# CHAPTER IX.

## RICHTER.

During the disputes as to Dalton's priority of discovery, it was frequently asserted that his atomic laws were not new, and they were, as is usual in such cases, attributed to various persons. Of these persons, Higgins, in this country, and Richter, in Germany, have been the most prominent. I have endeavoured to show exactly the position of Higgins; I shall do the same with Richter. Higgins came first with clearness and simplicity, uttering a beautiful idea which he failed to follow up; Richter came close after him, with great labour and enthusiasm, filled with a great idea of the study in which he was engaged, and obtained a law which he failed to follow up; he lost himself in complicated theories, having no idea how simple was the truth he sought for. Both were neglected, as happens when men fail to give completeness to their inquiries, even in the eyes of those who study and are willing to learn.

Richter's books are—" Anfangsgründe der Stoechyometrie oder Messkunst Chymischer Elemente." 3 vols. Bresslau und Hirschberg, 1792-4; and " Ueber die Neuern Gegenstände der Chymie," 1791-1802.

I shall give rather copious extracts from his works, shewing the direction of his inquiries, and the ends he attained.

### Richter, Vol. I., Preface.

" Mathematics includes all those sciences which refer to magnitude, and consequently a science lies more or less in the province of mathematics (geometry), according as it requires the determination of magnitudes. In chemical experiments this truth has often led me to the question, whether and how far chemistry is a part of applied mathematics; and especially in considering the well-known fact, that two neutral salts, when they decompose each other, form again neutral compounds. The immediate consequence, in my opinion, could only be, *that there are definite relations between the magnitude* of the component parts of neutral salts. From that time I considered how these proportions could be made out, partly by exact chemical experiments, partly combining chemical with mathematical analysis. In my inaugural dissertation, published at Königsberg, in 1789, I made a slight attempt, but was not then supplied with the requisite chemical apparatus, nor was I sufficiently ready with all requisite information, bearing on my present system, imperfect as it may be. The result, therefore, was very imperfect. I promised, however, not to let the matter rest with that imperfect essay, but to work out this branch with all the accuracy and profundity of which I was capable, as soon as I was supplied with the requisite conveniences. This promise, I hope in the present volume, to make good, although I am far from believing that what I am now going to say will not be in need of still more thorough and accurate elaboration, for who will venture to limit the extent and the power which is the destination of a young and budding science."

He was the first to speak of a science of stœchiometry, and began formally to lay the foundation. We may even say that he commenced the systematic study for which he gave us also the most appropriate word. I cannot say that he began the science, and it will be seen that his mode of inquiry was wanting in directness and his results in completeness.

In page 29 of the preface, he says, "as the mathematical portion of chemistry deals in a great measure with bodies which are either elements or substances incapable of being decomposed and as it teaches also their relative magnitudes, I have been able to find no more fitting name for this scientific discipline than the word stoechiometry, from *στοιχειον* which, in the Greek language, means a something which cannot be divided, and *μετρειν* which means to find out relative magnitudes."

Here, then, is a man prepared for the work, one who resolutely laboured for many years to find the law by which the elements combine, by "number, weight, and measure."

We have seen already that many facts were known, and that even reciprocal proportion was almost attained in the diagrams which have been given, and that the most far-sighted chemists saw the natural necessity for a constant proportion in combinations; but when the well-known laws agreed upon by chemists were put together, we see how few G. Morveau's list amounted to.

Richter did a great deal of work, especially in connection with the chemistry of the metals, but everything was held secondary to his great idea of definite proportionate quantities (bestimmte Grössenverhältnisse). On the title pages of the various papers or parts of volumes, written after his stœchiometry, he has preserved as a motto "*Παντα* (ΘΕΟΣ) *μετρω και αριθμω και σταθμω διεταξε*" (*ας*). This, from the 'Wisdom of Solomon,' chapter xi., v. 20, is exceedingly appropriate, but the context evidently shows that it was not applied to any such subject; at the same time it is introduced as a proverb would be, or a well-known universal law coming in aptly to illustrate one particular point to which it bears no more intimate relation than to innumerable others. It must, however, be confessed, that this expression is given with a minuteness and fulness which warrants the conclusion that it was not uttered until after many and profound speculations on the order of creation. The sentence is the expression of the circumstances in all their fulness, but like many other sentences of antiquity, the meaning is not clear till the facts have been discovered piece by piece.

The most important sentences bearing on the subject of Richter's volumes have been selected, including everything which seems to indicate any knowledge of the subject. His prolixity is excessive, every little idea is long dwelt upon, and as an example of the small fear he had of too much enlarging his book, it may be stated that he actually writes a system of algebra in one of the volumes, because a little algebra is wanted for the full understanding of his demonstrations. It may be that there are sentences hidden among other portions of the book less directly bearing on his subject which would indicate great knowledge, for although I have spent many days among his six volumes, I have certainly omitted some parts which seemed to me out of the range of stœchiometry. But his doctrines are not to be got in fragmentary sentences, so that the loss of any such sentences cannot, in the least, affect the result.

## Richter's Stœchiometry, Vol. I., Page 121.

### Definition 1.

"Stœchiometry (stœchyometria) is the science of measuring the quantitative proportions, or the proportions of the masses in which chemical elements stand in regard to each other. The mere knowledge of these relations might be called 'quantitative stœchiology.'

### Principle 1. P. 123.

"Every infinitely small particle of the mass of an element has an infinitely small part of the chemical attractive force or affinity.

### Experience 5.

"In order to make a neutral compound out of two elements, it is needful, as each of the elements is of the same constitution at one time as at another, to take the same quantity for the first part formed as for the second part. For example, if two parts of lime require five parts of muriatic acid for solution, six parts of lime will require fifteen of the same acid.

### Experience 6. P. 124.

"When two neutral solutions are mixed, and a decomposition follows, the new resulting products are almost without exception neutral also, but if the solutions of one or both are not neutral before mixing, the products after mixture are also not neutral.

### Corollary 1.

"The elements must therefore have amongst themselves a certain fixed proportion of mass. To determine which, their neutral compounds generally give the best opportunity.*

### Corollary 2.

"If the weights of the masses of two neutral compounds which decompose each other are A and B, and the mass of the one element in A is *a*, and that of the one in B is *b*, then the masses of the elements in A are A—*a*, *a* and those in B are B—*b*, *b*. The proportions of the masses of the elements in the neutral compounds before decomposition are A—*a* : *a* and B—*b* : *b*; but after decomposition the new products are *a*+B—*b*, and *b*+A—*a*, and the proportion of the masses of the elements is *a* : B—*b*, *b* : A—*a*. If the proportion of the masses in the compounds A and B is known, that in the new products is known also.

* In German "Der Stoff ihrer neutraler Verbindungen öfters einen Bestimmungsgrund abgeben kann." Stoff is explained thus: Einleiting: Erklärung 14. "Das materielle oder körperliche Subjekt, worinnen sich die chymische Verwandtschaft befindet, nenne ich die *Masse*, *Prinzip* oder *Stoff (Massa)* des Elementes. Die Summa der Massen der Elemente, so eine neutrale auflösung bilden, ist die *Masse* oder *Stoff (Massa)* der neutralen Auflösung."

That is, "I call the material or corporal *subjectum* in which the chemical affinity resides, the Mass, Principle or Stuff (Massa)."

In a note, he says,—"There is present in the Element a certain *subjectum* to which the chemical attractive power or the affinity is bound, this is the Mass of the Element."

If $a+B-b=C$ and $b+A-a=D$ then $a=C+b-B=b+A-D$ and $C-B=A-D$, so also $D-B=A-C$. In addition $b=a+B-C=D-A+a$.

THEOREM 1. P. 125.

"The chemically attracting power by which one element *a* enters into neutrality with another A—*a* presupposes an opposite action of the same kind in the latter, and these two powers are equal to each other.

THEOREM 2. P. 128.

"If a neutral compound A whose elementary masses A—*a* and *a* are removed from combination by a definite quantity of a third element *b*, and the whole mass of one element *a* for example is set free, the force that causes this phenomenon is equal to the difference between the separating element *b* and the separated element *a*.

THEOREM 3. P. 130.

"When two neutral compounds A and B, the masses of whose ingredients are A—*a*, *a* and B—*b*, *b* mutually decompose each other, so that the new products A—*a*+*b* and B—*b*+*a* are formed, the forces that partly cause and partly hinder this action, are equal to the difference of affinities of the elements A—*a* and B—*b* towards each of the elements *a* and *b*." Afterwards he said,

"When I finished the pure stœchiometry, two years ago, I did not think it would be needful to make any additions to its contents. In the first place I thought it had all that practical stœchiometry required, &c.*

VOL. II., PAR. V., P. 4.

Having decided by experiment that 1000 parts carbonate of lime contain 559 earthy matter, he sums up as follows

* Preface to Vol. I., Part 2. 1794. Later than Vols. II. and III.

his experiment with 5760 grs. of muriatic acid and 2393 grs. of chalk.

"If now we desire to find the proportion of the elements in the pure salt forming a neutral body, we must first seek to determine the amount of lime out of the weight of the crude lime used or the aerial salt of lime. This amounts to 2393 grains. According, then, to par. 1, 1000:559 = 2393 : lime, and the lime is equal to $\frac{2393 \cdot 559}{1000} = 1337$; this, when subtracted from the 2544 grains of the neutral mass obtained, leaves a residue of 1207 grains, the weight of the muriatic acid. If, then, 1207 : 2544* = 1000 : 1107, it is clear that in the salt of lime (chloride of calcium) 1000 parts of muriatic acid are united in a neutral state with 1107 parts of lime; the proportion of the elements in this neutral solution is then best designated by 1000 : 1107.

In this manner all the earths are treated, after which he gives the relation of the quantities of alkaline earths towards sulphuric acid and each other.

*Order of the masses of alkaline earths towards muriatic acid.* § XXII. P. 27.

"If we set in a row the numbers which have been found representing the masses of alkaline earths which unite with 1000 parts of muriatic acid, we obtain the first series of quantities of the alkaline earths. The muriatic acid is the determining element (elementum determinans) of this series, and every member of this series represents an element determined (elementum determinatum). In order to designate the elements to which we affix these numbers, we shall make use of the chemical signs for the sake of convenience, setting the determining element, or rather its sign, at the top, or at the side of the series of quantities; and when no number is placed, we shall suppose it to be 1000. In order to fix these signs in our memory, we shall here repeat them." (These signs it is not convenient to use.)

* This evidently ought to have been 1337.

"According to the paragraphs quoted, the following is the series of the alkaline earths in their relation to muriatic acid:—

MURIATIC ACID.

| ALUMINA. | MAGNESIA. | LIME. | BARYTA. |
|---|---|---|---|
| 734 | 858 | 1107 | 3099 |

"Little as the members of this series appear to follow any certain order, it is nevertheless decidedly the case; at the same time the inquiry into the law of these series is one of the most difficult problems which stœchiometry gives us to solve, and if we do not go to the inquiry with sufficient practical and theoretical exactness, we shall not succeed in our inquiry into these laws or orders (of the numbers). And now, to inquire into the law of the series before us, let us first seek the difference between each member and its successor, and we obtain 858—734=124, 1107—858=249, 3099—1107=1992. Let us then use the first difference to divide the two following differences, and we obtain $\frac{249}{124}=2+\frac{1}{124}$, $\frac{1992}{124}=16\frac{8}{124}$. Then let us see if one quotient allows of division by the other, that is, let us divide $16+\frac{8}{124}$ by $2+\frac{1}{124}$. If we bring divisor and dividend under the same denomination of 124, this will be $16+\frac{8}{124}=\frac{1992}{124}$ and $2+\frac{1}{124}=\frac{249}{124}$; therefore $\frac{1992}{249}\frac{:124}{:124}=\frac{1992}{249}$ and 249 is contained exactly 8 times in 1992, consequently $\frac{1992}{249}=8$. From this it is clear, that when we have the first difference $124\frac{1}{2}=\frac{249}{2}$, all the succeeding differences may be so divided by it that nothing remains; the half here mentioned is only $\frac{1}{1716}$ in 858 parts=0.0006 and still less in the other members of the series, it is, therefore, of no importance; it is impossible in experiments to arrive at such minuteness, at the same time in calculating the proportion to 1000 parts, it was necessary to throw away small unimportant fractions, otherwise it would be needful to use an enormous number of figures in order to designate the quantities. Now $\frac{249}{2}\times 2=249$; and $\frac{249}{2}\times 8=1992$, consequently $734+\frac{249}{2}=858\frac{1}{2}$, $734+\frac{249}{2}+\frac{249}{2}\times 2=1107\frac{1}{2}$; 734

$+\frac{249}{2}+\frac{249\times2}{2}+\frac{249\times16}{2}=3099\frac{1}{2}$. In order better to understand all, let us make $734=a$, $\frac{249}{2}=b$, then $734=a$, $858\frac{1}{2}=a+b$, $1107\frac{1}{2}=a+b+2b=a+3b$, $3099\frac{1}{2}=a+b+2b+16b=a+19b$. From this the quantitative series appears in the following order:—

MURIATIC ACID.

| ALUMINA. | MAGNESIA. | LIME. | BARYTA. |
|---|---|---|---|
| $a$ | $a+b$ | $a+3\,b$ | $a+19\,b$ |

"Now this series remains always the same, even when we put a higher or a lower number for the mass of the determining element, for if the mass of the determining element is *n* times greater or *n* times smaller, then, in the first case, all the terms would be *n* times greater; that is, multiplied by *n*; and in the latter case *n* times smaller or divided by *n*, and the order of the differences would remain always the same; because what occurs with one of the differences must occur also with the others, if otherwise the determining element must still be considered as such. When this series is attentively considered, we observe that the difference of the successive terms is a mathematical product of the first difference *b* with an odd number. According to it the quantities in which the hitherto known alkaline earths assert their neutrality with muriatic acid are terms of a real arithmetical progression, the terms of which are found, when the product of a certain quantity with an odd number is added to the first term, only that between them many odd numbers, such as 5, 7, 9, 11, 13, 17, are left out. This is more remarkable, as the differences which the first term makes with the succeeding ones may be represented entirely by odd numbers; for one need only suppose that the mass of the determining element is divided by *b*, then all the terms of the series would be at once divided by *b*, and appear in the following form:—

$$\frac{\text{Muriatic Acid.}}{b}=\frac{1000}{249:2}=\frac{2000}{249}=8\frac{8}{249}$$

| ALUMINA. | MAGNESIA. | LIME. | * * * | BARYTA. . . . . |
|---|---|---|---|---|
| $\frac{a}{b}$ | $\frac{a}{b}+1$ | $\frac{a}{b}+3$ | * * * | $\frac{a}{b}+19$ . . . . |

"In this case the first term would be $\frac{a}{b}$ and if it were all expressed in numbers then would $\frac{a}{b}=\frac{734}{249:2}=\frac{1478}{249}=5+\frac{233}{249}$ and the mass of the determining element $\frac{1000}{b}=\frac{1000}{249:2}=\frac{2000}{249}=8\frac{8}{249}$. In this way all the members are obtained in numbers, when 1, 3, and 19 are added to the first term $\frac{1478}{249}$, and the elements observed which are designated by these figures. It is very probable that the terms $\frac{a}{b}+5$, $\frac{a}{b}+7$, $\frac{a}{b}+9$, $\frac{a}{b}+11$, $\frac{a}{b}+13$, $\frac{a}{b}+15$, $\frac{a}{b}+17$ are wanting in the series, and the reasons for considering this probable, will be shewn in a suitable place.

"*Preliminary determination of the order of the alkaline earths which enter into neutrality with vitriolic acid.* § XXIII., p. 33.

"If we put in order the amount (mass) of alkaline earths which stand in neutrality with 1000 parts of vitriolic acid, in the manner adopted with muriatic acid, the following series of quantities is obtained:—

VITRIOLIC ACID.

| MAGNESIA. | LIME. | ALUMINA. | BARYTA. |
|---|---|---|---|
| 616 | 796 | 1053 | 2226 |

"In order to discover the law of this series let us, as in the former case, subtract the first term from all the succeeding, and we receive 796—616=180; 1053—616=437, 2226—616 =1610. Let us see now if the first difference can so divide all the rest, that nothing, or at least very little, remains, then $\frac{437}{180}=2+\frac{77}{180}$, $\frac{1610}{180}=8+\frac{170}{180}$. As nothing can be discovered here on account of the variety in the remaining fractions, let us divide every difference by 90 as the half of the first difference, and we obtain $\frac{180}{90}=2$, $\frac{437}{90}=5$, $\frac{1610}{90}=18-\frac{10}{90}$. The fractions here are not so considerable as before, although too large to be thrown away. Until, therefore, we are able to complete the order let us make 616=616, 796=616—2.90,* 1053=616+5.90—$\frac{13}{90}$, 2226=616+18.90—$\frac{10}{90}$."

* 2.90 means 2 × 90.

"*Nearer determination of the law by which the quantities of the alkaline earths, which enter into rest and neutrality with muriatic and vitriolic acid, increase or diminish in arithmetical progression.* § XXIV., p. 34.

"A. As we cannot completely ascertain the law by which the terms of the two series of numbers obtained by experiment proceed, we must try another source of information, to the obtaining of which the series itself which the determining element of muriatic acid makes with the alkaline earths, gives us an opportunity. As the differences of the quantities in § XXII. are a product of a quantity $b$ with an odd number, it is possible that as many terms are wanting as there are odd numbers between 3 and 19, and even that other terms may lie beyond the term $a+19b$ or $\frac{a}{b}+19$. Suppose, then, that this series were complete, namely, $a$, $a+b$, $a+3b$, $a+5b$, $a+7b$, $a+9b$, $a+11b$, $a+13b$, $a+15b$, $a+17b$, $a+19b$, $a+21b$, $a+23b$, &c., the masses of the elements which enter into neutrality with 1000 parts of muriatic acid would be the following:—

| | | | | | | |
|---|---|---|---|---|---|---|
| $a$ | | = | 734 | | = | 734 |
| $a$ + | $b$ | = | 734 | + $124\frac{1}{2}$ | = | $858\frac{1}{2}$ |
| $a$ + | $3b$ | = | 734 | + $3.124\frac{1}{2}$ | = | $1107\frac{1}{2}$ |
| $a$ + | $5b$ | = | 734 | + $5.124\frac{1}{2}$ | = | $1356\frac{1}{2}$ |
| $a$ + | $7b$ | = | 734 | + $7.124\frac{1}{2}$ | = | $1605\frac{1}{2}$ |
| $a$ + | $9b$ | = | 734 | + $9.124\frac{1}{2}$ | = | $1854\frac{1}{2}$ |
| $a$ + | $11b$ | = | 734 | + $11.124\frac{1}{2}$ | = | $2103\frac{1}{2}$ |
| $a$ + | $13b$ | = | 734 | + $13.124\frac{1}{2}$ | = | $2352\frac{1}{2}$ |
| $a$ + | $15b$ | = | 734 | + $15.124\frac{1}{2}$ | = | $2601\frac{1}{2}$ |
| $a$ + | $17b$ | = | 734 | + $17.124\frac{1}{2}$ | = | $2850\frac{1}{2}$ |
| $a$ + | $19b$ | = | 734 | + $19.124\frac{1}{2}$ | = | $3099\frac{1}{2}$ |
| $a$ + | $21b$ | = | 734 | + $21.124\frac{1}{2}$ | = | $3348\frac{1}{2}$ |
| $a$ + | $23b$ | = | 734 | + $23.124\frac{1}{2}$ | = | $3597\frac{1}{2}$ |
| | &c. | | &c. | | &c. | |

"Now let us suppose that these alkaline earths, which are partly real, partly possible, and designated by the above numbers, entered with muriatic acid into such neutral combinations as would decompose with a neutral compound out of the series § XXIII., such as the magnesia salt, by double affinity either positive or negative (see Pure Stœchiometry. Theor. 3, coroll. 3. Introd. definition 16), then only that neutral compound is excepted which the muriatic acid makes with the alkaline element of the neutral salt which we have chosen in the series XXIII., or the combination which is also taken with the magnesia salt. But according to experiment 6, coroll. 2, in the Pure Stœchiometry, in the decomposition by double affinity, out of three proportions the fourth may be determined. Let us suppose, then, that all the mentioned actual and possible neutral combinations, magnesia salt excepted, decompose with sulphate of magnesia (bitter salt) either positively or negatively, so that each constituent is placed in a state of rest (Pure Stœch. Theor. 1, coroll. 1); then we may find how many measures of each of the real and possible elements are wanted for 1000 parts of the vitriolic acid measures. (Pure Stoech. Introd. def. 14.)

"B. The first neutral compound in the series, § XXII., is an actual one, namely, alum salt, where 734 parts of alumina stand in neutrality with 1000 parts of muriatic acid. If this neutral or middle salt decomposes with sulphate of magnesia by double affinity, then 858½ parts of magnesia must be contained in the sulphate of magnesia, because the proportionate quantity in the magnesia salt is as 1000 : 858, or rather 1000 : 858½. § XXII. Now the proportionate quantity in the sulphate of magnesia is 1000 : 616 (§ XIX., XXIII.) and 616 : 1000=858½ : 1,394; that is, if 616 parts of magnesia insist on rest with 1000 parts of vitriolic acid, the same must occur between 858½ parts of the first and 1394 parts of the latter; therefore when alumina salt and magnesia salt decompose, 1000 parts of muriatic acid dissolve with 858½ parts of magnesia, and 1394 parts of vitriolic acid with 734 parts of alumina; the proportionate amount of the alum formed will then be 1394 : 734=1000 : 526, which is not the proportion of the neutral but the common alum. (§ XXI.) The quantity of the alkaline earth in common alum belongs accordingly to the series § XXIII.

"C. But when, in the decomposition of the first neutral compound, where muriatic acid is the determining element with sulphate of magnesia, the amount of the vitriolic acid is 1394, it is so in all subsequent possible decompositions which the neutral compounds of the other actual and possible elements of the series § XXII. make with the sulphate of magnesia, let these decompositions be positive or negative. (Pure Stœch. Theor. 3, coroll. 3.) The quantity, then, of real and possible elements which belong to 1000 parts of muriatic acid belong to 1394 of vitriolic, and the following proportions are obtained for the compounds where the vitriolic acid becomes at rest with the real and possible elements (Pure Stoech. Theor. 1, coroll. 1), all of which obtained by experiment except the common alum are neutral.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1394 | : | 734 | = | 1000 | : | 526 |
| 1394 | : | 858½ | = | 1000 | : | 616 |
| 1394 | : | 1107½ | = | 1000 | : | 796 |
| 1394 | : | 1356½ | = | 1000 | : | 973 |
| 1394 | : | 1605½ | = | 1000 | : | 1152 |
| 1394 | : | 1854½ | = | 1000 | : | 1330 |
| 1394 | : | 2103½ | = | 1000 | : | 1508 |
| 1394 | : | 2352½ | = | 1000 | : | 1687 |
| 1394 | : | 2601½ | = | 1000 | : | 1866 |
| 1394 | : | 2850½ | = | 1000 | : | 2045 |
| 1394 | : | 3099½ | = | 1000 | : | 2224 |
| 1394 | : | 3348½ | = | 1000 | : | 2402 |
| 1394 | : | 3597½ | = | 1000 | : | 2580 |

## § XXV.

" A. When we look on all these numbers found, viz., 526, 616, 796, 973, &c., as quantities of the elements which are at rest with 1000 parts of sulphuric acid, we obtain a series, the law of which soon appears to us. Let us first subtract the first term from all the succeeding, and we obtain the following differences, which may be expressed in various ways :—

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 616 | — | 526 | = | 90 | = | 90 | | | = | 90 | | |
| 796 | — | 526 | = | 270 | = | 270 | | | = | 3.90 | | |
| 973 | — | 526 | = | 447 | = | 450 | — | 3 | = | 5.90 | — | 3 |
| 1152 | — | 526 | = | 626 | = | 630 | — | 4 | = | 7.90 | — | 4 |
| 1330 | — | 526 | = | 804 | = | 810 | — | 6 | = | 9.90 | — | 6 |
| 1508 | — | 526 | = | 982 | = | 990 | — | 8 | = | 11.90 | — | 8 |
| 1687 | — | 526 | = | 1161 | = | 1170 | — | 9 | = | 13.90 | — | 9 |
| 1866 | — | 526 | = | 1340 | = | 1350 | — | 10 | = | 15.90 | — | 10 |
| 2045 | — | 526 | = | 1519 | = | 1530 | — | 11 | = | 17.90 | — | 11 |
| 2224 | — | 526 | = | 1698 | = | 1710 | — | 12 | = | 19.90 | — | 12 |
| 2402 | — | 526 | = | 1876 | = | 1890 | — | 14 | = | 21.90 | — | 14 |
| 2580 | — | 526 | = | 2054 | = | 2070 | — | 16 | = | 23.90 | — | 16 |

" B. The law by which the differences of the actual and possible alkaline earths increase in relation to vitriolic acid is then so far made out that it follows from the product of a number which is here 90 with the consecutive odd numbers; we may consider the numbers which are to be subtracted, such as 3, 4, 6, 8, 9, &c., as nothing, because the greatest error that could be caused is only $\frac{3}{450}=\frac{1}{150}=0.0066$, or $\frac{66}{10000}$; but even this is not necessary, because the numbers themselves proceed in distinct order, as the series shews; and if we inquire, as in § XXII., into the manner in which these numbers progress, we observe that if three of them increase by odd numbers, the succeeding four increase in the ordinary way by one, and so alternately; for example.

| | | | | | |
|---|---|---|---|---|---|
| — 3 | | | = | — | 3 |
| — (3 | + | 1) | = | — | 4 |
| — (3 | + | 3) | = | — | 6 |
| — (3 | + | 5) | = | — | 8 |
| — (3 | + | 6) | = | — | 9 |
| — (3 | + | 7) | = | — | 10 |
| — (3 | + | 8) | = | — | 11 |
| — (3 | + | 9) | = | — | 12 |
| — (3 | + | 11) | = | — | 14 |
| — (3 | + | 13) | = | — | 16 |
| — (3 | + | 15) | = | — | 18 |
| — (3 | + | 16) | = | — | 19 |
| | | &c. | &c. | | |

" These quantities accordingly proceed in arithmetical progression down to the most insignificant fractions, as we may see by a glance at them.

" *The quantities in which the alkaline earths enter into neutrality with muriatic acid are terms of an endless series, which increase by the product of a determinate quantity with the consecutive odd numbers. The same thing occurs with the alkaline earths in relation to sulphuric acid, only that in this case a quantity must be taken from the terms of the last series, the first three excepted; this quantity increasing also in progression.*

## § XXVI.

" A. After finding out the law by which the quantities of the alkaline earths increase towards the two acids (sulphuric and muriatic), it becomes necessary to form the series themselves, that we may see clearly the correctness of the proposition advanced as a hypothesis; for if it is done rightly the proposition ceases to be a hypothesis. We shall designate the terms that are wanting in both series by a star, and the elements which produce with acids a very violent heat when freed from their air, for example, lime and magnesia, by △, as the sign of fire.

Muriatic Acid .... $a = 734$, $b = \frac{249}{2} = 124\frac{1}{2}$.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Alumina... | $a$ | | | = | 734 | + | | = | 734 |
| △ | Magnesia.. | $a$ | + | $b$ | = | 734 | + | $\frac{249}{2}$ | = | $858\frac{1}{2}$ |
| △ | Lime .... | $a$ | + | $3b$ | = | 734 | + | $\frac{3 \cdot 249}{2}$ | = | $1107\frac{1}{2}$ |
| | * | $a$ | + | $5b$ | = | 734 | + | $\frac{5 \cdot 249}{2}$ | = | $1356\frac{1}{2}$ |
| | * | $a$ | + | $7b$ | = | 734 | + | $\frac{7 \cdot 249}{2}$ | = | $1605\frac{1}{2}$ |
| | * | $a$ | + | $9b$ | = | 734 | + | $\frac{9 \cdot 249}{2}$ | = | $1854\frac{1}{2}$ |
| | * | $a$ | + | $11b$ | = | 734 | + | $\frac{11 \cdot 249}{2}$ | = | $2103\frac{1}{2}$ |
| | * | $a$ | + | $13b$ | = | 734 | + | $\frac{13 \cdot 249}{2}$ | = | $2352\frac{1}{2}$ |
| | * | $a$ | + | $15b$ | = | 734 | + | $\frac{15 \cdot 249}{2}$ | = | $2601\frac{1}{2}$ |
| | * | $a$ | + | $17b$ | = | 734 | + | $\frac{17 \cdot 249}{2}$ | = | $2850\frac{1}{2}$ |
| | Baryta .. | $a$ | + | $19b$ | = | 734 | + | $\frac{19 \cdot 249}{2}$ | = | $3099\frac{1}{2}$ |
| | * | $a$ | + | $21b$ | = | 734 | + | $\frac{21 \cdot 249}{2}$ | = | $3348\frac{1}{2}$ |
| | * | $a$ | + | $23b$ | = | 734 | + | $\frac{23 \cdot 249}{2}$ | = | $3597\frac{1}{2}$ |
| | | | | &c. | | | | &c. | | |

" B. Before we set down the quantitative progression in the case of vitriolic acid, we must first inquire if the quantity of alumina in neutral alum belongs to this series; it is 1053. Let us subtract 526 from 1053, and we obtain 527; now 527 = 540—13=6.90—13, and consequently 1053=526+6.90—13. But as the series determined by vitriolic acid proceeds by the uninterrupted odd numbers, and no neutral alum can be found in decomposing by double affinity, the quantity 526+6.90—13 does not belong to this series. We must take it, however, in the meantime into the series, because it belongs to the quantities which enter into neutrality. We shall, however, put such in brackets, as must happen when considering the quantity of alumina in common alum, if it is not a legitimate member of the series, and capable of double affinity.

No. 2.

Sulphuric Acid......$a = 526$, $b = 90$

| | | | |
|---|---|---|---|
| Alumina.. | $a$ | $=526$ | $= 526$ |
| △ Magnesia. | $a + b$ | $=526 + 90$ | $= 616$ |
| △ Lime . . . | $a + 3b$ | $=526 + 3.90$ | $= 796$ |
| * | $a + 5b - 3$ | $=526 + 5.90 - 3$ | $= 973$ |
| Alumina.. | $(a + 6b - 13)$ | $=526 + (6.90 - 13)$ | $=1053$ |
| * | $a + 7b - (3 + 1)$ | $=526 + 7.90 - (3 + 1)$ | $=1152$ |
| * | $a + 9b - (3 + 3)$ | $=526 + 9.90 - (3 + 3)$ | $=1330$ |
| * | $a + 11b - (3 + 5)$ | $=526 + 11.90 - (3 + 5)$ | $=1508$ |
| * | $a + 13b - (3 + 6)$ | $=526 + 13.90 - (3 + 6)$ | $=1687$ |
| * | $a + 15b - (3 + 7)$ | $=526 + 15.90 - (3 + 7)$ | $=1866$ |
| * | $a + 17b - (3 + 8)$ | $=526 + 17.90 - (3 + 8)$ | $=2045$ |
| Baryta . . | $a + 19b - (3 + 9)$ | $=526 + 19.90 - (3 + 9)$ | $=2224$ |
| * | $a + 21b - (3 + 11)$ | $=526 + 21.90 - (3 + 11)$ | $=2402$ |
| * | $a + 23b - (3 + 13)$ | $=526 + 23.90 - (3 + 13)$ | $=2580$ |
| | &c. | &c. | |

"C. If we convert the differences into simple consecutive odd numbers, the quantity of the determining element and all the terms of the series have only to be divided by $b$, and we receive:

No. 1.

$\frac{\text{Muriatic Acid,}}{b}$ $a = 734$, $b = \frac{249}{2}$ $\frac{\text{Muriatic Acid,}}{b} = 8\frac{+8}{249}$

| | | | | |
|---|---|---|---|---|
| Alumina.. | $\frac{a}{b}$ | $= \frac{734}{124\frac{1}{2}}$ | $= 5 + \frac{223}{249}$ |
| △ Magnesia. | $\frac{a}{b} + 1$ | $= \frac{858\frac{1}{2}}{124\frac{1}{2}}$ | $= 6 + \frac{223}{249}$ |
| △ Lime.... | $\frac{a}{b} + 3$ | $= \frac{1107\frac{1}{2}}{124\frac{1}{2}}$ | $= 8 + \frac{223}{249}$ |
| * | $\frac{a}{b} + 5$ | $= \frac{1356\frac{1}{2}}{124\frac{1}{2}}$ | $= 10 + \frac{223}{249}$ |
| * | $\frac{a}{b} + 7$ | $= \frac{1605\frac{1}{2}}{124\frac{1}{2}}$ | $= 12 + \frac{223}{249}$ |
| * | $\frac{a}{b} + 9$ | $= \frac{1854\frac{1}{2}}{124\frac{1}{2}}$ | $= 14 + \frac{223}{249}$ |
| * | $\frac{a}{b} + 11$ | $= \frac{2103\frac{1}{2}}{124\frac{1}{2}}$ | $= 16 + \frac{223}{249}$ |

$* \quad \frac{a}{b} + 13 = \frac{2352\frac{1}{2}}{124\frac{1}{2}} = 18 + \frac{223}{249}$

$* \quad \frac{a}{b} + 15 = \frac{2601\frac{1}{2}}{124\frac{1}{2}} = 20 + \frac{223}{249}$

$* \quad \frac{a}{b} + 17 = \frac{2850\frac{1}{2}}{124\frac{1}{2}} = 22 + \frac{223}{249}$

Baryta.. $\frac{a}{b} + 19 = \frac{3099\frac{1}{2}}{124\frac{1}{2}} = 24 + \frac{223}{249}$

$* \quad \frac{a}{b} + 21 = \frac{3348\frac{1}{2}}{124\frac{1}{2}} = 26 + \frac{223}{249}$

$* \quad \frac{a}{b} + 23 = \frac{3597\frac{1}{2}}{124\frac{1}{2}} = 28 + \frac{223}{249}$

&c. &c.

## No. 2.

Further—

Vitriolic Acid, $a=526$, $b=90$ $\frac{\text{Vitriolic Acid}=11\frac{1}{3}}{b}$

---

Alumina. $\frac{a}{b} = \frac{526}{90} = 5 + \frac{76}{90}$

Magnesia $\frac{a}{b} + 1 = \frac{616}{90} = 6 + \frac{76}{90}$

Lime .. $\frac{a}{b} + 3 = \frac{796}{90} = 8 + \frac{76}{90}$

$* \quad \frac{a}{b} + 5 - \frac{3}{b} = \frac{973}{90} = 10 + \frac{73}{90}$

Alumina. $\left[\frac{a}{b} + 6 - \frac{13}{b}\right] = \left[\frac{1053}{90}\right] = \left[11 + \frac{63}{90}\right]$

$* \quad \frac{a}{b} + 7 - \frac{(3+1)}{b} = \frac{1152}{90} = 12 + \frac{72}{90}$

$* \quad \frac{a}{b} + 9 - \frac{(3+3)}{b} = \frac{1330}{90} = 14 + \frac{70}{90}$

$* \quad \frac{a}{b} + 11 - \frac{(3+5)}{b} = \frac{1508}{90} = 16 + \frac{68}{90}$

$* \quad \frac{a}{b} + 13 - \frac{(3+6)}{b} = \frac{1687}{90} = 18 + \frac{67}{90}$

$* \quad \frac{a}{b} + 15 - \frac{(3+7)}{b} = \frac{1866}{90} = 20 + \frac{66}{90}$

$* \quad \frac{a}{b} + 17 - \frac{(3+8)}{b} = \frac{2045}{90} = 22 + \frac{65}{90}$

Baryta.. $\frac{a}{b} + 19 - \frac{(3+9)}{b} = \frac{2224}{90} = 24 + \frac{64}{90}$

$* \quad \frac{a}{b} + 21 - \frac{(3+11)}{b} = \frac{2402}{90} = 26 + \frac{62}{90}$

$* \quad \frac{a}{b} + 23 - \frac{(3+13)}{b} = \frac{2580}{90} = 28 + \frac{60}{90}$

&c. &c.

"D. When the numbers in the last series are compared with those found by experiment, they are found to agree perfectly, as far as regards alumina, lime, and magnesia. On the other hand, the amount of baryta in the sulphate is 2224, but in § XIX. 2226. No doubt the difference comes from the greater difficulty in finding the point of saturation in the case of this earth than in the case of the others, when combining them with sulphuric acid. At the same time, the supposed error is so small that it may be left out of consideration, for it amounts only to $\frac{2}{2224}$ or 0.0009 or $\frac{9}{10000}$, which is a difference that may be reckoned as nothing. It must be remembered that decimal fractions only are used here.

"E. Now if the quantities found by experiment exactly fit into the series, if all the terms of these series entirely correspond to the possibility of double affinity, if even a quantity which is capable of neutrality, but not of double affinity, is banished out of one series by the rule of the series; further, if one series becomes possible only through the other, the proposition is absolutely certain, that the quantities of the hitherto known alkaline earths which enter into rest or equilibrium with sulphuric and muriatic acids are terms of an infinite series in arithmetical progression, each of which proceeds according to its own law.

"G. Shall we then conclude from the laws of the two series, in which so many terms are wanting, that there are many alkaline earths existing in nature? So far as probability and possibility are concerned it is a fair conclusion, especially since the knowledge of magnesia and baryta are the property of only the last half century. If they had not been discovered until after the study of the stœchiometric sphere had commenced, the second and eleventh term of every series would be wanting, and a * substituted, and besides it would not have been possible, with such a small number of terms to have found out the law. Who knows if there are not other elements in existence which interrupt the last series as neutral quantities, precisely as with the alumina? But if we should conclude from the law of these series that the existence of the failing elements is necessary, then we should commit as great an error as if we were to conclude that a planet must exist between Mars and Jupiter, because it corresponds to the law of the distance of the planets from the sun.

"H. The use of these series of quantities is not small, for if we know only the first member and are acquainted with the law, we find all the other members and all the proportionate quantities with the greatest exactness, and who does not know what differences there have hitherto been in the numbers representing the proportions? How many uses shall we find also in chemical analysis for series of this kind, of which probably there are many, and to what perfection might it not bring the chemical system, if they could be used as tables of affinities?

"*The two series of quantities*, 1 *and* 2, § XXVI., *are really quantitative series of the affinity of alkaline earths towards muriatic and sulphuric acid.* Page 51.

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Page 56. "*Determination of the decomposing forces*, § XXVIII.

"A. The experiments now detailed enable us to state the proposition that affinities are as the masses.

"C. P. 61. If now in these cases of affinity the attracting forces of the elements are as the masses of the elements, and we take 3099 as the attracting force or affinity of baryta towards muriatic acid, the numbers 1107, 858, 734, or the attractive force of the elements represented is quite unaltered towards muriatic acid, on the other hand we must calculate the affinity of these earths to sulphuric acid from the numbers given and the proposition adopted. According to the proposition, 1000 : 1394=3099 : 4320 and 1000 : 1394=734 : 1023, in the same way 3099 : 734= 4320 : 1023. If, then, the attractive power of baryta towards muriatic acid is 3099, towards vitriolic acid it is 4320, and if alumina acts towards muriatic acid with the force of 734, and towards vitriolic acid with a force of 1023 forming common alum, in the same manner the baryta is attracted with a force of 4320 towards vitriolic acid, forming heavy spar, and so the power by which this acid forms common alum is only 1023. If we inquire into the affinity of the other alkaline earths towards vitriolic acid by the rule of three, we obtain for lime $\frac{1394 \cdot 1107}{1000}=1543$, for magnesia $\frac{1394 \cdot 858}{1000}=1196$. If, then, in the cases of double affinity given, we put instead of the quantity the attractive force by which one element works on another, we obtain, according to the first theorem of the 'Pure Stœchiometry,' as follows:—

No. 1.

| | | |
|---|---|---|
| Baryta. | | Muriatic Acid. |
| 3099 | Baryta Salt. | 3099 |
| 4320 | | 734 |
| | Heavy Salt. | |
| | Alum. Spar. | |
| 734 | | 4320 |
| 1023 | Common Alum. | 1023 |
| Alumina. | | Vitriolic Acid. |

"D. * * * In No. 1 the two positive or decomposing elements are 4320 and 734, the negative which hinder the compound are 3099 and 1023, consequently 4320+734=5054 the whole positive or furthering, and 3099+1023 =4122 the whole negative or hindering power. * * *" The difference (equal to the power, as he says) =+932 is positive.

He then endeavours to shew in the same way, page 171, &c., that "The masses (quantities) of the three alkaline salts, which enter into neutrality with an equal amount of vitriolic or muriatic acid, are the three first terms of two series, of which, that which belongs to muriatic acid proceeds by the odd numbers without interruption, and the other is the product of a quantity with the numbers in regular succession."

Page 167. "When an aqueous solution of vitriolic salammoniac is poured into a solution of muriate of lime, an abundant precipitate is caused, which is completely formed gypsum; if the exact quantity of the salammoniac solution has been used which is necessary to complete the precipitation, the liquid above the precipitate contains nothing but perfectly formed common salammoniac. But the proportion in the salt is 1000 : 1107½, and to 1000 of the chloride are to be calculated 889 parts of the volatile alkali; now let us inquire how much of the vitriol is needed for 1107½ parts of the lime, the proportion of the last to the first is 796 : 1000, consequently 1107½ parts of lime demand $\frac{1000 \cdot 1107\frac{1}{2}}{796} = \frac{2215000}{1592} = 1394$ parts of vitriol, which belong to the 889 parts of the volatile alkali.

He gives a list, page 279, of "*Proportional quantities of neutral compounds which decompose each other, when entirely deprived of water.*" * * * * "In each of these cases it is only necessary to add the numbers representing the quantities standing against each other horizontally, by which the power of the affinity is estimated, and we receive the neutral quantities which decompose each other, and consequently their proportion."

| Salammoniac Vitriol. | | Common Salt. |
|---|---|---|
| 689 + 1000 | : | 960 + 717 = 1689 : 1677 |
| Salammoniac Vitriol. | | Common Salt. |
| 638 + 1000 | : | 960 + 717 = 1638 : 1677 |
| Magnesia Salt. | | Vitriolized Potash. |
| 858 + 1000 | : | 2239 + 1394 = 1858 : 3633 |

&c., &c., &c.; this is from a list of 28: the second and third are supposed hydrous.

Then we have, p. 284, "*Proportional quantities of neutral compounds containing muriatic acid, considered as anhydrous, when decomposed by vitriolic acid.*" Also, "*Proportional quantities, when the neutral compounds which vitriolic acid makes with the alkaline salts and magnesia are decomposed negatively or by free muriatic acid.*" P. 293.

At page 190, he says, that the affinities are as the amount of the combining proportions, and here also the atomic weights of ammonia, soda, and potash, are such as to lend some countenance to it. The series, however, is still considered the most important thing, and he finds afterwards, in the vol. for 1800, that smaller weights may precipitate larger ones.

These inquiries were continued with great labour, and in his work "On the newer subjects in chemistry," we have many attempts to define the relations between the acids and bases. In the vol. for 1798, we find him fixing the relation between the metals and some of the acids, but always on the same plan.

At page xv. in the preface to the vol. for 1800, he says, "To follow an author step by step, in a path trodden by him alone, and to judge him with fairness, is not in the power of every one, still less can it be done by merely reading through his book."

Page xxiii. Again, "Whoever looks on the remarkable order, which reigns in the quantitative proportions, by which every kind of substance has a peculiar quantitative character with respect to another, as a mere play of figures, or as a mere accident, would only show his complete ignorance of the whole structure of stœchiometry, but would be indemnified for it by a still greater degree of philosophical faith; for it requires much more credulity to believe in so many accidents, than is needed to perceive that the Lord of nature has not only qualitatively but quantitatively endued it with the most wonderful order, both in great things and in small."

Another extract from the same, page 206, "In the simpler affinities every kind of neutralizable substance has its own quantitative law of affinity, because the amount of affinities among the alkalies may be expressed by the mass, that of the acids by the substratum (that is, the body of which the oxygen of the acid is an oxide); but this is not found to be the case either with the metallic or nonmetallic combustible elements."

What then did Richter attain to is the question to be now answered. In the extract from the preface he raises the study of atomic chemistry to a science, and gives it a name. This is itself no small honour. The chemists before him had certainly not been gifted with such a clear appreciation of the importance of the study. We find that Richter has made it the leading object of his life to elucidate the laws of combination; as a young beginner, making it a subject of his inaugural dissertation, and looking forward to the time when he might have opportunity to prosecute his investigations. The word stœchiometry is preserved in Germany, with us it is too abstract for daily use.

The first definition of stœchiometry has appended to it six *experiences* (erfahrung), most of them with corollaries (zusatz). The reading becomes, therefore, exceedingly cumbrous, the words are marvellously multiplied, pure abstraction is aimed at in every step with painful strains, as it would appear, or perhaps only caused by a mathematical habit of mind too exclusively followed. In this way the few truths that we still hold to, and which are contained in the book, are so ornamented and overdressed as to have been to most persons entirely hidden under the richness of the elaboration.

He expresses his belief that the smallest portions of a body are of the same composition as the largest. He says that the affinity exists in every particle. Then adds that every piece must have the same composition. His own words are very cumbrous, but this meaning is distinctly there. This was the illustration which Dalton afterwards used on the same subject, but it was expressed in clearer words, and still earlier, by Higgins. This idea leads directly to the atomic theory and theory of equivalents. Here it is not followed out.

The sixth *experience* of first definition gives the theory of reciprocal saturation, when double decomposition takes place in solutions. This is the discovery which has been attributed to Wenzel. Let us translate his formulas into the present symbols by an example:—

$$AgO\,NO_5—NO_5,\ NO_5+KO\,SO_3—SO_3,\ SO_3$$
$$=NO_5+KO\,SO_3—SO_3+SO_3+AgO\,NO_5—NO_5.$$

He says the products of neutral salts are nearly without exception neutral, but nevertheless sees enough to form a law. Wenzel, with similar results, had not seen a law.

He endeavours to shew the relative amount of force exerted by different substances when decomposition takes place, but he gets no farther than the fact that certain forces are equal, some must be greater, and others must be less. In this district of inquiry, an example of which may be found in Theorem I., what appears to be the enunciation of an important law, frequently turns out to be the mere expression of a common-place, giving no information to the chemist. Such laws being in a certain sense universal, they are now left out of chemical works, as the mind can readily draw the conclusion for itself, if the opportunity offers.

He then shews the method of obtaining the proportion of the elements in a compound. This had been pursued with great care by Wenzel.

The great aim of Richter is not perceived in reciprocal proportion, but in the attempt to make the combining numbers of all bodies a series in arithmetical progression, and so to bring number, quantity, and order into the arrangement of the elements. In the series which he has formed, I think we may say that he has failed to prove his point. The numbers he had were too few, and the mode of obtaining the order is by no means satisfactory. There is, however, a great probability recognised by most chemists of the existence of an order in which the elements are related to each other. If this order should ever be found to be similar to that which Richter has indicated, we must do the greatest honour to his genius, although we cannot even now, when it stands before us, say that it is a discovery, or that it has any value at all.

The discovery of reciprocal proportion is given by no one before Richter as far as I know, but he himself does not speak of it as a discovery, but as a well-known fact, with which he was familiar before he wrote his inaugural dissertation. We find in the preface that it was well known that neutral salts gave neutral results on decomposition; this Richter has put formally amongst the laws of stœchiometry, and given it rank amongst chemical truths. He deduced from it, as he himself says, that there must be "distinct proportionate quantities amongst the component parts of neutral salts," and he strove hard to bring all combinations under number and quantity. The knowledge of this fact seems to have first set in motion his stœchiometry; instead then of being the point which he gained, it is the point from which he starts, according to his own account. He does not, however, seem to have seen the reason for it, nor its general bearing in chemistry, otherwise it could not have been left for Fischer to shew that the combining number of an element would fit its combination with every other element.

The mode in which he obtains the relation of the combining weights of the earths to each other is remarkably self-delusive, but at the same time exceedingly ingenious. They are given at length, so that every one may compare for himself.

He endeavours to find out a similar relation between the atomic weights of the alkalies, and readily does so. He is led away by the numbers observed to mistake them for representations of actual force, and so calculates in a relative and abstract way the force needed for decomposition. This is very characteristic of him, but unfortunately he has gone on a wrong assumption.

He has evidently been a man of great quickness, at the same time apparently of haste; he has enunciated the most beautiful truths, and left them untouched for worthless speculations, which seemed to need more ingenuity, almost leaving us to doubt how far he understood his own writings. We must, however, give him the honour of understanding what he wrote, smaller honour we can give no man. Still it is perfectly clear that if his theory were as fully developed in his mind as we with our superior opportunity can now see to be deducible from his words, men would have understood him, and the process would have been continued, but neither did he make any advance, nor did he teach others clearly, although the young Berzelius was much excited to curiosity.

It certainly is difficult to tell how discoveries grow, often impossible to tell who is the discoverer; but this we may consider a fair rule, not always easily applied, it is to be confessed, that he is a discoverer who sees distinctly the full bearing of his discoveries; when this does not happen there is a difficulty in giving that man the place due to him. It is clear that Richter, like some others already mentioned, had fundamental principles which would have led him to the atomic theory; but he has evidently been led by foregone conclusions, and the law of planetary distances has been floating in his mind and misleading him, when seeking for the differences in the combining weights of bodies.

The discovery of reciprocating proportion was a very important and memorable one, although the scientific world did not recognise it, another among the many proofs that scientific men are subject to the same bigotted attachment to the laws they have learned, as that class of men hitherto most blamed for bigotry, nor is there any bigotry more engrossing than that which appears to the possessors to be upheld by experimental proof. Who discovered this important fact, it is still left unascertained: as the expression of a law it is Richter's, but as a fact regarding neutral salts the author appears not to be known.

Among the many disputes on this point it is rather surprising that people should speak without reading the authors they discuss. The supporters of Wenzel have not read him, the supporters of Richter have overlooked his own writings and his own confession, as it appears to me in the preface. But as I give the words every one may judge for himself.

In proceeding with his inquiry one cannot but admire the energy and activity of Richter's mind, and his enthusiastic desire to prove the beauty of the arrangement of creation; it is clear that he lost his way, and spent the greatest part of his energy on a subject which could not with his data lead to great results, and which even now gives us no help, and which was not the next step wanted in chemistry. The science was straining after definite laws, it had none; Richter, with his one great law, might have done wonders, had he only seen its value; he might have found on examination that it was, properly speaking, an inference from another much more general law, and would have then expressed himself in universal terms. But Higgins had expressed himself much more clearly as to combination before him, as already shewn, and only failed because he had not seen it to be a general law.

Richter attempted to give the proportion of the acids to bases as an expression of affinity, but this had been already attempted by Kirwan, and was shewn to be unsuccessful.

As a general summary of Richter's most important work, we may say, he found that there was a certain quantitative relation between all bodies, and he made out the laws so far, that when he knew the quantitative analysis of a salt, he could tell its quantitative decomposition with another, but he never saw it with sufficient clearness to be able to express the combining quantities each by its own distinct number, nor does he appear to have ever proceeded far enough to be able to assign a cause for the phenomenon, or to connect it with any fundamental idea.

He was the founder of the systematic study of stœchiometry, he was an illustrator of one of its important laws, and a defender of regularity in nature. His scientific life was laborious, his love of science sincere, and in all respects he seems to have been a man of high character. After reading his works, and coming occasionally on a sentence which makes us for the moment believe that he has discovered a greater law than we can give to him, and finding that during his whole life he was just on the point of the present atomic laws, one feels that he was perhaps the only man that deserved to discover them, having given himself up entirely to that purpose. It is with regret, therefore, that I leave him also, another combatant who died before the victory.

It has been said that Dalton had read Richter, and had never acknowledged his claims. It is a melancholy thing to see men of talent and learning so readily distrusting their own class, as if dishonesty were so common. I might say the same of Richter, that for more than ten years he continued to publish on stoechiometry, and never once mentioned Higgins, but his whole works shew that he did not see Higgins's writings, or he would have probably got less involved than he did. We learn from Dr. Henry that Dalton had seen Richter's results on reciprocal proportion,* and had received assistance from them, but although they may have assisted him in proving his laws, Richter could never have given him

* Dr. Thomson had said the contrary; but let us take Dr. Henry's information, as being an intimate friend. Dalton could not have seen Richter's whole works, but probably an account of them. They are scarce in England. It cost me a good deal of trouble to get one, even in Germany. The British Museum does not possess a complete copy. Dalton certainly had not read Higgins; and although Dr. William Henry had a copy, we may conclude from his son's work that he had not seen in it the Atomic Theory, as he seems not to have thought it necessary to mention its existence to Dalton.

fundamental ideas. These are much wanted in Richter's chemistry. Richter's cotemporaries did not obtain the atomic theory, although some were students of his work. Berzelius himself did not obtain the atomic theory from Richter, although the most illustrious of the students of Richter's books. Dalton then could not have obtained it, and the direction he takes is perfectly different, the road he went quite clear, and the result he came to entirely distinct from that aimed at by Richter.

In such early days it required a mind of a high order to see as Richter did into the great necessity of permanent laws, and the great structure he raised to make the inquiry shews us that he saw its importance. Had chemists been accustomed to study the works of their own class, such books as his would have rapidly produced results, but the history of the matter speaks ill for the apathy of the men of even that period, and well for his untiring energy and devotion.