III.—CONTRIBUTIONS FROM THE LABORATORY OF
GONVILLE AND CAIUS COLLEGE, CAMBRIDGE.No. X.—*The Interaction of Zinc and Sulphuric Acid.*By M. M. PATTISON MUIR, M.A., and R. H. ADIE, B.A., Scholar of
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I. IN 1830 De la Rive examined the action which occurs between zinc and aqueous solutions of sulphuric acid (*Pogg. Ann.*, **19**, 221). He employed both commercial and redistilled zinc, and measured the times required for the production of equal volumes of hydrogen from acids of different concentrations. De la Rive found that the change proceeded much more rapidly with commercial than with redistilled

zinc; he also found that the most rapid action occurred when commercial zinc interacted with an acid solution containing about 30 per cent. H_2SO_4 . De la Rive added known quantities of tin, lead, copper, and iron, respectively, to molten redistilled zinc, and found that the rates of action of the products with sulphuric acid solutions were greater than the rate of action of redistilled zinc. Finally, De la Rive proved that the solution of sulphuric acid which showed maximum electrical conductivity interacted most rapidly with commercial zinc, and with redistilled zinc to which a few per cent. of iron had been added. De la Rive concluded that the interaction between pure zinc and dilute sulphuric acid is probably a direct chemical change, but that with ordinary commercial zinc the action is chiefly electrochemical.

In the seventh series of his *Experimental Researches* (pars. 863 *et seq.*), Faraday proved that a plate of amalgamated zinc remained unchanged in sulphuric acid, to which 30 parts of water had been added, while a similar plate in the same acid put in contact with a plate of platinum lost 5.2 per cent. of its weight.

These experiments conducted by De la Rive and Faraday showed that the interaction which occurs between zinc and dilute sulphuric acid is to some extent at least an electrolytic action.

2. It is well known that hydrogen is not the only gaseous product of the interaction of dilute sulphuric acid and ordinary zinc. Everyday experience in the laboratory proves that both sulphur dioxide and sulphuretted hydrogen are often produced in the reaction in question. We have made a fairly complete qualitative examination of this interaction, and have found it to be one of great complexity.

About 10 grams of zinc were used in each experiment, and usually about 50 c.c. of the acid. The reactions proceeded in small flasks, each of which was connected by a T-tube with a flask containing a dilute aqueous solution of iodic acid mixed with a very little starch-paste, and also with a flask containing a dilute solution of silver nitrate to which excess of ammonia had been added. Exit-tubes from these flasks communicated with a water-pump; a current of air could thus be sucked through the whole apparatus, and traces of gases produced in the interactions could be swept out from the reaction-flask into the testing-flasks.

Those experiments wherein the reaction was allowed to proceed for long periods, sometimes extending to three weeks, were conducted in small flasks which were not connected with testing-flasks; at the end of the allotted time a rapid current of well-washed carbon dioxide was swept through the liquids in the flasks and the escaping gas was bubbled through the testing solutions.

The higher temperatures were maintained by heating the flasks in

baths of zinc chloride: for our purposes, it was unnecessary to attempt to regulate the temperatures within a few degrees. The specimens of zinc employed were (1) "redistilled zinc," (2) "pure rod zinc," (3) "pure zinc foil," (4) "commercial granulated zinc," the chief impurities in which were lead, iron, arsenic, and traces of cadmium, (5) "platinised zinc foil," and (6) "approximately pure zinc," prepared by us by dissolving "pure redistilled zinc" in pure very dilute sulphuric acid, saturating with sulphuretted hydrogen, boiling, filtering, electrolysing (after complete removal of H_2S), digesting the zinc thus obtained with a slightly warm aqueous solution of recrystallised "pure zinc sulphate," redissolving in pure dilute sulphuric acid, electrolysing, &c., and repeating the series of operations a third time.

The sulphuric acid employed was that sold as "pure redistilled," diluted with measured quantities of water. What is hereafter called "approximately pure H_2SO_4 " was prepared by redistilling the "pure redistilled" acid, collecting the middle portion of the distillate, repeating this process, then freezing out the H_2SO_4 , and pouring off the remaining liquid.

The concentrations of the various acids used are represented by formulæ, but these are to be regarded merely as approximate representations of the ratio of H_2SO_4 to H_2O in the liquids. The concentration varied from H_2SO_4 to $\text{H}_2\text{SO}_4, 100\text{H}_2\text{O}$.

No attempts were made to measure the quantities of the different products of the reactions. When a blue colour in the iodic acid and starch test-liquid, or a brown colour in the silver nitrate test-liquid, appeared only after the current of air or carbon dioxide had swept through the apparatus for 30 minutes, we note the result as "a trace" of SO_2 , or SH_2 , as the case may be. Production of a deep-blue colour, or a brown-black precipitate, immediately the first bubbles of gas came into contact with the testing liquid, is noted as "abundance" of SO_2 (or SH_2). To save space and frequent repetition we have adopted the following letters for indicating (very roughly it is to be remembered) the results of the experiments:—

<i>t.</i>	<i>l.</i>	<i>m.</i>	<i>a.</i>
Trace.	A little.	Moderate quantity.	Abundance.

Statements are made in the sequel regarding the appearance of hydrogen: when the acid used was concentrated and the changes proceeded very slowly, the presence of hydrogen among the products was proved by continually passing a rapid current of carbon dioxide through the reaction-flask, and allowing the escaping gas to bubble through potash solution into a tube filled with the same solution, and testing the gas which collected in this tube.

Statements are also made in the sequel regarding the solid matter

formed in the reaction-flasks: this solid was proved to be free from zinc sulphide by collecting it on glass-wool filters, washing with sulphuric acid, thoroughly drying on a porous tile, and then decomposing it by fairly concentrated warm sulphuric acid in a flask connected with testing-flasks as already described. Direct experiments proved that zinc sulphide is decomposed by moderately dilute warm sulphuric acid, with formation of sulphur dioxide, sulphuretted hydrogen, and sulphur; the absence of these three substances was taken as evidence that the solid examined was free from zinc sulphide. Traces of sulphur were detected by warming the solid products of the reaction with carbon bisulphide, decanting, and evaporating the bisulphide.

The experiments, which were performed in duplicate, were always stopped when some zinc remained undissolved.

The following formulæ approximately represent the concentrations of the acids used; each acid is distinguished by a letter or number.

Letter.....	AA.	A.	B.
Concentration of acid..	H ₂ SO ₄	9H ₂ SO ₄ ,H ₂ O	7H ₂ SO ₄ ,2H ₂ O

Letter.....	C.	D.
Concentration of acid..	7H ₂ SO ₄ ,4H ₂ O	7H ₂ SO ₄ ,6H ₂ O.

Number....	1.	2.	3.	4.
Concen. of } acid.... }	H ₂ SO ₄ ,H ₂ O	H ₂ SO ₄ ,2H ₂ O	H ₂ SO ₄ ,3H ₂ O	H ₂ SO ₄ ,4H ₂ O;

and so on, the number n representing an acid of concentration H₂SO₄, n H₂O.

The following letters indicate roughly the quantity of the gas produced: t , trace; l , a little; m , moderate; a , abundance. The lines — — — indicate the absence of SO₂, SH₂, or S; these three bodies are always enumerated in this order; thus t — — means "a trace of sulphur dioxide, sulphuretted hydrogen and sulphur absent."

3. The following tables embody the greater number of our results:—

Products obtained by using Commercial Granulated Zinc and Acids of various concentrations.

Temperature	0°.	20°.	100°.	160°.
Concentr. of acid.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.
A		<i>t</i> — —	<i>m</i> — —	<i>a</i> <i>l</i> <i>t</i>
B		<i>l</i> <i>l</i> —	<i>a</i> <i>t</i> <i>t</i>	
C		<i>l</i> <i>l</i> —		
D		<i>l</i> <i>l</i> —	<i>l</i> <i>l</i> <i>t</i>	
1			<i>m</i> <i>l</i> <i>t</i>	
2		— <i>t</i> —	— — —	<i>t</i> <i>a</i> —
4			— <i>t</i> —	<i>l</i> <i>t</i> —
6	— <i>l</i> —			
7	<i>l</i> <i>l</i> —	<i>m</i> <i>m</i> —		
8	<i>l</i> <i>l</i> —		— <i>m</i> —	
9	<i>l</i> <i>l</i> —			
10	<i>l</i> <i>l</i> —			
11	<i>m</i> <i>m</i> —			
12	<i>m</i> <i>m</i> —		<i>l</i> <i>a</i> —	
13	<i>l</i> <i>m</i> —			
16		<i>a</i> <i>a</i> —		
25	<i>t</i> <i>m</i> —		<i>t</i> <i>a</i> —	
50	— <i>l</i> —			
100	<i>t</i> <i>l</i> —			

Products obtained by using Redistilled Granulated Zinc and Acids of various concentrations.

Temperature	0°.	110°.	160°.
Concentr. of Acid.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.
A			<i>a</i> <i>t</i> <i>t</i>
1			<i>a</i> <i>a</i> <i>a</i>
2	— — —		
3	— — —		
4		<i>l</i> <i>l</i> —	
5	— — —		
7	— — —	<i>t</i> <i>l</i> —	
9	— <i>t</i> —		
11	<i>t</i> <i>t</i> —		
12		<i>t</i> <i>t</i> —	
13	— <i>t</i> —		
16	— <i>t</i> —		
25	— — —		
50	— — —		

Products obtained by using Platinised Zinc Foil and Acids of various concentrations.

Temperature	0°.	20°.	100°.	150°.	160—170°.	B. p. of acid.
Concentr. of acid.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	
A	—	m	m	SO ₂ , SH ₂ , S.	m	a
B	—	—	l	—	m	m
C	—	t(?)	m	l	m	a
1	—	t(?)	m	l	m	a
2	—	—	l	m	m	m
3	—	—	—	m	m	m
4	—	—	—	t	—	—
5	—	—	t(?)	—	—	—
7	—	—	—	—	—	—
9	t	—	—	—	—	—
11	l	—	—	—	—	—
13	l	—	—	—	—	—
16	l	—	—	—	—	—
25	t	—	—	—	—	—
50	—	t	—	—	—	—
100	—	—	—	—	—	—

Products obtained by using "Approximately Pure" Zinc and Acids of various concentrations.

Temperature	15—18°.	110—112°.	135°.	145°.	160°.	200—250°.
Concentr. of acid.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	
A	t	—	l	a	m	a
B	—	—	—	—	t	t
2	—	—	—	—	m	—
12	—	t	—	—	m	—

Products obtained by using Pure Rod Zinc and Acids of various concentrations.

Temperature	110°.	160°.	B. p. of acid.
Concentr. of acid.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.
A		<i>a</i> <i>t</i> <i>m</i>	<i>l</i> <i>t</i> —
B		<i>a</i> <i>a</i> <i>a</i>	
C		<i>a</i> <i>a</i> <i>a</i>	
D		<i>a</i> <i>a</i> <i>t</i>	
1		<i>a</i> <i>a</i> <i>t</i>	
2		<i>a</i> <i>a</i> <i>t</i>	
3		<i>l</i> <i>l</i> —	
4		<i>l</i> <i>l</i> —	
8	<i>t</i> <i>t</i> —		
12*	— <i>l</i> —		

* Acid of this strength gives only hydrogen at 85°.

Products obtained by using Pure Zinc Foil and Acids of various concentrations.

Temperature	20°.	100°.	160°.	B. p. of acid.
Concentr. of acid.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.	SO ₂ , SH ₂ , S.
A	— — —	<i>m</i> — —	<i>a</i> <i>l</i> —	
B	— — —			
1	— — —	<i>l</i> — —		<i>l</i> <i>m</i> <i>t</i>
2	— — —	<i>l</i> <i>l</i> —		
3	— — —			
4	— — —			
5	— — —			

4. We think it may be safely asserted that hydrogen was produced in all the reactions. Direct proof of the presence of hydrogen was sought for and found in the cases of the acids $\text{H}_2\text{SO}_4, \text{H}_2\text{O}$ at the ordinary temperature, $9\text{H}_2\text{SO}_4, \text{H}_2\text{O}$ at 100°, $7\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$ at 100°, and platinised zinc with $7\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$ at 150—180°, at which temperature sulphur was freely produced.

The only solid product of the interaction is zinc sulphate. This was proved for acid of very varying concentrations and at different temperatures; for $9\text{H}_2\text{SO}_4, \text{H}_2\text{O}$ at 180°, $7\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$ at 100°, and $\text{H}_2\text{SO}_4, 3\text{H}_2\text{O}$, $\text{H}_2\text{SO}_4, 4\text{H}_2\text{O}$, and $\text{H}_2\text{SO}_4, 6\text{H}_2\text{O}$ at ordinary temperatures.

5. The results of our experiments, when regarded broadly, establish a similarity between the interaction of sulphuric acid with approximately pure zinc and with commercial zinc. But at the same

time there are differences. Thus the results show that as the zinc becomes purer the quantities of sulphur dioxide and sulphuretted hydrogen, particularly the latter, produced at the ordinary temperature ($12-18^{\circ}$) become markedly less, whether the acid be concentrated or dilute; when the acid is so dilute as $\text{H}_2\text{SO}_4, 10$ or $12\text{H}_2\text{O}$, hydrogen is almost the sole gaseous product, even at temperatures up to the boiling point of the acid used. When approximately pure zinc is employed and the temperature is high (160° or so), dilution of the acid is accompanied by diminution both of sulphur dioxide and sulphuretted hydrogen; but when commercial zinc is used, the sulphur dioxide diminishes more than the sulphuretted hydrogen; when commercial zinc was used, however, small quantities of sulphuretted hydrogen were indeed obtained with every acid examined, even with $\text{H}_2\text{SO}_4, 100\text{H}_2\text{O}$, and at temperatures varying from the boiling point of the acid to 0° .

Platinised zinc foil behaves on the whole similarly to commercial zinc; sulphur dioxide and sulphuretted hydrogen are produced at very varying temperatures, and with almost every acid examined. When the acid is fairly concentrated, sulphur dioxide begins to be produced at a temperature lower than that at which sulphuretted hydrogen appears, both in the case of platinised foil and commercial zinc; when the acids are dilute, the tendency in the case of platinised zinc foil is to produce sulphuretted hydrogen more freely than sulphur dioxide.

It is somewhat remarkable that scarcely any sulphur dioxide or sulphuretted hydrogen should be produced when commercial zinc and acid, approximately of the concentration $\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$, interact at 100° , but that at 165° abundance of sulphuretted hydrogen accompanied by a little sulphur dioxide should be formed, and that at 180° torrents of the former gas nearly free from sulphur dioxide should be evolved. In connection with this result it is of interest to note that "approximately pure" zinc, interacting with acid of the same concentration as the above ($\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$) at 160° , produces quantities of both the gases in question.

6. The production of sulphur requires a little examination. The conditions under which sulphur appeared are noted in the table on p. 55.

In the experiments with platinised foil, sulphur disappeared again at $210-220^{\circ}$, and SH_2 increased very much.

Sulphur did not appear in any other experiment with "approximately pure zinc;" the other acids examined were H_2SO_4 and $\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$.

Sulphur is produced neither at low temperatures, nor with acids less concentrated than $\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$; the formation of sulphur is always accompanied by the evolution of sulphur dioxide and sulphuretted hydrogen, but the quantity of the latter gas is sometimes extremely

Kind of zinc.	Concentration of acid.	Temp.	Remarks.
"Pure rod zinc".....	Approx. H_2SO_4	165°	Very little S; plenty of SO_2 ; merest trace of SH_2 .
"....."	$9\text{H}_2\text{SO}_4, \text{H}_2\text{O}$	165	Decided S; plenty of SO_2 ; merest trace of SH_2 .
"....."	$7\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$	165	Decided S; plenty of SO_2 and SH_2 .
"....."	$7\text{H}_2\text{SO}_4, 4\text{H}_2\text{O}$	165	Decided S; much SO_2 ; little SH_2 .
"....."	$7\text{H}_2\text{SO}_4, 6\text{H}_2\text{O}$	165	Little S; much SO_2 and SH_2 .
"....."	$\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$	165	Trace of S; much SO_2 and SH_2 .
"Pure zinc foil".....	$\text{H}_2\text{SO}_4, \text{H}_2\text{O}$	190	Distinct S; fair quantities of SO_2 and SH_2 .
"Commercial granulated zinc"	$9\text{H}_2\text{SO}_4, \text{H}_2\text{O}$	165	Little S; much SO_2 ; little SH_2 .
"....."	$7\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$	100	Little S; much SO_2 ; very little SH_2 .
"....."	$7\text{H}_2\text{SO}_4, 6\text{H}_2\text{O}$	100	Little S; little SO_2 and SH_2 .
"....."	$\text{H}_2\text{SO}_4, \text{H}_2\text{O}$	100	Trace of S; fair quantity of SO_2 ; little SH_2 .
"Platinised foil".....	$7\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$	175—185	Much S; very much SO_2 ; little SH_2 .
"....."	$7\text{H}_2\text{SO}_4, 4\text{H}_2\text{O}$	175—180	Much S; much SO_2 ; little SH_2 .
"....."	$7\text{H}_2\text{SO}_4, 6\text{H}_2\text{O}$	175	" "
"....."	$\text{H}_2\text{SO}_4, \text{H}_2\text{O}$	170	" "
"....."	$\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$	130	Trace of S; much SO_2 ; fair quantity of SH_2 .
"Approximately pure zinc"	$7\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$	160°	Small quantity of S; quantity of SO_2 ; trace of SH_2 .

small. When "approximately pure" zinc and sulphuric acid are used, there is scarcely any separation of sulphur; with platinised foil, on the other hand, sulphur is formed in large quantities. The sulphur can scarcely be a product of the interaction of sulphur dioxide and sulphuretted hydrogen, else we should expect to find it generally accompanying these gases; nor can it always be produced by the reducing action of the nascent hydrogen on either the sulphur dioxide or sulphuretted hydrogen, because these gases are so frequently found at moderate temperatures unaccompanied by sulphur. It may be that the formation of sulphur is sometimes to be traced to the mutual action of sulphuretted hydrogen and hot concentrated sulphuric acid. This supposition would account for the preponderance of sulphur dioxide over sulphuretted hydrogen when the acid is concentrated, and for the increase in the quantity of the latter gas as the acid becomes more dilute: for the sulphuretted hydrogen supposed to be formed when the acid is concentrated would be decomposed by

reacting with the hot acid, but would escape unchanged when the acid becomes more dilute. The fact that the cessation in the production of sulphur is accompanied by a marked increase in the quantity of sulphuretted hydrogen in the reaction of platinised foil with concentrated acids, is also in keeping with this supposition. The non-production of sulphur when "approximately pure" zinc is used supports the view that some of the sulphur is formed in secondary reactions between the gaseous products, or between these and the acid, rather than in the direct interaction of the metal and acid.

The sulphur produced was soluble in carbon bisulphide.

7. Increase of the mass of the zinc relatively to that of the acid does not produce any regular and definite effect on the nature or quantities of the gaseous products of the change. This is shown by the tabulated results given on p. 57.

8. The interaction between zinc and sulphuric acid evidently differs considerably from the interaction between copper and sulphuric acid (see Pickering, *Trans.*, 1878, 112). The latter change proceeds in two definitely marked stages expressible by the equations—

Hydrogen is not obtained in the reaction between copper and sulphuric acid nor is sulphuretted hydrogen evolved; the sulphur dioxide produced is most probably the result of secondary reactions occurring between the acid and the cuprous sulphide formed. In the interaction between zinc and sulphuric acid, on the other hand, hydrogen appears to be always produced; both sulphuretted hydrogen and sulphur dioxide are very frequently formed, and the production of these gases cannot be traced to a secondary reaction between the acid and zinc sulphide formed in the primary change; the entire interaction is more irregular than that between copper and sulphuric acid.

The dependence of the production of large quantities of sulphur dioxide and sulphuretted hydrogen in the interaction between zinc and sulphuric acid on the temperature and the concentration of the acid indicates, we think, that the formation of these gases is not to be altogether ascribed to the reducing action of nascent hydrogen on the acid. This view is confirmed by the fact that variations in the mass of the zinc employed, and hence in the quantity of hydrogen produced in a specified time, do not exert any marked or regular effect on the nature of the change. The behaviour of commercial zinc with acid of the concentration $\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$, and of approximately pure zinc with the same acid, also confirms this supposition: in the case of commercial zinc, very little sulphur dioxide or sulphuretted hydrogen is

Various Zincs with Acids of different concentrations; 50 c.c. acid used in each case.

Acid.	Weight of zinc used.	Approximate temp. of appearance of		Remarks.
		SO ₂ .	SH ₂ .	
	grams.	°	°	
I. <i>Pure rod zinc—</i>				
7H ₂ SO ₄ , 2H ₂ O	{ 7	144—146	135—137	Little SH ₂ even at 150°.
	{ 14	150	137	
H ₂ SO ₄ , 2H ₂ O	{ 7	150—155	145	Plenty of both gases at 155°.
	{ 14	135—140	130—135	
II. <i>Pure zinc foil—</i>				
7H ₂ SO ₄ , 2H ₂ O	{ 7	120—125	90—95	
	{ 14	105—110	70—75	
	{ 21	105—110	70—75	
7H ₂ SO ₄ , 6H ₂ O	{ 7	125—130	105—110	
	{ 14	130—135	100	
	{ 21	115—120	85	
H ₂ SO ₄ , 2H ₂ O	{ 7	140—145	130	
	{ 14	145—150	135	
	{ 7	135—140	120—125	
H ₂ SO ₄ , 4H ₂ O	{ 14	140	125	
	{ 21	135—140	120—125	
III. <i>Redistilled zinc—</i>				
H ₂ SO ₄ , 2H ₂ O	{ 3.5	150	120	SO ₂ rapidly at once; SH ₂ slowly increas- ing.
	{ 5	150	130—135	
	{ 7	130—135	130—135	
	{ 14	140—145	125—130	
	{ 28	140	135—140	
	{ 35	135	125—130	
IV. <i>Commercial granu- lated zinc—</i>				
H ₂ SO ₄ , 2H ₂ O	{ 7	140—145	135—140	Not much SH ₂ till 145°. Plenty SH ₂ at 150°.
	{ 14	140—145	125—135	
V. <i>Platinised zinc foil—</i>				
H ₂ SO ₄ , 2H ₂ O	{ 7	110	70—80	Not much SO ₂ till 130°, and SH ₂ till 90°.
	{ 14	105	85—90	

formed at 100°; at 165° both gases are produced freely; and at 180° the latter gas is evolved in very large quantity; in the case of approximately pure zinc, both gases are produced in quantity at 165°. Moreover, if the gases in question were altogether secondary products of the reduction of sulphuric acid by the hydrogen evolved in the primary change, we should expect to find them formed as freely when

the former zinc is used as when commercial zinc is employed; but this supposition is not confirmed by experiment. We are inclined to think that the interaction between approximately pure zinc and acid is chiefly a direct chemical interaction, and that the products of the reactions with the less pure zincs are largely due to the occurrence of secondary electrolytic changes. With pure, or almost pure, zinc and dilute acid (say $\text{H}_2\text{SO}_4, 12$ to $15\text{H}_2\text{O}$), hydrogen and zinc sulphate are the only products of the reaction; with the same zinc and concentrated acids (say $\text{H}_2\text{SO}_4, \text{H}_2\text{O}$ to H_2SO_4) the chief gaseous product is sulphur dioxide, and sulphuretted hydrogen is also produced at higher temperatures; with an acid of intermediate concentration (in our experiments with $\text{H}_2\text{SO}_4, 2\text{H}_2\text{O}$) both compounds of sulphur are formed in considerable quantities at fairly high temperatures (160°). But the results of our experiments make it certain that whether the zinc be pure or commercial, the concentration of the acid used plays a most important part in the chemical change; hence it is probable that the bodies actually interacting are numerous, and that the reactions are much more complex than can well be represented in any series of equations which can at present be devised. It seems to us that the chemical change which occurs is to be ascribed to the interaction of the zinc with various molecular aggregates of H_2SO_4 and H_2O , probably also of SO_3 and H_2O , or of H_2SO_4 , SO_3 , and H_2O ; and that the compositions of these aggregates probably vary with variations in the concentration of the acid used and with variations of temperature.

The results of experiments on the electrolysis and electrolytic conductivity of sulphuric acid* establish a close resemblance between the electrochemical behaviour of this acid and its chemical behaviour as described in this paper.

* Wiedemann, *Die Lehre von der Elektrizität*, 2, 538; also F. Kohlrausch, *Ann. Phys. Chem.*, 26, 206; also Ostwald, *Phil. Mag.*, August 1886, and other places; also Gladstone and Tribe, this Journal, Trans. for 1879, 177.