containing Bicarbonates and Sulphates of Alkaline Earths Treated with Lime.

carbonate and alkalinity to both methyl orange and phenolphthalein. In this series of tests there was present in the original water 103 parts per million of sulphates of calcium or magnesium. According to the method of making hypothetical combinations which has been used in this laboratory, this would be considered magnesium sulphate. The amount of sulphates (see incrustants Plate 4) of the alkaline earths are unchanged by treatment with lime. There is here a possible confirmation of the statement that the sulphate exists as magnesium sulphate, since during the third stage there is not sufficient calcium present in the water to combine with all of the sulphates present, and when the magnesium becomes insufficient to combine with all of the sulphates, the calcium content increases. We may therefore consider that a reaction takes place between magnesium sulphate and calcium hydroxide, forming magnesium hydroxide and calcium sulphate. Our data is as yet insufficient to show whether an intermediate reaction takes place between magnesium hydroxide and magnesium acid carbonate, or whether there is interference by other salts. The work of Stillman and Cox¹ would suggest the latter explanation. The series of tests indicates that lime alone is insufficient for the treatment of such water.

Before undertaking the combined treatment with lime and sodium carbonate a similar series of tests was carried on, using varying amounts of

¹ This Journal 25, 732.

sodium carbonate. The results of these tests are shown in Table 5 and a diagrammatic representation is given on Plate 5. This series shows that the reactions take place in three stages. First, the reaction is between sodium carbonate and free carbon dioxide, with an increase in the alkalinity to methyl orange. Second, calcium bicarbonate is precipitated as calcium carbonate and incrustants are removed. Third, there is denoted an excess of reagent. The alkalinity to phenolphthalein and the alkalinity to methyl orange increase rapidly. The magnesium carbonate content remains constant throughout the whole series. The reactions of the first two stages are as follows:

1. $\text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O} = 2\text{NaHCO}_3$.
2. (a) $\text{Na}_2\text{CO}_3 + \text{CaH}_2(\text{CO}_3)_2 = \text{CaCO}_3 + 2\text{NaHCO}_3$.
- (b) $2\text{NaHCO}_3 + \text{MgSO}_4 = \text{MgH}_2(\text{CO}_3)_2 + \text{Na}_2\text{SO}_4$.

In the next series of tests sufficient sodium carbonate was added to each liter of water to react with the alkaline earth sulphates present. Varying amounts of lime were then added. The analytical results are shown in Table 6 and the diagrammatic representation on Plate 6. The reactions take place in four stages. First, by sodium carbonate the neutralization of the carbon dioxide. Second, the reactions with the alkaline earth sulphates and part of the calcium bicarbonate. Third, the removal of more

TABLE 5
TREATMENT OF WATER FROM SHALLOW WELL AT CHAMPAIGN, ILLINOIS,
WITH SODIUM CARBONATE.

No.	Sodium Car- bonate Solu- tion cc.	Am't of Sodium Car- bonate Used milli- grams as CaCO_3	Alkalinity to Phenol- phthalein		Alkalinity to Methyl Orange		Calcium		Magnesium		Incrustants as CaCO_3 parts per million
			Fil- trate parts per mil- lion	Cor. for volume parts per million	Fil- trate parts per mil- lion	Cor. for volume parts per million	CaO in 250 cc. milli- grams	CaCO ₃ cor. for volume parts per million	Mg ₂ P ₂ O ₇ from 250 cc. milli- grams	MgCO ₃ as cor. for volume parts per million	
1	0	0	0	0	334	334	36.1	257.6	57.3	173.2	103.9
2	20	22	0	0	369	376	39.4	260.4	56.6	174.3	101.0
3	40	44	0	0	391	404					59
4	60	66	0	0	380	402	28.1	212.4	53.3	170.4	16
5	80	88	0	0	380	411	25.7	186.8	51.8	169.0	
6	100	110	0	0	376	415	16.1	135.6	51.0	170.4	-67
7	120	132	0	0	380	426	14.4	114.8	51.0	173.2	-91
8	140	154	18	20	374	428	7.8	64.0	50.2	173.2	
9	160	176	11	13	404	468					-206
10	180	198	29	33	417	492	6.7	52.8	45.5	162.1	-221
11	200	220	35	42	437	525					-208
12	220	242	53	64	457	558	4.9	42.8	45.5	167.6	-279
13	240	264	59	72	481	597					-358
14	260	286	55	70	503	633	3.2	28.8			-426
15	280	308	57	73	525	672					-411
16	300	330	61	83	556	722	3.9	34.0	43.1	169.	-475
17	320	352	81	106	569	751					-620
18	340	374	92	121	590	789	3.4	31.6	42.3	170.4	-561

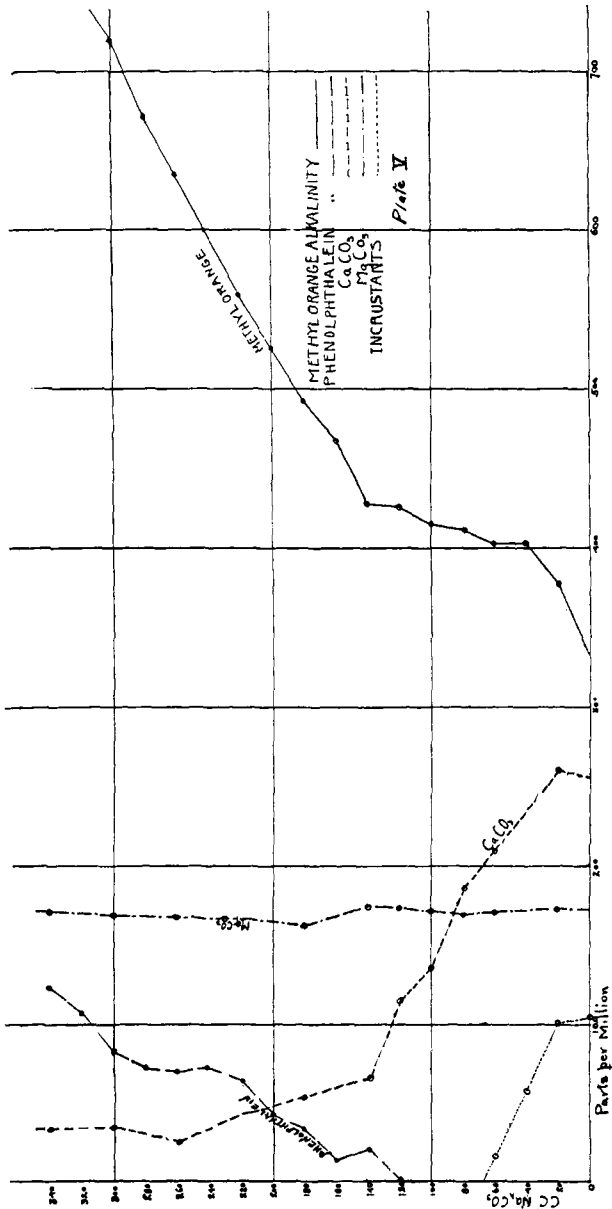
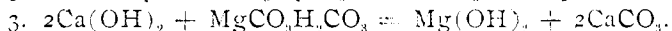
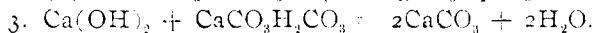


PLATE 5.—Water Containing Bicarbonates and Sulphates of Alkaline Earths Treated With Soda Ash.

calcium bicarbonate. Fourth, reaction between magnesium bicarbonate and calcium hydroxide, with removal of magnesium bicarbonate. The reactions during the various stages are as follows:

1. $\text{Na}_2\text{CO}_3 + \text{CO}_2 + \text{H}_2\text{O} = 2\text{NaHCO}_3$.
2. (a) $\text{Na}_2\text{CO}_3 + \text{CaCO}_3\text{H}_2\text{CO}_3 = \text{CaCO}_3 + 2\text{NaHCO}_3$.



Conclusion.

A general comparison of the results would indicate that reactions in water treatment take place in regular order depending on the amount of reagent used.

A practical application of these results may be found useful in determining the advisability of partial or complete treatment, in the latter case adding a considerable excess of the reagent in order to remove as completely as possible incrusting constituents.

During the first and second stages of treatment with lime there is removed from 70 to 80 per cent. (see Tables) of the carbonates of calcium or about 50 per cent. of the alkaline earth carbonates. To remove only a small percentage more requires nearly double the amount of lime; and to obtain the maximum removal (about 80 per cent. in these waters) would require nearly three times as much lime.

The presence of sodium bicarbonate must be considered in water treatment. It is also probable that other salts than the acid carbonate of sodium interfere with the reactions.

Neither lime or sodium carbonate alone will give a maximum removal of incrusting constituents in waters containing sulphates. If either is to be used alone, sodium carbonate is the better.

TABLE 6.

TREATMENT OF WATER FROM SHALLOW WELL, CHAMPAIGN, ILLINOIS, WITH A CONSTANT AMOUNT OF SODIUM CARBONATE, AND VARYING AMOUNTS OF LIME.

No.	Lime Water Used cc.	Am't of Lime Used milli- grams	Alkalinity to Phenol- anthalein		Alkalinity to Methyl Orange		Calcium		Magnesium		Incrustants as CaCO ₃ parts per million
			Fil- trate parts per mil- lion	Cor. volume parts per million	Fil- trate parts per mil- lion	Cor. volume parts per million	CaO in 200 cc milli- grams	CaCO ₃ cor. for volume parts per million	Mg ₂ P ₂ O ₇ from 200 cc milli- grams	as MgCO ₃ cor. for volume parts per million	
1	0	0	0	0	334	334	29.9	266.4	45.7	173.1	103.9
2	20	36	0	0	340	347	18.0	200.0	43.2	165.0	--5.7
3	40	72	0	0	312	324	14.4	133.5	32.7	167.5	--5.8
4	60	108	0	0	279	296	11.2	106.0	41.3	164.0	0
5	80	144	0	0	257	273	9.8	95.0	41.1	168.	--19.
6	100	180	0	0	242	266	8.1	79.5	38.0	157.5	--13.2
7	120	216	0	0	224	251					
8	140	252	20	23	211	241	7.1	72.5	37.0	159.5	18.2
9	160	288	29	34	211	245					
10	180	324	62	79	200	236	6.9	72.5	34.3	154.0	9.4
11	200	360	44	53	185	222					
12	220	396	33	40	158	192	5.2	46.0	29.8	137.0	--6.8
13	240	432	26	32	126	156	5.3	47.0	29.8	138.5	--6.9
14	260	468	28	35	110	139	6.4	57.0	15.9	75.0	--7.0
15	280	504	9	11.5	66	84	4.9	53.5	5.2	24.0	--18.0
16	300	540	11	14	70	91					
17	320	576	18	24	70	92	5.4	64.5	6.0	29.5	--15.8

Note.—To each portion of water 11 cc of sodium carbonate solution containing 116.6 milligrams Na₂CO₃ was added.

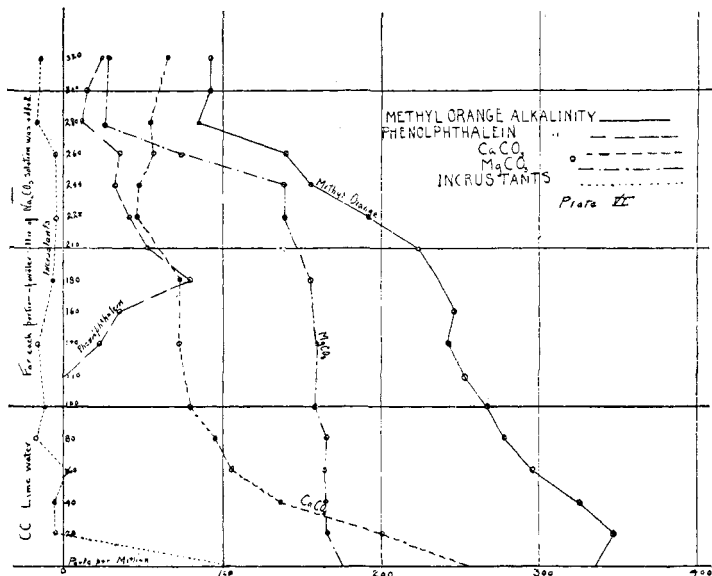


PLATE VI.—Water Containing Bicarbonates and Sulphates of Alkaline Earths Treated With Soda Ash and Lime.

ON THE OXIDATION OF HYDRAZINE. I.

BY A. W. BROWNE AND F. F. SHETTERLY.
 Received July 10, 1907.

In 1902 Tanatar¹ showed that hydronitric acid could be obtained by treating a molecular mixture of hydrazine sulphate and hydroxylamine chloride in acid solution with certain oxidizing agents. Three years later it was demonstrated in this laboratory² that the acid could be prepared by the action of hydrogen peroxide upon hydrazine sulphate in the presence of free sulphuric acid. Still later it was found³ that by the action of several other oxidizing agents, respectively, upon hydrazine sulphate in acid solution, varying amounts of hydronitric acid could be produced. In the present article is described a series of experiments performed for the purpose of ascertaining the conditions under which hydronitric acid is formed by the action of ammonium metavanadate in acid solution upon hydrazine sulphate.

Examination of Materials Employed.—In order to test the purity of the hydrazine sulphate (obtained from Kahlbaum, Berlin) used in these experiments, the percentage of sulphur was determined in six different samples of the material. Found: 24.57, 24.60, 24.56, 24.59, 24.58 and 24.54 per cent. ; theory, 24.64 per cent.

¹ Ber. 35, 1810-1811.

² Browne, This Journal 27, 551-555 (1905).

³ Browne, Science (N. S.) 22, 81 (1905).