LVII.—*On the Part played by Carbon in reducing the Sulphates of the Alkalis.*

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THE action when an alkaline sulphate, such as the sulphate of soda, is reduced by carbon, although investigated by such men as Liebig, Gay-Lussac, Berthier, Berthollet, and Vauquelin, has been a much misunderstood subject.

The general idea that the decomposition was a simple change of elements resulting in the formation of sodium sulphide (Na_2S), though seductive, has been shown by experiments made from time to time to be insufficient.

In a series of documents which have been entrusted to me by Mr. John Tennant, of St. Rollox, the late Professor Liebig describes at length a process which he had invented for the production of carbonate of soda. His letter announcing his discovery is dated 11th July, 1839, and his process was founded, as he himself says, on a discovery of Gay-Lussac's, that "caustic potash heated with wood sawdust, gave off *pure hydrogen*, and produced oxalate and acetate of potash. These two salts, if heated to redness, are converted into carbonates, the formation of oxalic and acetic acid taking place from the decomposition of water, the oxygen of which combines with the carbon while the hydrogen goes off":—

"Proceeding from this, and considering the great alkalinity of sulphuret of sodium, I thought it ought to have the same action upon wood fibre, that is, by heating a concentrated solution of this sulphuret with sawdust, there ought to be, at a certain temperature, the formation of oxalate and acetate of soda, and the evolution of sulphuretted hydrogen.

"This is exactly what takes place at 200°C . Heated to 300°C . these two salts are converted into carbonates."

Liebig says that he "had submitted this process to the judgment of the greatest chemists, and Gay-Lussac thinks it the most rational, and at the same time most simple process for producing carbonate of soda, and for using the sulphur." And again, in the same communication, he says, "In the opinion of Gay-Lussac and Berzelius this process will entirely supersede the present method."

The late Professor Graham had the process submitted to him, and reported to Liebig, "Your new experiment I have carefully repeated, and I do hope great things from it."

Gay-Lussac tried the process at Chauny on a very extended scale.

These experiments, and also a series conducted in St. Rollox Works, proved the process to be a failure as a method of manufacturing carbonate of soda, and it was abandoned; but Liebig, in reasoning on the causes of failure, seems to have been led to believe that it was owing to the decomposition of sulphate of soda by carbon being much more complex than had been thought, and he formulated the action as being—

(This formula has been altered into new notation for more convenient comparison.)

Unger, however, further examined the subject at Liebig's request, and seems to have decided that the decomposition of sulphate of soda by carbon resulted in—

But he again, in the second part of his memoir, examines the subject, and modifies his views so as to assume that it was—

My own investigations made at various times had led me to be dissatisfied with the explanation of what at first sight seems a very simple decomposition, and with a view of elucidating the question, I have made a series of experiments, the results of which I have now the honour of laying before the Chemical Society.

The method of conducting the experiments was as follows:—

The sulphate of soda thoroughly dried, and (a lamp-black which on examination proved to be remarkably pure) carbon thoroughly ignited and cooled out of contact with air under a desiccator, were mixed as rapidly but thoroughly as possible, and placed in a platinum crucible covered with a tight-fitting lid; this was then heated by gas in a jacketed support: after heating it was cooled under a desiccator and weighed. The crucible, with its lid and contents, was then placed in a flask fitted with a stopcock funnel and evolution tube, connected with a series of absorption vessels:—

A, evolution flask: B, trap flask containing a small quantity of dilute HCl; C, C, flasks containing a solution of As_2O_3 in HCl; D, D,

are absorbing tubes containing the same solution of As_2O_3 in HCl ; E, E, E, E, are absorbing tubes containing solution of barium and sodium hydrates; F is an exit-tube leading to the Bunsen pump.

The crucible and contents having been placed in the evolution flask A, water was added, and the apparatus connected together. The reduced sulphate was then decomposed with dilute hydrochloric acid, the sulphuretted hydrogen given off was absorbed in the arsenic solution in C, C, and D, D, and carbonic acid by the barium and sodium hydrates in E, E, E, E.

The decomposition was completed by boiling the flask A, and finally the flasks B and C, C, are also boiled to expel the carbonic acid that may have been retained in them.

The steam from C, C, raises the tubes D, D, to the boiling point, and all the carbonic acid was thereby expelled and collected in E, E, E, E. The last tube of the series was not found at any time to contain any trace of carbonic acid, thus proving the complete absorption by the previous tubes of the series E.

The contents of the tubes E, E, E, E, were emptied into a beaker, and enough hydrate of baryta added to precipitate all the carbonic acid as carbonate of baryta; this is then filtered off, the filter and its contents placed in a carbonic acid apparatus, and the carbonic acid determined by loss of weight.

The contents of C, C, and D, D, were emptied into a beaker, the filtrate from the carbonate of baryta from E, E, E, E, if it was found to contain any sulphide, was added, and the whole filtered through a tared filter, washed, dried, and weighed.

The contents of flask A were filtered through a tared filter, and the filtrate made up to 500 c.c., of which 100 c.c. were evaporated to dryness for total soda, and 200 c.c. were precipitated with barium chloride for sulphate undecomposed. The platinum crucible, after being thoroughly cleansed, was dried, weighed, ignited, and again weighed, the loss in weight giving sulphur in combination with platinum. The insoluble matter on the filter, washed and dried, is treated with bisulphide of carbon, dried, and weighed; it was then oxidised with nitric acid, filtered, and any metallic platinum estimated. The sulphuric acid thus formed is determined by precipitation with barium chloride in the usual way; the sulphur thus found is calculated into PtS_2 ; and this amount subtracted from the total weight of residue on the tared filter, gives by difference the amount of unconsumed carbon.

The bisulphide of carbon solution was then evaporated to dryness, and the sulphur weighed.

The first five experiments were made merely as a test as to whether carbonate of soda was formed in the decomposition:—

A. A mixture of—

Sulphate of soda 7.1 grams.

Carbon 1.2 „

Equal to $2\text{Na}_2\text{SO}_4 + 4\text{C}$,submitted to a bright red heat for 45 minutes, yielded for 100 Na_2SO_4 employed—19.3 per cent. as undecomposed Na_2SO_4 .11.91 „ „ converted into Na_2CO_3 .14.75 per cent. of the Na_2SO_4 decomposed being converted into Na_2CO_3 .

B. A mixture of—

Sulphate of soda 7.1 grams.

Carbon 1.2 „

Equal to $2\text{Na}_2\text{SO}_4 + 4\text{C}$,submitted to a bright red heat for 60 minutes, yielded for 100 Na_2SO_4 employed—10.8 per cent. as converted into Na_2CO_3 .

C. The crucible was lined with carbon and a mixture of—

Sulphate of soda 10.65 grams.

Carbon 1.8 „

Equal to $2\text{Na}_2\text{SO}_4 + 4\text{C}$,

was placed in the cavity, and covered with a layer of carbon, the excess carbon amounting to—

3.901 grams.

The crucible was exposed for 45 minutes to a red heat, and then to a high red heat for 15 minutes more.

Yielded for 100 Na_2SO_4 employed—.50 per cent. as undecomposed Na_2SO_4 .1.00 „ „ converted into Na_2CO_3 .1.05 per cent. of Na_2SO_4 decomposed is converted into Na_2CO_3 .We can here see the effect of the higher temperature and excess of carbon, the amount of Na_2CO_3 being much less than in the cases A and B.

	C.	S.	O.	Na.	Na_2SO_4 .
Na_2SO_4 employed	—	22.535	45.07	32.395	100.00
with	53.531	—	—	—	—
Obtained as undecomposed carbon	20.61	—	—	—	—
„ „ Na_2SO_4	—	0.112	0.225	0.162	0.50
„ carbonate Na_2CO_3 . . .	0.084	—	0.335	0.321	1.00
Total obtained	20.694	0.112	0.560	0.483	1.50
As undetermined	—	22.423	—	31.912	98.50
Loss	32.837	—	44.51	—	—

The carbon and oxygen have in this case been given off in such proportions that it is evident the carbon must have been evolved nearly altogether in the form of carbonic oxide.

32·837 carbon require for conversion into CO 43·782 oxygen; whilst 44·51 oxygen has actually been lost. Thus ·738 oxygen apparently has been evolved as CO₂, and of 100 parts carbon employed—

98·34 per cent. has gone to form CO, and
1·66 „ „ „ CO₂.

D. A mixture of—

Sulphate of soda 10·65 grams
Carbon 1·8 „
Equal to 2Na₂SO₄ + 4C,

submitted to a low red heat over a Bunsen lamp for 30 minutes, then to white heat over a blowpipe for 20 minutes more, yielded for 100 Na₂SO₄ employed—

20·377 per cent. as undecomposed Na₂SO₄
1·340 „ „ converted into Na₂CO₃.

1·68 per cent. of the Na₂SO₄ decomposed being converted into Na₂CO₃.

E. A mixture of—

Sulphate of soda 10·65 grams
Carbon 1·8 „
Equal to 2Na₂SO₄ + 4C,

submitted to a low red heat over a Bunsen lamp for 60 minutes, yielded for 100 Na₂SO₄ employed—

19·1 per cent. as converted into Na₂CO₃.

A number of subsidiary experiments were made to ascertain the temperature at which the decomposition took place, and it appears from these that below a dull red heat the decomposition of sulphate of soda by carbon does not take place to any appreciable extent, but that at a red heat it takes place readily—

F. A mixture of—

Sulphate of soda 10·65 grams
Carbon 1·8 „
Equal to 2Na₂SO₄ + 4C

submitted to a dull red heat for 60 minutes over a Bunsen lamp. Approximate temperature 1270° F.

Note.—The temperature in this and succeeding experiments was taken by heating the copper ball of a pyrometer in the same position as the crucible, and taking the temperature thus determined as approximately that of the crucible and contents.

Yielded for 100 Na_2SO_4 employed—

21·73 per cent. as undecomposed Na_2SO_4

23·20 „ converted into Na_2CO_3 .

29·64 per cent. of the Na_2SO_4 decomposed being converted into Na_2CO_3 .

	C.	S.	O.	Na.	Na_2SO_4 .
Employed Na_2SO_4	—	22·585	45·070	32·395	100·00
With	16·901	—	—	—	—
Obtained as undecomposed carbon	—	—	—	—	—
„ „ Na_2SO_4	—	4·897	9·794	7·039	21·73
„ carbonate Na_2CO_3 ...	1·961	—	7·843	7·516	23·20
„ sulphide Na_2S	—	11·412	—	16·400	50·632
„ sulphur, free S	—	3·953	—	—	—
„ „ with Pt = S	—	2·320	—	—	—
Total obtained	1·961	22·582	17·637	30·955	95·562
Undetermined	—	—	—	1·440	4·445
Loss.....	14·940	—	27·433	—	—

In this experiment the Na not accounted for as undecomposed Na_2SO_4 , or as Na_2S and Na_2CO_3 , amounted to Na 1·44, and this calculated into $\text{Na}_2\text{S}_2 = 2·004$ S = 3·444 Na_2S_2 ; the total sulphur, free and combined with Pt, amounted to 6·273. Deducting 2·004, we have 4·269 calculated into $\text{Na}_2\text{S}_2 = 10·406$ $\text{Na}_2\text{S} = 14·675$ Na_2S_2 . This added to 3·444 $\text{Na}_2\text{S}_2 = 18·119$ Na_2S_2 , and as the Na_2S as found = H_2S evolved = 27·812 — 10·406 = 17·406 Na_2S existing as such, there has been decomposed $100 - 21·73 = 78·27$ per cent. of the Na_2SO_4 employed, with a loss of oxygen equal to 27·433. As it is shown by experiment C that the excess carbon acts by reducing CO_2 to CO, we must, in calculating the formulæ of the actual decomposition of the Na_2SO_4 , take the carbon in the same ratio as the Na_2SO_4 , in this case 78·27 per cent.

78·27 per cent. of 16·901 carbon employed = 13·28, corresponding to the equation $2\text{Na}_2\text{SO}_4 + 4\text{C}$. Deducting from this the C equivalent of the $\text{Na}_2\text{CO}_3 = 19·61$, there is left 11·267 as evolved in combination with 27·433 oxygen.

Calculating the carbon in the first instance into CO—

$$11·267 \text{ C} + 15·022 \text{ O} = 26·289 \text{ CO}.$$

Then—

$$27·433 \text{ O} - 15·022 \text{ O} = 12·411 \text{ O}.$$

This into $\text{CO}_2 =$

$$12·411 \text{ O} + 21·719 \text{ CO} = 34·130 \text{ CO}_2,$$

and—

$$26·289 \text{ CO} - 21·719 \text{ CO} = 4·57 \text{ CO}.$$

These figures when reduced correspond closely with the formula—
 $10\text{Na}_2\text{SO}_4 + 20\text{C} = 3\text{Na}_2\text{CO}_3 + 3\text{Na}_2\text{S}_2 + 4\text{Na}_2\text{S} + 14\text{CO}_2 + 3\text{CO}$.

G. A mixture of—

Sulphate of soda. 7.10 grams

Carbon 1.20 „

Equal to $2\text{Na}_2\text{SO}_4 + 4\text{C}$,

submitted to a dull red heat for 60 minutes over a Bunsen lamp, approximate temperature 1270°F ., yielded for 100 Na_2SO_4 employed—

24.412 per cent. undecomposed Na_2SO_4

26.867 „ converted into Na_2CO_3

35.40 per cent. of the Na_2SO_4 decomposed being converted into Na_2CO_3 .

	C.	S.	O.	Na.	Na_2SO_4 .
Employed Na_2SO_4	—	22.535	45.07	32.395	100.00
With	16.901	—	—	—	—
Obtained as undecomposed carbon	1.109	—	—	—	—
„ „ Na_2SO_4	—	5.440	10.880	7.822	24.142
„ carbonate Na_2CO_3 ..	2.270	—	9.082	8.704	26.867
„ sulphide Na_2S	—	9.124	—	13.116	40.485
„ sulphur, free S	—	3.155	—	—	—
„ „ with Pt = S	—	4.746	—	—	—
Total obtained	3.379	22.465	19.962	29.642	91.494
Undetermined	—	—	—	—	8.506
Loss	13.522	0.07	25.108	—	—
Total Na determined.	—	—	—	32.38	—

The Na accounted for by the Na_2CO_3 , Na_2S , and undecomposed Na_2SO_4 amounts to 29.642 only, while the amount actually determined is 32.38, the difference 2.738 calculated into $\text{Na}_2\text{S}_2 = 3.809 \text{ S} = 6.547 \text{ Na}_2\text{S}_2$. The total sulphur, free and combined with platinum, is 7.901, this — 3.809 = 4.092 combined with Na_2S to form $\text{Na}_2\text{S}_2 = 9.974 \text{ Na}_2\text{S} = 14.066 \text{ Na}_2\text{S}_2$; this added to 6.547 $\text{Na}_2\text{S}_2 = 20.613 \text{ Na}_2\text{S}_2$, and as the Na_2S as found from the H_2S evolved = 22.24 — 9.974 = 12.266 as Na_2S .

The loss of carbon amounts to 13.522, and of oxygen to 25.108, while the Na_2SO_4 has been decomposed to the extent of 75.858 per cent. Calculating as in case F on the same proportion of carbon as there has been of Na_2SO_4 decomposed, we have $16.901 \times \frac{75.858}{100} = 12.820 - 2.270 (= \text{the carbon as } \text{Na}_2\text{CO}_3) \text{ equals } 10.550 \text{ carbon combined with the } 25.108 \text{ oxygen. Then—}$

which lead to the approximate formula for the decomposition of—

H. A mixture of—

Sulphate of soda..... 7.1 grams.

Carbon..... 1.2 „

Equal to $2\text{Na}_2\text{SO}_4 + 4\text{C}$,

submitted to a dull red heat over a Bunsen lamp for 75 minutes, approximate temperature 1260°F ., yielded for $100 \text{ Na}_2\text{SO}_4$ employed—

24.98 per cent. as undecomposed Na_2SO_4 .

25.68 „ „ converted into Na_2CO_3 .

34.23 per cent. of the Na_2SO_4 decomposed being converted into Na_2CO_3 .

	C.	S.	O.	Na.	Na_2SO_4 .
Employed Na_2SO_4	—	22.535	45.070	32.395	100.00
With	16.901	—	—	—	—
Obtained as undecomposed C	0.930	—	—	—	—
„ „ Na_2SO_4	—	5.629	11.259	8.092	24.98
„ carbonate Na_2CO_3 ..	2.170	—	8.681	8.319	25.68
„ sulphide Na_2S	—	9.456	—	13.591	41.95
„ sulphur, free S	—	4.183	—	—	—
„ „ with Pt = S	—	3.268	—	—	—
Total obtained	3.100	22.536	19.940	30.002	92.615
Undetermined	—	—	—	—	7.385
Loss	13.801	—	25.130	—	—
Total Na determined.....	—	—	—	32.387	—

The Na not accounted for as undecomposed Na_2SO_4 , or as Na_2CO_3 , and Na_2S amounted to 2.393, and this calculated into $\text{Na}_2\text{S}_2 = 3.329 \text{ S} = 5.722 \text{ Na}_2\text{S}_2$.

The total sulphur, free or combined with platinum, amounted to 7.541; deducting 3.329 as above, we have 4.122; this calculated into $\text{Na}_2\text{S}_2 = 10.047 \text{ Na}_2\text{S} = 14.169 \text{ Na}_2\text{S}_2$; this added to 5.722 $\text{Na}_2\text{S}_2 = 19.891 \text{ Na}_2\text{S}_2$, and as the Na_2S as found from H_2S evolved = $23.047 - 10.047 = 13.00 \text{ Na}_2\text{S}$ existing as such.

Then there has been decomposed $100 - 24.98 = 75.020$ per cent. of the Na_2SO_4 employed, and calculating the carbon in the same proportion—

$$16.901 \times \frac{75.020}{100} = 12.679 - 2.17 \text{ (= the carbon as carbonate) =}$$

10.509 carbon combined with 25.130 oxygen.

Then calculating the carbon in the first instance into CO—

$$\begin{aligned} 10.509 \text{ C} \times 14.012 \text{ O} &= 24.521 \text{ CO,} \\ 25.130 \text{ O} - 14.012 \text{ O} &= 11.118 \text{ O. This into CO}_2, \\ 11.118 \text{ O} + 19.456 \text{ CO} &= 30.574 \text{ CO}_2, \\ 24.521 \text{ CO} - 19.456 \text{ CO} &= 5.065 \text{ CO,} \end{aligned}$$

leading to the approximate formula—

I. A mixture of—

Sulphate of soda..... 7.1 grams.

Carbon..... 1.2 „

Equal to $2\text{Na}_2\text{SO}_4 + 4\text{C}$,

submitted to a dull red heat over a Bunsen lamp for 60 minutes, approximate temperature 1235°F ., yielded for $100 \text{Na}_2\text{SO}_4$ employed—

19.781 per cent. as undecomposed Na_2SO_4 .

27.181 „ „ converted into Na_2CO_3 .

33.883 per cent. of the Na_2SO_4 decomposed being converted into Na_2CO_3 .

	C.	S.	O.	Na.	Na_2SO_4 .
Employed Na_2SO_4	—	22.535	45.070	32.395	100.00
With	16.901	—	—	—	—
Obtained as undecomposed C	2.211	—	—	—	—
„ „ Na_2SO_4	—	4.458	8.915	6.408	19.781
„ carbonate Na_2CO_3 ...	2.297	—	9.188	8.805	27.181
„ sulphide Na_2S	—	9.543	—	13.718	42.346
„ sulphur, free S	—	4.070	—	—	—
„ „ with Pt. S ..	—	4.454	—	—	—
Total obtained	4.508	22.525	18.103	28.931	89.308
Undetermined	—	—	—	—	10.692
Loss.....	12.393	—	26.967	—	—
Total Na determined.....	—	—	—	32.45	—

The Na not accounted for as Na_2SO_4 undecomposed, or as Na_2CO_3 , and Na_2S amounted to 3.464, and this calculated into $\text{Na}_2\text{S}_2 = 4.819 \text{ S} = 8.283 \text{Na}_2\text{S}_2$.

The total sulphur free or combined with platinum amounted to 8.524; deducting 4.819 as above, we have 3.705; this calculated into $\text{Na}_2\text{S}_2 = 9.031 \text{Na}_2\text{S} = 12.736 \text{Na}_2\text{S}_2$; this added to 8.283 $\text{Na}_2\text{S}_2 =$

21·019 Na_2S_2 , and as the Na_2S as found from H_2S evolved = 23·261 – 9·031 = 14·23 Na_2S existing as such.

Then there has been decomposed $100 - 19·781 = 80·219$ per cent. of the Na_2SO_4 employed, and calculating the carbon in the same proportion, $16·901 \times \frac{80·219}{100} = 13·557 - 2·297 (= \text{carbon as } \text{Na}_2\text{CO}_3) =$

11·260 carbon combined with 26·967 oxygen.

Then calculating the carbon in the first instance to CO —

$$\begin{aligned} 11·260 \text{ C} &= 15·013 \text{ O} = 26·273 \text{ CO}, \\ 26·967 \text{ O} - 15·013 \text{ O} &= 11·954 \text{ O. This into CO}_2, \\ 11·954 \text{ O} + 20·929 \text{ CO} &= 32·873 \text{ CO}_2, \\ 26·273 \text{ CO} - 20·929 \text{ CO} &= 5·354 \text{ CO}, \end{aligned}$$

leading to the approximate formula—

Summary of the Experiments.

A and B. These two experiments were merely preliminary, and to prove whether carbonate of soda was or was not formed in the decomposition of sulphate of soda by carbon at a red heat.

C. This experiment shows the effect of excess carbon and higher temperature than red heat, the decomposition giving only a very small proportion of carbonate of soda, and approximating closely to the formula—

D. This experiment gave results closely agreeing with C, the carbonate of soda formed being equal only to 1·68 per cent. of the sulphate of soda actually decomposed.

E. This experiment shows that with the proportions used, submitted to a dull red heat, 19 per cent. of the sulphate of soda employed was converted into carbonate of soda.

Note.—A series of subsidiary experiments showed that under a dull red heat little or no decomposition took place.

F. This experiment shows that a mixture of $2\text{Na}_2\text{SO}_4 + 4\text{C}$, submitted to a dull red heat for 60 minutes, has given 29·24 per cent. of the sulphate of soda decomposed, as carbonate of soda, the reaction approximating closely to the formula—

the temperature being about 1270°F .

G. This experiment, with the same mixture as in F, submitted for 60 minutes to about the same degree of heat = 1270°F ., gave 35·4 per

cent. of the sulphate of soda decomposed as converted into carbonate of soda, the reaction approximating closely to the formula—

H. This experiment with the same mixture as in F and G, was submitted to a dull red heat for 75 minutes. Temperature about 1260° F. Gave 34.23 per cent. of the sulphate of soda decomposed as converted into carbonate of soda, the reaction approximating closely to the formula—

I. This experiment was similar to G, except that the temperature was about 1235° F. It gave 33.883 per cent. of the sulphate of soda decomposed as being converted into carbonate of soda, the reaction approximating closely to the formula—

Assembling these formulæ we have—

	F.	G.	H.	I.	Total.	Mean.
Na_2SO_4	10	11	3	3	27	3
C	20	22	6	6	54	6
Na_2CO_3	3	4	1	1	9	1
Na_2S_2	3	4	1	1	9	1
Na_2S	4	3	1	1	9	1
CO	3	4	1	1	9	1
CO_2	14	14	4	4	36	4

These experiments show that :—

1st. When sulphate of soda is mixed with a quantity of carbon in excess of two equivalents, and exposed to a temperature considerably above red heat, out of contact with air, the reaction which takes place is, that the sulphate is ultimately converted into monosulphide of sodium, while the oxygen is evolved as carbon monoxide—

2nd. When sulphate of soda and carbon, finely divided and intimately mixed, are exposed to a temperature of dull redness (say from 1150° to 1300° F.), out of contact with the air, there is formed a certain quantity of carbonate of soda, with an equivalent proportion of sodium bisulphide, as well as sodium monosulphide, while the carbon combines with the oxygen of the sulphate of soda to form carbon monoxide and carbon dioxide.

The amount of carbonate and bisulphide formed varies inversely as

the temperature, while the amount of sulphate decomposed varies directly as the temperature.

The reaction which is most in accordance with these experiments being—

Any excess of carbon acts apparently in the first instance on the CO_2 , reducing it to CO , and finally on the $\text{Na}_2\text{CO}_3 + \text{Na}_2\text{S}_2$, producing $\text{Na}_2\text{S} + \text{CO}$.

The decomposition of sulphate of potash by carbon takes place at lower temperature, but as shown by a number of experiments, the decomposition is of the same character as in the case of sulphate of soda, carbonate of potash and bisulphide of potassium being produced.

[Although Liebig was clearly the first to explain the reaction of wood-fibre on Na_2S , such a method of producing alkaline carbonates had been used practically many years previously by soap-boilers, and is thus described in a note book before me dated 1800:—

“To make Hepar of Soda or Potass from the Sulphates.

“It is necessary to dry these salts in a reverberatory furnace, then mix them with their weight of fir sawdust, and fuse them in a reverberatory furnace. When the surface becomes calm, the operation is complete—let the sulphure run out. If it is a sulphure of potass, break it up with a hammer, dissolve in water, evaporate it, and when the salt begins to form, put in sawdust till it is thick.

“Then put it into the calcining furnace, roast it for an hour, two-thirds of the sulphate will be decomposed. Separate the undecomposed part by solution.

“If you operate on the sulphate of soda, after the first sulphure is produced, add more sawdust, melt a second time to a sulphure, then operate as with the potass.”]

It is not too great an assumption that this is the general type of decomposition for all the alkaline and earthy sulphates, the well known slow decomposition of soluble sulphates by organic matter showing that the formation of bisulphides such as FeS_2 is constantly occurring in the operations of nature.

Even when the materials used in above experiments are moistened with as much as 40 per cent. of water and then heated, the reaction still remains apparently the same, the water no doubt being all driven off before the decomposition of the sulphate by the carbon takes place to any extent.

Having established the formation of Na_2CO_3 and Na_2S_2 , it seemed not unlikely that in the usual method of manufacturing alkali by Leblanc's process, that the second atom of sulphur in the Na_2S_2 would be driven off, while the Na_2S then remaining was converted into Na_2CO_3 and CaS , and a series of experiments made to elucidate this point showed most conclusively that no appreciable quantity of sulphur was lost in this way working in closed crucibles. As, however, the Na_2S_2 oxidises very rapidly when exposed to the air while hot, it is probable that a small proportion may be thus lost, when the operation is conducted in large furnaces, where an oxidising flame is employed. I trust to be able shortly to complete an investigation upon this and kindred points in the decomposition of sulphate of soda by carbon and carbonate of lime.