

**Elementary lectures on chemistry and natural history : containing a methodical abridgement of all the chemical knowledge acquired to the present time : with a comparative view of the doctrine of Stahl, and of that of several modern chemists : the whole forming a complete course of those two sciences / translated from the French of M. Fourcroy, doctor of the Faculty of Medicine of Paris, and of the Royal Society of Medicine by Thomas Elliot ; with many additions, notes, and illustrations, by the translator. In two volumes.**

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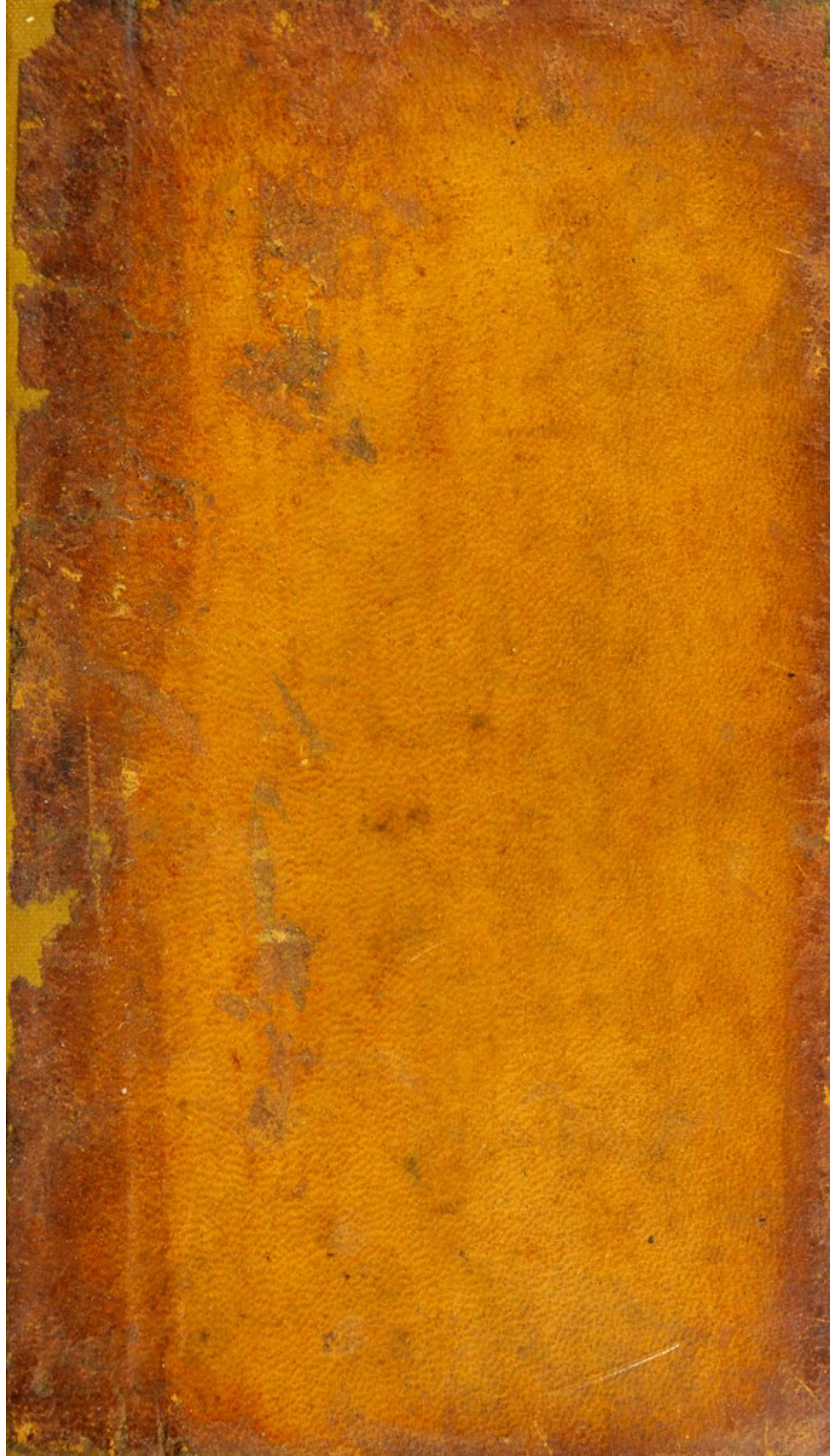
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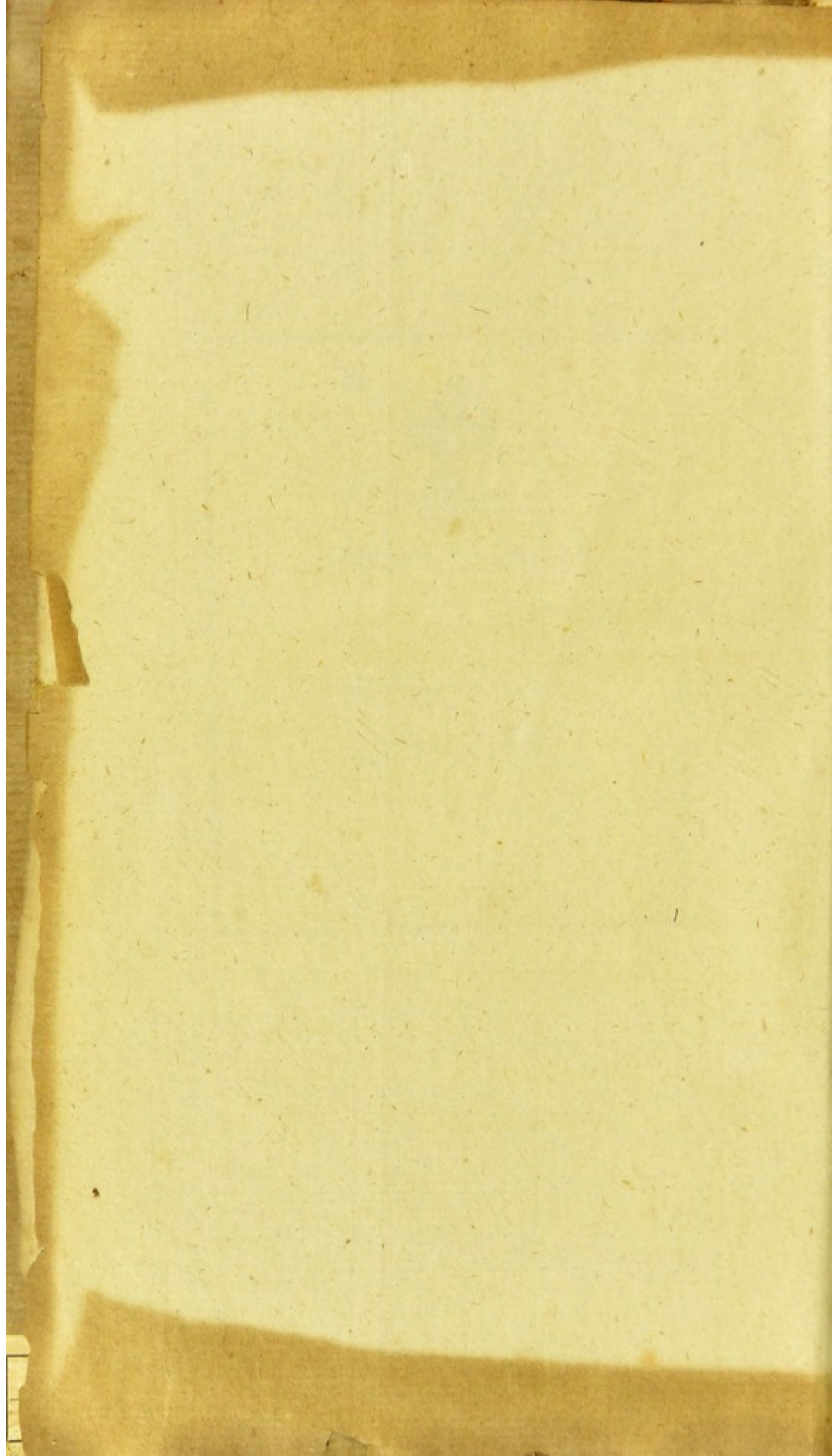
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12  
ELEMENTARY LECTURES  
ON  
C H E M I S T R Y  
AND  
N A T U R A L H I S T O R Y.

C O N T A I N I N G  
A M E T H O D I C A L A B R I D G E M E N T  
OF ALL THE  
C H E M I C A L K N O W L E D G E  
ACQUIRED TO THE PRESENT TIME;



W I T H  
A C O M P A R A T I V E V I E W O F T H E D O C T R I N E O F S T A H L,  
AND OF THAT OF SEVERAL MODERN CHEMISTS:  
THE WHOLE FORMING A  
C O M P L E T E C O U R S E O F T H O S E T W O S C I E N C E S.

Translated from the French of  
M. F O U R C R O Y,  
Doctor of the Faculty of Medicine of PARIS, and of the Royal  
Society of Medicine.

B Y T H O M A S E L L I O T.

WITH MANY ADDITIONS, NOTES, AND ILLUSTRATIONS,  
BY THE TRANSLATOR.

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I N T W O V O L U M E S.

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V O L. I.

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E D I N B U R G H:  
Printed for C. ELLIOT; G. ROBINSON, LONDON;  
And W. GILBERT, DUBLIN.

M,DCC,LXXXV.

BRISTOL ROYAL INFIRMARY.







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## ADVERTISEMENT BY THE TRANSLATOR.

IT is hoped, that a translation of M. Fourcroy's Lectures upon Chemistry and Natural History will meet with a favourable reception, on account of the great merit of the original work, which contains by far the most distinct, comprehensive, connected, and accurate view of modern improvements of any system which has hitherto been published. There was indeed a very pressing call for a publication of this kind, which should abridge and methodise, and save the student the toilsome labour of consulting all the fugitive and detached essays, in which alone those discoveries are to be found. So that the Author's intention, to present whatever was worthy to be known in Chemistry, under a methodical and orderly arrangement, with occasional remarks to illustrate particular doctrines, and with general observations to unite the whole together as one body of science, all confirmed by the result of experiments fairly and distinctly detailed, was a design most laudable in itself; and he has completed it in a very judicious and masterly manner.

With regard to the conduct of the translation, it shall only be observed, that it has been invariably studied to translate the original with the strictest attention to the true meaning of the author, and in the most literal language which was consistent with the precision and perspicuity of the style.

The addition of Notes was made with a view to amplify and illustrate the original text. And the Translator has here to acknowledge his obligation to Mr James Russel, Fellow of the Royal College of Surgeons, Edinburgh, for the communication of all the valuable matter which those notes contain, and of some new experiments upon different subjects: And wherever the notes deviate from the text of M. Fourcroy, he has either given the author of the assertion, or he has endeavoured to determine the point in doubt by a decisive experiment.

EDINBURGH,  
Jan. 1785.



# C O N T E N T S

OF

## THE FIRST VOLUME.

|  |   |      |            |
|--|---|------|------------|
| Preface  | - | Page | xix—xxviii |
| Preliminary Dissertation upon Chemical Affinities                  | - |      | 29         |
| LAW First, <i>Of the Affinity of Composition</i>                   | - |      | 36         |
| Second,  | - |      | 37         |
| Third,   | - |      | 38         |
| Fourth,  | - |      | 39         |
| Fifth,   | - |      | 40         |
| Sixth,   | - |      | 42         |
| Seventh,   | - |      | 43         |
| Eighth,  | - |      | 44         |
| Ninth,   | - |      | 47         |
| Tenth,   | - |      | 48         |
| LECTURE I. <i>General heads on Chemistry</i>                       | - |      | 59         |
| <i>History of Chemistry</i>  | - |      | 64         |
| First Epoch,   | - |      | 64         |
| Second,  | - |      | 65         |
| Third,   | - |      | 66         |
| Fourth,  | - |      | 68         |
| Fifth,   | - |      | 70         |
| Sixth,   | - |      | 71         |
| LECT. II. <i>Chemical affinities</i>                               | - |      | 73         |
| <i>Of the affinity of aggregation</i>                              | - |      | ib         |
| <i>Of the affinity of composition</i>                              | - |      | 75         |
| LECT. III. <i>Of the principles of the chemists</i>                | - |      | 80         |
| <i>Of the division of the natural bodies into several kingdoms</i> | - |      | 83         |
| <i>Of the four elementary bodies</i>                               | - |      | 84         |
| Article 1. <i>Examination of the properties of fire</i>            | - |      | ib         |
| <i>Effects of fire</i>   | - |      |            |
| § 1. <i>Light</i>  | - |      | 85         |
| § 2. <i>Heat</i>   | - |      | 86         |
| — according to M. Scheele's system                                 |   | Note | ib         |
| — according to Dr Crawford's system                                |   | Note | 89         |
| — according to M. Lavoisier's system                               |   | Note | 91         |
| LECT. IV. § 3. <i>Rarefaction</i>                                  | - |      | 93         |
| <i>Thermometer</i>   | - | Note | 95         |
| § 4. <i>Of the action of heat considered chemically</i>            | - |      | 96         |
| <i>Degrees of heat inferior to boiling water</i>                   | - |      | 100        |
| <i>Degrees of heat above boiling water</i>                         | - |      | ibid       |
|  |   |      | § 5.       |



# C O N T E N T S.

|   |           |
|---|-----------|
| § 5. <i>Of phlogiston</i>                                     | 100       |
| LECT. V. <i>Examination of the properties of air</i>          | 103       |
| § 1. <i>Physical properties of air</i>                        | ibid      |
| § 2. <i>Chemical properties of air</i>                        | 104       |
| <i>Enumeration of its different kinds</i>                     | Note ibid |
| <i>Empyrean or dephlogisticated air</i>                       | 105       |
| <i>Fixed air, or ærial acid, (l'acide crayeuse)</i>           | 106       |
| <i>Inflammable air</i>  | ibid      |
| <i>Mephitic or phlogisticated air</i>                         | 107       |
| <i>Nitrous air</i>  | ibid      |
| <i>Nitrous acid air</i>                                       | 108       |
| <i>Vitriolic and marine acid airs</i>                         | ibid      |
| <i>Alkaline air</i>   | ibid      |
| <i>Hepatic air</i>  | ibid      |
| <i>Specific gravity of elastic fluids</i>                     | 109       |
| LECT. VI. <i>Examination of the properties of water</i>       | 112       |
| § 1. <i>Of water in the state of ice</i>                      | 113       |
| § 2. <i>Of fluid water</i>                                    | 114       |
| <i>Alterability by distillation, and various treatment</i>    | Note 115  |
| § 3. <i>Of water in the state of vapour</i>                   | 116       |
| § 4. <i>Application of these facts to the uses of life</i>    | 117       |
| LECT. VII. <i>Examination of the properties of earths.</i>    |           |
| <i>Of earths in general</i>                                   | ibid      |
| <i>General distinction of the earths into three sorts</i>     | 118       |
| <i>General reflections upon the globe and its alterations</i> | 119       |
| Mineral Kingdom.  |           |
| <i>First class of minerals, Earths and Stones</i>             | 121       |
| <i>Divisions of the naturalists</i>                           | 122       |
| Sands, Earths, and Stones.                                    |           |
| Class 1. <i>Stones striking fire with steel</i>               | 123       |
| <i>Vitreous quartz stones</i>                                 | ibid      |
| Class 2. <i>Stones neither striking fire nor effervescent</i> | 125       |
| Class 3. <i>Effervescent earths or stones, or</i>             | 126       |
| <i>Calcareous substances</i>                                  | ibid      |
| <i>Volcanic productions.</i>                                  | 127       |
| LECT. VIII. <i>Chemical division of the earths and stones</i> | ibid      |
| Order 1. <i>Vitreous stones</i>                               | 128       |
| Genus 1. <i>Rock crystal</i>                                  | ibid      |
| Genus 2. <i>Precious vitreous stones</i>                      | 129       |
| <i>Analysis of gems</i>                                       | Note 130  |
| Order 2. <i>Quartz stones</i>                                 | 132       |
| LECT. IX. Order 3. <i>Argillaceous earths and stones</i>      | 136       |
| Order 4. <i>False clays</i>                                   | 138       |
| LECT. X. <i>Compound earths and stones</i>                    | 141       |
|   | Lapis     |



|  |   |   |   |                  |      |
|--|---|---|---|------------------|------|
| <i>Lapis lazuli</i>  | - | - | - | Note             | 144  |
| LECT. XI. <i>Mixed earths and stones</i>                         | - | - | - | -                | 146  |
| LECT. XII. <i>Earths and stones mixed by the fire</i>            | - | - | - | -                | 151  |
| <i>Volcanic products</i>   | - | - | - | Note             | ibid |
| Second Class of Minerals.  |   |   |   |                  |      |
| <i>Saline Substances</i>   | - | - | - | -                | 156  |
| <i>Of taste considered as a character of saline substances</i>   | - | - | - | -                | 157  |
| <i>Of solubility in water considered as a character, &amp;c.</i> | - | - | - | -                | 159  |
| <i>Of the tendency to combination considered, &amp;c.</i>        | - | - | - | -                | 160  |
| <i>Of incombustibility considered, &amp;c.</i>                   | - | - | - | -                | 161  |
| <i>Of the division of the mineral salts</i>                      | - | - | - | -                | 162  |
| <i>Simple or primitive saline substances</i>                     | - | - | - | -                | 162  |
| <i>Terra ponderosa</i>   | - | - | - | -                | 163  |
| <i>Magnesia</i>  | - | - | - | -                | 165  |
| LECT. XIII. <i>Quicklime</i>                                     | - | - | - | -                | 166  |
| <i>Alkaline salts</i>  | - | - | - | -                | 167  |
| <i>Vegetable fixed alkali</i>                                    | - | - | - | -                | 168  |
| <i>Mineral fixed alkali</i>                                      | - | - | - | -                | 171  |
| <i>Volatile alkali</i>   | - | - | - | -                | 172  |
| LECT. XIV. <i>Acids</i>  | - | - | - | -                | 175  |
| <i>Acid of chalk, or ærial acid</i>                              | - | - | - | -                | ibid |
| <i>Marine acid</i>   | - | - | - | -                | 179  |
| <i>Sparry acid</i>   | - | - | - | -                | 181  |
| LECT. XV. <i>Nitrous acid</i>                                    | - | - | - | -                | 183  |
| <i>Aqua regia</i>  | - | - | - | -                | 188  |
| LECT. XVI. <i>Vitriolic acid</i>                                 | - | - | - | -                | 191  |
| <i>Acid of borax, sedative salt</i>                              | - | - | - | -                | 196  |
| <i>Secondary, compound or neutral salts</i>                      | - | - | - | -                | 199  |
| <i>Neutral salts with base of fixed alkalis</i>                  | - | - | - | -                | 201  |
| <i>Vitriolated tartar</i>  | - | - | - | -                | ibid |
| LECT. XVII. <i>Glauber's salt</i>                                | - | - | - | -                | 206  |
| <i>Nitre</i>   | - | - | - | -                | 209  |
| <i>Mother-water.</i>   | - | - | - | Note             | 213  |
| LECT. XVIII. <i>Rhomboidal nitre</i>                             | - | - | - | -                | 219  |
| <i>Febrifugal salt of Sylvius</i>                                | - | - | - | -                | 221  |
| <i>Marine salt</i>   | - | - | - | -                | 223  |
| <i>Manufacture and purification.</i>                             | - | - | - | Note             | 226  |
| LECT. XIX. <i>Borax</i>  | - | - | - | -                | 232  |
| —— <i>Vegetable</i>  | - | - | - | -                | 236  |
| <i>Sparry tartar</i>   | - | - | - | -                | 237  |
| <i>Sparry soda</i>   | - | - | - | -                | 238  |
| <i>Æriated tartar</i>  | - | - | - | -                | ibid |
| —— <i>soda, or natrum</i>  | - | - | - | -                | 242  |
| LECT. XX. <i>Neutral salts, with base of volatile alkali</i>     | - | - | - | -                | 244  |
|  |   |   |   | <i>Vitriolic</i> |      |



|  |   |   |            |
|--|---|---|------------|
| <i>Vitriolic ammoniac</i>  | - | - | 244        |
| <i>Nitrous ammoniac</i>  | - | - | 246        |
| <i>Sal ammoniac</i>  | - | - | 247        |
| <i>Sedative sal ammoniac</i>   | - | - | 253        |
| <i>Sparry sal ammoniac</i>   | - | - | ibid       |
| <i>Aërated sal ammoniac</i>  | - | - | ibid       |
| <i>Neutral calcareous salts</i>  |   |   | 256        |
| <i>Vitriol of lime, selenite, gypsum</i>                                 |   | - | ibid       |
| LECT. XXI. <i>Calcareous nitre</i>                                       | - | - | 261        |
| <i>Calcareous marine salt</i>  | - | - | 263        |
| <i>Calcareous borax</i>  | - | - | 266        |
| <i>Sparry fluor, vitreous spar</i>                                       | - | - | 267        |
| <i>Calcareous spar</i>   | - | - | 270        |
| <i>Natural history of the calcareous substances</i>                      |   | - | 273        |
| <i>Shelly earths and stones</i>  | - | - | 274        |
| <i>Chemical properties of spar, and of calcareous matters in general</i> | - | - | 280        |
| LECT. XXII. <i>Neutral salts with base of magnesia</i>                   |   |   | 284        |
| <i>Vitriol of magnesia, Epsom salt</i>                                   |   | - | ibid       |
| <i>Nitrous magnesia</i>  |   | - | 287        |
| <i>Marine magnesia</i>   | - | - | 289        |
| <i>Borax with base of magnesia</i>                                       | - | - | 291        |
| <i>Sparry magnesia</i>   | - | - | ibid       |
| <i>Aërated magnesia</i>  | - | - | ibid       |
| LECT. XXIII. <i>Neutral salts with base of clay</i>                      |   | - | 297        |
| <i>Vitriol of clay, alum</i>   | - | - | ibid       |
| <i>Argillaceous nitre, nitrous alum</i>                                  |   | - | 306        |
| ----- <i>marine salt</i>   | - | - | ibid       |
| <i>Borax with base of clay</i>   | - | - | 307        |
| <i>Sparry clay</i>   | - | - | ibid       |
| <i>Aërated clay</i>  | - | - | ibid       |
| <i>Neutral salts with base of terra ponderosa</i>                        |   | - | 308        |
| <i>Heavy spar</i>  | - | - | ibid       |
| <i>Nitrous terra ponderosa</i>   | - | - | 312        |
| <i>Muriatic terra ponderosa</i>  |   | - | ibid       |
| <i>Sedative terra ponderosa</i>  | - | - | 313        |
| <i>Sparry terra ponderosa</i>  | - | - | ibid       |
| <i>Aërated terra ponderosa</i>   | - | - | ibid       |
| <i>Newly discovered acids</i>  |   |   | 314        |
| <i>Acid of sorrel</i>  |   |   |            |
| ----- <i>citrons</i>   |   |   |            |
| ----- <i>benzoine</i>  |   |   |            |
| ----- <i>amber</i>   |   |   |            |
| ----- <i>milk</i>  |   |   |            |
|  | - | - | Notes ibid |



|  |   |      |             |
|--|---|------|-------------|
| <i>Acid of ants</i>                                      | } |      |             |
| <i>— suet</i>  |   |      |             |
| <i>Acidum perlatum</i>                                   |   |      |             |
| <i>Acid of Prussian blue</i>                             |   |      | Notes 314   |
| LECT. XXIV. <i>Third class of minerals</i>               |   |      |             |
| <i>Combustible substances</i>                            |   |      | 315         |
| <i>The diamond</i>                                       |   |      | 319         |
| <i>Inflammable gas</i>                                   |   |      | 327         |
| LECT. XXV. <i>Sulphur</i>                                |   |      | 331         |
| LECT. XXVI. <i>Metallic substances</i>                   |   |      | 350         |
| <i>Of the physical properties of metallic substances</i> |   |      | 351         |
| <i>Of their chemical properties</i>                      |   |      | 354         |
| <i>Of their natural history</i>                          |   |      | 362         |
| <i>Of docimasia</i>                                      |   |      | 365         |
| <i>Use of the blow-pipe.</i>                             |   | Note | <i>ibid</i> |
| <i>Of metallurgy</i>                                     |   |      | 368         |
| <i>Distinction of the metallic substances</i>            |   |      | 370         |
| <i>Division of them</i>                                  |   |      | 371         |
| LECT. XXVII. <i>Arsenic</i>                              |   |      | <i>ibid</i> |
| <i>— acid of</i>   |   | Note | 380         |
| <i>Cobalt</i>  |   |      | 382         |
| LECT. XXVIII. <i>Bismuth</i>                             |   |      | 388         |
| <i>Nickel</i>  |   |      | 394         |
| <i>Manganese</i>   |   |      | 401         |
| <i>Its relation to inflammables</i>                      |   | Note | 404         |
| <i>Regulus of antimony</i>                               |   |      | 405         |
| <i>Butter of antimony</i>                                |   | Note | 412         |
| <i>Kermes mineral</i>                                    |   | Note | 421         |
| LECT. XXIX. XXX. <i>Zinc</i>                             |   |      | 429         |
| LECT. XXXI. XXXII. XXXIII. <i>Mercury</i>                |   |      | 443         |
| <i>Its congelation</i>                                   |   | Note | 444         |
| <i>Its solubility in the alkalis</i>                     |   | Note | 455         |
| <i>Calomel by precipitation</i>                          |   | Note | 456         |
| <i>Sweet mercury, calomel</i>                            |   | Note | 476         |
|  |   | Note | 478         |
| LECT. XXXIV. <i>Tin</i>                                  |   |      | 483         |
| <i>Aurum musivum</i>                                     |   | Note | 495         |
| LECT. XXXV. <i>Lead</i>                                  |   |      | 503         |
| <i>Liquor probatorius</i>                                |   | Note | 515         |
| <i>Uses of the calces of lead</i>                        |   | Note | 517         |
| <i>Granulation of lead</i>                               |   | Note | 520         |



## P R E F A C E.

CHEMISTRY has made so rapid a progress these some years, that with truth it may be said to be a science entirely new. The discovery of the Gases, which are of so much consequence in the chemical combinations and decompositions, is a copious source which is continually giving rise to some new discoveries: It has thrown new light on a great number of facts, which the sublime theory of Stahl was unable to explain, and which even seem to explode that theory: It has opened an immense field for the labours of chemists; and the experiments on this subject are so multiplied, that a very long time is necessary to acquire a complete knowledge of them by reading the academical dissertations; it is even necessary to repeat them frequently.

THIS discovery, which will be a grand epoch in the history of chemistry, has, by considerably promoting this beautiful science, produced an effect directly contrary with respect to the elementary works. All those which were written before this epoch, and even those which appeared a little after it, are now found far below the present state of our knowledge, and no longer to offer that collection of facts necessary to constitute true elements. It was to supply this kind of vacuum, and to present the students with the results of modern researches, that the late M. Bucket, my master and my friend, whose loss I shall always regret, some time before his death had projected the execution of a work on the Elements of Chemistry. Various occupations, and the long sickness he laboured under, prevented



ed him from putting that design in execution. He had the kindness to choose me for an associate in his undertaking, and I had even finished some pieces, when a premature death carried him off from the science which he cultivated with so great ardour and success. Thus left alone to a difficult and tedious task, I should certainly have relinquished my intentions of fulfilling it, if I had not felt its utility, or if I had only consulted my own inclinations. The necessity under which I found myself of collecting the facts recently discovered, and of repeating the modern experiments for the course which I taught every winter, induced me gradually to complete this undertaking; and the advantage which I thought might accrue to those who devote themselves to the study of chemistry, engaged me to publish it.

ALTHOUGH the Work which I present to the Public comprehends both Chemistry and Natural History, it will very soon be perceived that it is only the first of these two sciences which occupies the greatest part of it. I had it in view to give only preliminary and general notions on Natural History: 1. Because it has been beyond my ability to prosecute these two sciences to an equal extent. 2. Because there is a great number of Treatises upon Natural History, from which may be collected every thing that regards the details in which I am not employed. 3. Because it was my design simply to connect these two sciences, and to show how necessary the knowledge of Chemistry is to Natural History, and how much they elucidate each other.

THE order which I have followed in this Work, is that which M. Bucket had adopted. After treating of the general topics in Chemistry, which comprehend its definition, the examination of the object which it proposes, the means which it employs, its utility in life, and its history; I then proceed to Chemical Affinity. It is absolutely necessary that the laws and phenomena of this grand property be well understood, before we come to examine the reciprocal action of all the natural bodies on



on one another. Afterwards I proceed to examine the substances which hitherto have been looked upon as elements. Those substances do not seem to belong to any of the kingdoms of nature, or rather seem to belong to all of them equally. It appears, then, that we ought to make a separate class of them, and so follow the idea of some ancient philosophers who considered them as a fourth kingdom. Besides, the history of their properties is so important for rightly understanding the properties of the other productions of nature or of art, that it would be almost impossible to get acquainted with the nature of these last bodies, before considering those which have got the name of Elements. The details which comprehend the history of those elements, of the affinities and of the generalities, form a first part, or a kind of introduction to the whole work. They are followed by an explanation of the properties of the natural bodies, according to the known division into three kingdoms. I begin with the Minerals, because their analysis is better known, and their study is attended with less difficulty; and because the knowledge which we gain from their chemical properties is necessary for understanding the history of Vegetables and Animals. In their chemical nature, they are divided into three great classes; the earthy, saline, and combustible bodies. In the examination of the bodies of the first class, the earths and stones are presented successively, according to the order of the Naturalists, and according to their chemical qualities. I have given a summary of the division of the stones by M. Daubenton.

THE lithological method of this celebrated chemist is the most precise and perspicuous. With regard to the distinctions of the earthy and stony substances by their chemical qualities, those which I have followed are entirely due to M. Bucket; and they must be thought a sketch only, which will not be exact until the chemists shall have made a greater number of accurate analyses of these substances.



THE mineral saline substances are handled at great length. That article is one of those which furnish many new facts. I judged it necessary to insist on them, because they make up the most difficult, the most complicated, and at the same time the most important part in chemistry. The salts, to the number of 500, are methodically disposed according to their chemical properties. I have taken the liberty to give new names to a very great number of saline substances, which hitherto had received no name, but which it was necessary to distinguish properly; chiefly to the combinations of fixed air, which I, after M. Bucket and Lavoisier, have called Acid of Chalk, with the different alkalis. I was the more induced to do this, that the difference between the pure and caustic alkalis, and the same salts neutralized by fixed air, had not, at least to be intelligible to beginners, as yet been sufficiently explained. With respect to the rest, a part of these new names had been given them by M. Bucket. I cannot too much recommend to students repeatedly to read the history of the saline substances. By my own experience I am convinced, that upon a complete acquaintance with the properties of these substances, depends all the knowledge which can be acquired of chemistry. I have too frequently seen persons, otherwise very expert in chemical and pharmaceutical preparations, ignorant of the different combinations of the neutral salts, not to make it necessary for me to warn beginners on this head. Several substances, heretofore regarded as earthy, are arranged among the salts; such as the calcareous stones and spars, the vitreous spars, and the heavy spars. And though they have saline characters in a small degree only, they are, however, true neutral salts, formed by the union of the acids with lime or terra ponderosa, as the experiments of Messrs Black, Scheele, and Bergman, have shown. The mineral combustible bodies are divided into five genera: the diamond, inflammable gas, sulphur, the metallic substances, and the bitumens. At first



first sight there seems to be a great difference among these various substances, particularly betwixt the diamond and the rest; but as, when heated, they all possess the property of burning with flame by the contact of air, and as their nature is singularly changed in this operation, I thought it necessary to unite them under the same class, as M. Bucket did in his last course. These substances are too useful in the arts and in medicine, not to require a full examination of all their properties; and with this view I have made of them one of the most extensive divisions in this Work. The metallic substances alone constitute more than the fourth part.

IN the history of each of the substances which belong to the mineral kingdom, I have begun with examining their physical properties; from thence I pass to their natural history; and after having insisted in a special manner on their chemical properties, I give a short account of their uses both in medicine and in the arts. With regard to the denomination of each mineral, I have followed the idea of M. Daubenton, who designs each of them by the name of *sort*; and thinks that we ought to give the name of *species* to organic bodies only, the individuals of which are perpetuated by generation.

IT may be proper to observe, that I have taken the greatest care to mention the facts recently discovered concerning combustible substances. As it was the end of my undertaking, to unite under one point of view the researches of all the modern chemists which have come to my knowledge, it necessarily made a part of my plan to offer the most complete summary possible. But I ought to take notice, that I have made choice only of the facts that are necessary to form the elements of chemical knowledge. From the great number of those which I have mentioned, I thought it necessary to point out the sources from whence I collected them, as well to give every one his due, as to put students on the method of consulting every author, and of acquiring



the most extensive knowledge on any particular subject. For this end, what belongs to me, either in the history of the saline matters, or in that of the combustible substances, I have described with accuracy, which I had occasion in particular to observe, in order that the experiments I mention may be repeated, and their reality evinced.

THE history of the mineral waters is placed at the end of this kingdom, as we cannot comprehend the principles of these fluids, unless we be familiarly acquainted with the properties of the saline and combustible substances. This article is of considerable length; and contains under several paragraphs the history of the waters, the enumeration of the bodies which they can hold dissolved, their methodical distribution into several classes; the way of examining them by their physical properties, by the tests, by distillation, and evaporation; and lastly, the means of proving their analysis by the preparation of the artificial mineral water. The paragraph which comprehends the analysis by the tests, is much longer than the others. It is designed to prove, that these substances may be more useful than we have supposed for determining the principles of the waters, when we employ them pure and in a great quantity.

THE plan which I have laid down in the Vegetable Kingdom is a little different from that after which the minerals are described. The chemistry of vegetables is but little advanced. To make as much progress in it as in the mineral kingdom requires immense and difficult researches, which can be the effects of time alone. Besides, all we know of the chemistry of vegetables is very well described in a great many works; and in particular in that of M. Bucket, which is intitled, *An introduction to the Study of the Bodies of the Vegetable kingdom*, Paris 1773. I have been therefore under the necessity of being more brief on this head, though I am certain my plan contains all that is known even



even the most modern, on vegetable analysis. It was impossible for me to enter into the botanic detail; and I have supplied its place, by giving a short account of the external and internal structure, and of the functions or physiology, of vegetables. In this last account I have not forgot the elegant experiments of M. Ingenhouz, by which this physician has discovered, that the leaves of plants, exposed to the rays of the sun, are a source, from which a stream of pure air, destined to renew the atmosphere, perpetually issues.

THE chemical properties of vegetables, which are described after the botanic philosophy, may be considered under three points of view relatively to the state in which these bodies are found. We either examine the fluids or solids of plants, after having separated them by mechanical means, and without their having suffered any alteration; or we submit them to the action of fire, which alters and deprives them of their nature; or lastly, they undergo, of themselves, when exposed to a warm temperature, an intestine motion, called Fermentation. I have represented the properties of vegetables under these three different heads.

IN the first, I have treated of the principles of which these bodies are composed, obtained by a simple, mechanical, and even natural separation. I have taken a successive view of the vegetable juices, the extracts of different kinds, the essential acid and sweet salts, manna, the gums and the mucilages, the gross and essential oils, camphor, spiritus rector, the balsams, the resins, the gum-resins, elastic gum, the feculent parts, the farina, and lastly the colouring parts. Among these substances I have particularly enlarged on some essential salts, on the acid of sugar, on spiritus rector, on elastic gum, and on the farinas. The importance of these objects, and the researches of several modern chemists, who have made valuable discoveries on each of them, require them to be more fully explained than the other substances which are more generally known.



The analysis of vegetables by the naked fire deserves to be examined with care. Though this agent alters and deprives them of their nature; it may, however, be employed with success, to establish some differences between the principles of plants, and to determine their nature. In order to explain this idea, I have enumerated the phenomena of the distillation of vegetables in the retort; and I have particularly insisted on the varieties of these phenomena. I have observed, that in this operation, it is essential to collect the gaseous vapours in a pneumatological apparatus. The charry residuum, which this species of slow combustion leaves, is a body of a singular nature, and which it would be of very great importance to understand. To rouse the attention of chemists, I have given all we know of the properties of charcoal: and lastly, I have finished the history of the action of fire on vegetables, by the examination of the residuum of their incinerated charcoals, and of the fixed salts, as potashes and soda, which are extracted from them.

THE spontaneous changes which the juices of plants may undergo when exposed to a warm and moist air, constitute the third state in which we ought to consider these substances. Although it might have been possible to discover more than three kinds of fermentation, after Boerhaave, I have acknowledged three only. After having described the conditions and the phenomena of the spirituous fermentation, and mentioned the different vegetable substances proper to undergo this intestine motion, I have examined wine. The two principles of this product of art, which it is of great importance to know, are Ardent Spirits and Tartar. These substances, which are of such advantage to chemistry and the arts, are treated of at great length, as also the combinations which they are capable of forming. The acetous fermentation, and vinegar which is produced from it, hold the second rank in the history of the spontaneous changes  
of



of vegetables. In the article, comprehending this acid, I have given as full an explanation, as its utility and numerous properties required. Lastly, the putrid fermentation of vegetables is the bound where nature stops, and by which it destroys the texture of these organic substances. The vegetable juices once brought to this state, lose their properties, and approach to the simple and elementary bodies from which they have their origin. With the phenomena of this alteration I have ended the history of the vegetable kingdom.

THE order which I have observed in the examination of Animals, nearly approaches to that I have observed in regard to vegetables. Although the analysis of animal matters be still less advanced than that of the products of plants, I cannot help saying, that the labours to which I have directed myself concerning the animal kingdom, appeared to me more satisfactory than the former; whether it was that every thing which belongs to this kingdom was capable of interesting a physician particularly; or that the collection of facts which I have made respecting animals seemed to me more striking, and more adapted to excite curiosity, and inspire a love of study. All that concerns the organic substances in my work, may be referred either to their natural history, to their physiology, or to the chemical analysis of their juices.

WITHOUT entering into details on the genera and species, my sole intention has been to give beginners a view of the methods thought of by naturalists of classing and distinguishing animals. In order to guide them in the outset of the study, I thought it would be useful to explain to them, in a short and clear manner, the principles on which these artificial divisions are founded, by explaining, in a few words, the structure of the parts which serve for characters; and afterwards, by representing to them, in tables, the most approved methods, according to which each class of animals is disposed in families, in sections,  
and



and in genera. Although these systems of classification are far from nature, which knows and produces individuals only, they are necessary, however, to facilitate the study, by representing, in the form of characters easy to be retained, the structure of the external parts of animals, or by sparing much labour and aiding the memory.

THE Physiology comes after the Natural History. It is discussed in a few words; for here I have made mention only of the most striking facts which are presented in the functions of animals, considered from man down to the polype. I have not taken notice of all the systems which have been proposed to explain the cause of their mechanism, because I think them more fit to retard than to promote the progress of the science. I observe nothing but real facts. It appeared to me, that by uniting the structure of the viscera of each class of animals, their functions were rather more easily understood. With respect to the chemical examination of the fluid, the soft, and the solid parts of these organized bodies, I have enlarged more upon it; because that is the newest part, in general the least known by physiologists and physicians, and at the same time the most capable of favouring the progress of medicine. The blood, the milk, the fat, the bile and biliary calculi, the saliva and pancreatic juice, the seminal fluid, the urine and urinary calculi, the fluid of perspiration; all these are examined in detail. I have been particularly studious to determine the nature of those matters that are peculiar to this part, and to which nothing is found analogous in vegetables; such as the lymph, the fibrous part, the fusible salts, and the singular substance which makes the base of the phosphoric glass furnished by these salts. These details led me to write the history of phosphorus, and of the acid of phosphorus. The last I have prosecuted in all its known combinations. The analysis of the soft and white parts, of the flesh and of the bones, immediately follows that of their fluids: the



the discoveries made by the moderns concerning the calcareous phosphoric salt, which makes the base of the bones, and their influence on the history of the diseases of these organs, constitute one of the newest and most interesting objects in the chemistry of animals.

LAST of all, I briefly run over the different animal products which are of use in medicine and in the arts: I show their known chemical properties: And after having pointed out the chemical analogies subsisting between the vegetable and animal substances, I consider the putrefaction of the last as the final alteration that they undergo; which, by destroying their texture, makes them pass to the state of simple bodies, and enter the class of those which belong to the inorganic kingdom\*.

I HAVE divided the whole work into seventy lectures, in respect to the course which I have every winter. This division could not be methodical; it is founded on the time which the experiments demand: it can therefore be of no other advantage than that of following my lectures, and it has no relation to the order established in the work itself.

I HAVE only one word more to say on the manner in which each article is treated. We may distinguish in it the facts and the theory. The first are related with the greatest precision, and in the fewest words possible: it was the only means of uniting a great number of them in a little space. As to the theory, my

\* This short account suffices to show of what extension the plan of the animal kingdom was susceptible. What I offer just now, is to be regarded only as a slight sketch of a more extensive work that I propose to publish, which will be designed specially for the students of medicine. It will contain the natural history of animals, a comparative physiology, and the chemical properties of their humours, considered in the different periods of life, in the state of health and of disease; and lastly, the history of the products of animals, employed as medicines: so that it will comprehend what is most important to be known in the animal kingdom.



my object throughout the whole has been to compare the doctrine of Stahl with the pneumatic doctrine of several modern chemists. I declare, that I neither reject the one nor adopt the other: I assume the simple part of an historian. In a science, wholly consisting of facts, it is only facts which merit the confidence of those who devote themselves to its study. In several places, however, I have proposed a new theory: but I must take notice, that I give it as an hypothesis only, proper for reconciling some facts; that I am not in any way attached to it; and I would much rather have found out a new fact, than have established the most brilliant theory. The importance of this last, however well founded, and however probable it may appear, is always below the merit of the discoveries; it is destined to be overturned by a new one, which in its turn must yield to those that follow. However, as it is absolutely impossible to pass them over, I have thought proper to mention those which at present divide the chemists, but always with the reserve and diffidence which they ought to inspire.

DISSER-



DISSERTATION  
ON THE  
CHEMICAL AFFINITIES †.

WE cannot advance a step in the science of nature, without observing the effects of the admirable force, established between all the bodies of nature, by which they are reciprocally attached, and, to use the expression, by which they search for and endeavour to approach one another. On this grand law depend the phenomena of the universe, which the philosopher contemplates, and which the unlearned man cannot behold without admiration.

This force, so essential to the harmony of the world, prevails between the smallest as well as between the greatest bodies; but its laws are very different according to the mass, the volume, and the distance of the substances over which it exerts its power. Without searching after the effects of it among the planetary bodies, whose distance and motions it regulates, let us observe them upon those of our own globe, and endeavour to discover its laws.

Natural

† As the very important article of the chemical affinities, which makes the subject of the second lecture, appeared to me, after it was printed, a little too short, and not so clear as I had wished, I thought it necessary to supply the deficiency, by inserting, at the beginning of the work, a dissertation, which at first I had intended for another occasion. This dissertation will explain the second lecture, which was only an extract from it; and I thought it would not be misplaced, if inserted at the beginning of the Elements of Chemistry. I ought also to remark beforehand, that it will consist of facts only, and that it contains the grandest and most beautiful phenomena which this science presents.



Natural philosophy informs us, that two solid bodies of the same nature, when put in contact, adhere with a force proportionate to the extent and polish of the surface with which they touch each other. Thus two planes of ice, two sections of a metallic sphere slightly flipt on one another, become as if they were glued together, and often require an effort very considerable to separate them. This effect is still much more striking in two drops of the same fluid, as oil, water, or mercury: But at a certain distance from one another, and upon an even surface, a reciprocal attraction is observed; they advance toward one another, and mix, so as to make only one globule. This force is the cause of all the phenomena observed in chemistry: it is of the greatest importance, then, to study all its circumstances.

The most part of chemists have distinguished it by the name of Affinity, or of Relation. M. Bergman has called it Attraction; though it seems to differ from the Newtonian Attraction, as will be proved hereafter. It may take place between bodies of a similar nature, or between those of a different nature. Let us observe it then under this double point of view. When two bodies of the same nature, as two globules of mercury, put at a certain distance from one another, tend to unite by virtue of this force, and actually do unite; there results from that union a globule of a greater bulk, but which has not changed its nature. In this instance, then, the force of affinity acts only on the physical or apparent qualities. It unites molecules of the same nature which were separated: it increases the volume, by confounding the masses, and forms a whole of several distinct parts. We give it the name of Affinity of Aggregation, in order to distinguish it from that affinity which prevails between bodies of a different nature. It gives rise to an aggregate. Its character is to change the apparent or physical properties, without influencing the chemical qualities in a sensible manner.



The aggregate is only a coherent body, whose molecules adhere to one another by virtue of their force of aggregation. It is necessary to mark the difference of it from the simple collection or heap, which is only a mass of parts of the same nature separated from one another, but possessing no cohesion; as well as from mixture, whose character consists in being composed of different bodies mixed with one another, without coherence. A familiar example will render the thing very clear:—Some flowers of sulphur which do not cohere, and which can be separated by the least effort, form a collection or mass over which the force of aggregation exercises no power: Mix with them another mass, as that of nitre in powder, and you obtain a confused mixture: By the aid of fusion, you make the affinity of aggregation act; then the molecules, or integrant parts of sulphur, drawn towards one another by means of their state of liquefaction, approach, unite, and mix, adhering so to one another, that after they are cooled they constitute a solid body of a single mass, and become a true aggregate.

The force or the affinity of aggregation has different degrees, which are measured by the attachment which the component parts of an aggregate body show to one another respectively. It is the effort necessary to separate the parts of an aggregate which serves to calculate the degree of adhesion, or of the affinity of aggregation which subsists between them. We distinguish four genera of aggregates, under which may be comprised all the bodies of nature.

1. The hard or solid aggregate; in which the force, which unites the component parts, is very considerable, and which requires a violent effort to be deprived of its aggregation. There are many species or degrees in this genus, from the hardness of precious stones or of rock crystal, down to the solidity of the most tender wood. Its character is to form a mass, the integrant parts of which cannot be sensibly moved without being broken or separated.



2. The soft aggregate; whose coherent parts, by means of a slight effort, can slip on one another, and change their situation. The force which unites the parts of a soft body is less than that which makes the parts of a solid aggregate cohere; so less force is required to destroy the aggregation.

3. The fluid aggregate. Its component parts are very slightly united, the least force being capable not only of making them roll and slide on one another, but even of separating and dividing them into globules.

4. Lastly, the aeriform aggregate, whose component molecules are too fine to be perceived, as the air of the atmosphere, and in which the affinity of aggregation prevails in the smallest possible degree.

To speak properly, these four genera of aggregation are only different degrees of the same force, but which we have thought necessary to distinguish with care, because their varied state singularly influences the chemical phenomena. It may be proved in the most satisfactory manner, that in reality they are only degrees of one another, since many bodies may be found successively in all the four states. Water, in the form of ice, is a solid aggregate: When exposed to a colder temperature, it flows, and acquires a kind of softness, which it is seen to assume in the same manner when exposed to a gentle heat\*. All the world knows its fluid state; and naturalists have calculated the power of expansibility which it possesses, when exposed to the state of vapour, or in the aeriform aggregation. It is the same with regard to the metals, the oils, the concrete oils, wax, and other substances.

In proportion to our advancement in the knowledge of the laws of affinity, it will be perceived how important

\* This expression in the original is not very elegant; and seems, we think, not to convey fully the author's meaning: on which account it may not be improper to hint, that it requires some salt to produce this effect; which addition is known to convert the ice into a state of fluidity, and at the same time to render the mixture considerably colder.



tant it is to distinguish and ascertain exactly these four genera of aggregation: It is chiefly from the actual state of the force of aggregation, with respect to the true affinity, which we shall soon examine, that it becomes useful to fix the ideas on this subject.

As these two forces, which seem to depend on the same cause or to have the same principle, are, however, always opposite to one another in the chemical phenomena; for we may infer from facts, which we shall mention afterwards, that they are even in the *inverse ratio* of one another; therefore, when the chemist wishes to have the one act, it is indispensably necessary that the other be weakened, or even that it be rendered of no effect. Now, about what we have been hitherto speaking, it is almost always such that it has the intention of diminishing, and it is also such that art may modify according to pleasure.

In order to destroy or weaken the affinity of aggregation, we have only to present to an aggregate a more active external force than that which draws its molecules to one another; and besides, it is perceived that this force ought always to be proportioned to the adhesion of the parts of the bodies whose aggregation we wish to destroy. Such is the grand rule which we ought always to observe in the preparatory operations, the only purpose of which is to annihilate the affinity of aggregation. Pulverisation, porphyrisation, the action of lime, of the file, of the scissars, all destroy the cohesion of solids, and separate their parts. Filtration and evaporation produce the same effect on fluids. We shall say nothing of these different operations, which belong solely to practice; we just mention them here, to show the relation they have to theory.

If art hold out numberless ways to oppose the force of aggregation, and even to destroy it entirely, the same art also furnishes means to restore and to make this force act with all the energy of which it is capable. All the



manipulations which it teaches us for this purpose consist in putting the bodies, whose aggregation it is proposed to restore, into such a state of division and fluidity, that their molecules, endowed with the motion which is proper to them, may attract, search for, and adhere to one another, with surfaces the most convenient; so that by their union they constitute an aggregate, whose regular figure and cohesion often equal those which nature gives them, and frequently even surpass it. On this occasion it may be remarked, that all the aggregate bodies may be distinguished under two states, that of irregular or regular aggregates. Nature has given every body the property of appearing in one or the other of these two states; and art, always the imitator and often the rival of nature, may produce at its pleasure an irregular or regular aggregate. All the bodies that are susceptible of passing through the different states of aggregation, which we have more fully distinguished above, particularly the salts and the metals, according to the manner in which the artist modifies their passage from fluidity to solidity, may appear in the form of a shapeless mass, or in that of a body with regular facets; in a word, in that of a crystal. To obtain the first state, it is only necessary to keep the molecules of the bodies, put into a state of fluidity, very near one another, and to make their liquefaction cease suddenly; so that all of them may touch at once, that the affinity of aggregation may act upon all at the same time, and that they may adhere in a solid mass. On the contrary, crystallization requires that we keep the parts of the bodies which we wish to crystallize, separate from each other, in order that they may be balanced some time before they unite, and in order that they may mutually present the surfaces which have the greatest relation.

After these brief details, we see, that crystallization is entirely owing to the affinity of aggregation, which it even serves to illustrate. It is in this point of  
view



view that we have considered it hitherto : we reserve a more full explanation of the phenomena of this property for different places of the elements.

When two bodies of a different nature endeavour to unite, they combine by virtue of a force different from that which we have been examining, and to which we give the name of affinity of *composition* or *combination*. This species of affinity, still more important to be known than the first, takes place in all the operations of chemistry : it is it alone which can explain to the chemist the phenomena that continually occur to him. This force has been at all times known ; but that attention, which it deserves, has only been paid it, since it has been perceived, that it influences the practice as much as it does the theory of the science in which we are employed. It is chiefly the affinity of composition which ought to guide the artist who labours to advance chemistry, and the philosopher who collects and compares facts. This ought to be the object of both ; and it may be advanced, that he who is well acquainted with the affinities possesses the grandest and most sublime knowledge in chemistry.

Strongly convinced of this truth, we are next to endeavour to make a faithful collection of all the facts that relate to it, by laying aside the hypotheses which have been given of the cause of affinity.

Observation, the mother of chemistry as of all the sciences of facts, has taught, that the affinity of composition presents constant and invariable phenomena, which we may regard as the laws established by nature, and which nature seems to hide only from the eyes of those who cannot follow and study it. These laws, founded on a great number of positive experiments, may be reduced to ten, which we shall proceed to explain.



*First LAW of AFFINITY of COMPOSITION.*

*The affinity of composition prevails only among bodies of a different nature.*

THIS law is invariable, and never admits of exception. It is absolutely necessary that two bodies be of a different nature, in order to combine, and form a compound. Indeed, if two bodies of a similar nature unite with one another, from that union an aggregate can only result, whose mass, volume, and dimensions, will be equally augmented; but which shall not have lost any of its essential properties. This will be the effect of the force of aggregation only, which will keep them united, as we have already observed in speaking of that kind of affinity. Hence we easily perceive the difference between the affinity of aggregation and the affinity of composition.

This law is so true and so constant, that the affinity of composition is never stronger, than when the bodies, between which it takes place, differ most in their nature from one another. It is thus that the acid salts, opposite in their properties to the alkalis, combine with them so intimately, and form compounds so perfect. The same opposition of properties is found between the alkalis and sulphur, the same salts and oil, the acids and the metals, spirit of wine and water, all of them substances which have a great tendency to unite with one another and constitute very intimate compounds. It is so much the more necessary that this grand law of the affinity of composition be well understood, that several chemists, at the head of whom we ought to place Stahl, have endeavoured to prove, that bodies never combine but by virtue of a certain relation or of a certain resemblance between their properties; a principle which cannot subsist, as soon as we conceive the extent which we give to this first law. By reading what the greatest chemists have said of this matter, we perceive, that the relations which they endeavour to find between the substances  
which



which have a great tendency to unite, are always very far-fetched; and that it is possible, with pains, to find the like in bodies the most opposite. Besides, it is easy to see, that those men of genius, by devoting themselves to these researches, have had in view the intention of rendering clearer the theory of the affinities; and those who know how difficult it is to establish systems in human knowledge, will ever have grateful feelings for them: their works are always useful, for the adduction of facts, and the connection which they show between them; but truth, to which we owe our first homage, constrains us to avow our ignorance of the cause of this grand phenomenon which we admit to be a law.

*Second LAW of the AFFINITY of COMPOSITION.*

*The affinity of composition takes place between bodies in the point of contact only.*

In this second law we find a sure character quite as constant and as invariable as in the first, to distinguish the affinity of composition from the Newtonian attraction, with which several natural philosophers have chosen to confound it. Before we demonstrate this grand difference, let us establish the basis of facts, by which it is supported. Chemists can never combine two bodies, except by putting them in contact. The more this contact is multiplied, the more the surfaces by which it takes place are themselves multiplied, the stronger is the affinity, and the more complete the combination. It cannot take place at the smallest distance: it then yields its place to the affinity of aggregation, which by this character appears to approach attraction, and to be only a modification of it.

Some facts seem to contradict this law; but those are only deceitful in appearance. Thus, for example, we know that two bodies, which have the quality of being very easily converted into the state of gas, as the marine acid and volatile caustic alkali, kept at a certain distance from one another in open vessels, approach,



attract each other, and at last touch and unite. But the force which makes them thus attract each other, is only the affinity of aggregation; since, before being in contact with one another, they exactly preserve their nature, and lose it to form a compound, known by the name of *sal ammoniac*, only when they are near enough to touch and to mix.

Now this law strikingly distinguishes the affinity of combination from the Newtonian attraction, since this last takes place only at very great distances, and even changes into a quite opposite force, that of repulsion, when the great bodies on which it acts are placed at a certain distance from one another. There is then a very great difference between these two forces, and they ought not to be confounded, as several modern philosophers seem willing to do.

*Third LAW of the AFFINITY of COMPOSITION.*

*The affinity of composition takes place between small bodies only.*

THAT this law may be well understood, it is quite necessary to distinguish the chemical from the physical subjects. The last are bodies whose external properties, as the mass, the volume, the surface, the extent, the figure, may be subjected to calculation, and estimated according to the evidence of the senses. They are aggregates, whose qualities the philosopher can observe and compare. The chemical subjects, on the contrary, are substances which have lost their aggregation, and consequently no longer present to the senses the physical properties of the aggregates. These are molecules so subtle and so fine, that their extent cannot be measured, nor their figure and volume known. It is only when bodies have been reduced to this degree of fineness by the different previous operations, which have been more fully insisted on already, that they yield to the affinity of combination; and the chemist can combine them only when he presents them to each other in  
this



this state. It seems that this force resides in bodies infinitely small; that it is a property which, to say so, belongs only to the last elements of bodies. However, we see, even by this law, in what it differs from attraction, which subsists only between great masses. We are sensible how difficult it would be to find out the cause of it; and we cannot help regarding as insufficient this theory, otherwise so seducing to the imagination, which makes the affinity of combination consist in attraction, modified by the figure and the surface, the ratio of which seems indeed necessarily to influence the smallest masses, though it be absolutely of no effect on the planetary bodies, which are kept and rolled in their orbits by the second of these forces.

*Fourth LAW of the AFFINITY of COMPOSITION.*

*The affinity of composition may take place among several bodies.*

THIS is one of the laws of affinity, in which we are the least advanced, and with which we are as yet but little acquainted. A great deal is known of affinities and combinations between two bodies. Much less is known of those between three bodies, and we have scarce any example of four bodies which can remain united to one another with an equal affinity. There are few substances, except the metals, which exhibit similar combinations, and which can be united in the number of two, three, or four. It is probable that compounds exist of more than four bodies, of six or eight for example; but as yet art has thrown no light on that point. The reason of the small progress in the study of this law of affinity will be clearly shown, when we treat of the sixth law. The affinity subsisting between several bodies, gets its name from their number; as, the affinity of two, three, or four bodies, and so on.

The advancement of chemistry in modern times, the multiplicity of the researches to which men are everywhere devoted, and the scrupulous exactness in them



which at present prevails, make us hope that in time we will arrive at the knowledge of these affinities, which we shall call Complicated.

*Fifth* LAW of the AFFINITY of COMPOSITION.

*That the affinity of composition may act betwixt two bodies, it is necessary that one of them be fluid.*

It is a long time since this law was known by the Chemists, and expressed by the axiom, *Corpora non agunt nisi soluta*. The longest and most exact observation has taught us, that two solid substances cannot combine with each other. For this reason, bodies which have the greatest tendency cannot unite, unless the one be in a fluid form. The more fluid the substances are which the chemist is to combine, and consequently the less aggregate force they have, the more easily and the more intimately are they united. Hence no combination takes place with more activity, and produces a more perfect compound, than two gases put in contact, as the marine acid and volatile alkaline gases. But it is not necessary that two bodies which we want to unite be both fluid; it is enough that one of them is so. In their union there appears a phenomenon which Chemists call Solution; that is, the attenuation, the division, and entire separation of the solid body, put in contact with the fluid. To understand this phenomenon thoroughly, we must conceive, that the affinity of combination existing between two substances, the one liquid, and the other solid, as the vitriolic acid and a bit of chalk, is stronger than the affinity of aggregation which unites the molecules of the chalk, and makes a solid body of it. Now, as by the third law this affinity takes place only between small bodies, it is quite necessary that the chalk should lose its aggregation, and be reduced into very small molecules, in order to enable it to unite with the vitriolic acid and form selenite. In every solution the ancient Chemists have distinguished the solvent, and the body to be dissolved; the first was the



the fluid body, the second the solid. This distinction, which supposes a force in the fluid superior to that which exists in the solid aggregate, cannot be admitted by the modern chemists, who observe with M. Gellert, that the action on the part of both the bodies in solution is equal; and that, in the fore-cited example, the vitriolic acid would not destroy the aggregation of the chalk, did not this last on its part tend to combine with the vitriolic acid, and attract it as much as the acid does the chalk. This word *solvent*, therefore, at present given to the fluids, is very little chemical, and only conveys the idea of a mechanical operation; it would therefore be very proper to proscribe it. As unluckily the use of it has prevailed, we must remember, that when in chemistry it is said that one body dissolves another, we only express the physical state of fluidity of the first body, and do not ascribe to it an activity or a greater energy than to the solid, which possesses the same or even a superior force; since the tendency which it has to combine with the fluid is such, that it overcomes its aggregation, and destroys it entirely.

This false idea of solution, which has prevailed even to these latter times, has undoubtedly arisen from the mechanical theory, which some chemist natural philosophers have given to this operation of nature. That theory, which is found in every page of Lemery's chemistry, consists in viewing the solvents, an acid for instance, as an assemblage of points or very acute needles; and the compound to be dissolved, as an infinity of pores, which receive the points of the acid that separate the parts of the body to be dissolved, detach and reduce them into such a state of division, that it seems to disappear and escape from the sight. It is sufficient to mention this opinion in order to refute it, and to make it appear how different it is from the accuracy which at present prevails in inquiries into the physical sciences.



*Sixth LAW of the AFFINITY of COMPOSITION.*

*The affinity of composition is in the inverse ratio of the affinity of aggregation.*

THE mention of this law teaches us, that the weaker the aggregation, the stronger the affinity of combination; and, on the contrary, the stronger the aggregation, the weaker the affinity of combination. No doubt can remain of this assertion, after what has been said in treating of each of the preceding laws. These two forces appear in fact to be opposite, and mutually to counterbalance one another. In fact, the affinity of aggregation resists the combination of bodies: thus, those whose aggregation is very strong, have very little tendency to combination; whilst the substances which have but a very small aggregation, have at the same time a very strong power of combination. The gases, for example, which, of all the substances that are known, have the weakest aggregation, have at the same time the strongest tendency to combination, and unite with the greatest number of bodies with the utmost readiness.

Lastly, to prove farther and to extend this great law, we have no hesitation in believing, that as there are many cases in which aggregation opposes itself to combination, as in all solid bodies, the metals, sulphur, the very hard and massy saline crystals, which cannot be united with the acids, alkalis, and water, in their state of solidity; so there are several cases in which the affinity of composition not only opposes, but even destroys, the force of aggregation. Thus when we bring two fluids near to each other which have a strong affinity, and which are apt to be volatilized into a vapour or gas, as marine acid and volatile alkali, each of them exhales a great quantity very quickly, and allows a visible fume to escape, which is nothing but the same substance, whose aggregation is broken by the force of combination, and which approaches and comes in contact with that which is near to it, in order to unite with



with it. This phenomenon takes place when we put marine acid and volatile caustic alkali into two glasses at the side of each other.

*Seventh LAW of the AFFINITY of COMPOSITION.*

*When two or several bodies unite by the affinity of composition, their temperature changes in the instant of their union.*

THIS phenomenon appears to us so constant in all combinations effected by art, that we think proper to consider it as one of the laws of the affinity of composition. The temperature of bodies which combine may be altered in two ways; they produce either heat or cold. The first occurs more frequently than the last: but as some cold is produced in several synthetical operations, we have expressed this phenomenon by the change of temperature in general.

It may be objected, that there are certain solutions or flow combinations, in which the change of temperature is not apparent. We beg of those who shall be led to make this objection, to plunge a comparative thermometer into such solutions, and they will be very soon convinced that their temperature is always different, and almost always hotter than that of the atmosphere. This phenomenon also appears to depend on the change of the aggregation of the substances combined, on their passage from a solid to a fluid state, or from a fluid to a solid, according to the accurate observation of M. Baumé, whom we shall speak of elsewhere. But as this change of aggregation itself depends on the action of the affinity of combination, it is evident that it is this affinity which changes the temperature as well as the aggregation.

We will mention, when we come to treat of heat and its nature, that the variations of heat which take place in the act of combination, are owing to the different movements that affect the molecules of the bodies which unite with one another.

*Eighth*



*Eighth LAW of the AFFINITY of COMPOSITION.*

*Two or more bodies which have united by the affinity of composition, form a substance whose properties are new, and very different from those which any of the substances had before their union.*

THIS law it is of the utmost importance to establish clearly, because some of the greatest chemists of this age have entertained ideas of the properties of compounds, which do not appear to us to correspond with the greatest number of facts, and which flatly contradict that which we offer here as one of the principal and most remarkable phenomena of the affinity of composition.

Stahl and his followers, whose genius in other respects rendered such important services to chemistry, have advanced, that compounds always partake of the properties of the bodies which enter into their composition, and that they have mean qualities between those of their constituent parts. They have even carried this idea so far as to believe, that it is possible, from the properties of a compound substance, to discover the nature of those which enter into its composition. Thus Stahl has announced, that the salts are formed of water and earth, because he thought that he found in them all the mean properties of these two substances. As we reserve the discussion of this grand doctrine until we come to treat of the salts in general, we shall mention nothing on this head. We shall only observe, that the chemists who have followed Stahl in this opinion, have not been more successful in their proofs than he has been; and that the mean properties which they endeavour to find in compounds, have for the most part but a very distant relation to those of their component parts; a circumstance which we shall demonstrate by the most remarkable examples, chosen and adduced by Stahl himself. We cannot help even declaring, that it is the difficulty which he seems to have had in the establishment of this idea in his works, and the constraint which reigns in his explanations, that  
have



have induced M. Bucquet and myself to observe this theory attentively, and have led us to adopt another entirely opposite to it. In fact, to demonstrate rigorously the existence of the law of which we are treating, it will be sufficient to produce examples of compositions whose properties are entirely new, and do not in the least resemble those of their component parts. Now the history of all the chemical combinations confirms what we are advancing; there is none of them which does not serve to establish the truth which we lay down. We are going to select some striking proofs in well-known compositions; and we mean to show, 1. That bodies that are united, lose the properties which each of them had in their separate state: 2. That they acquire new ones that are quite different. In order to be more methodical, let us fix on some properties, the variations of which may be perceptible.

The *taste* is frequently very considerable in two distinct bodies, which, when they are combined, they possess in a very weak degree, if we compare it to that of the former state. Vitriolated tartar, which results from the combination of two powerful caustics, the oil of vitriol, and pure alkali of tartar, has a very bitter taste only; which certainly cannot be said to be a mean between the causticity of these two salts. On the other hand, two bodies which have none or but little taste, acquire a very strong one in their union. Mercury, and the marine acid, given separately in the dose of a few grains in a glass of water, are not capable of injuring the animal œconomy; whilst the same dose of corrosive sublimate, formed by the combination of these two substances, and administered in the same vehicle, is a most violent poison, and of the most corrosive taste.

The affinity of composition has as singular an influence on the *form*. Frequently two bodies, which are not capable of crystalizing singly, assume a regular form when united; as marine-acid gas, and volatile alkaline gas; which, in the instant of their union,  
form



form crystals of sal ammoniac. At other times the form is changed, and simply modified; as in the union of certain neutral salts with one another, of sulphur with the metals, and in the metallic alloys, which, according to M. l'Abbe Mongez, present crystallisations a little different from those of the pure metals. Lastly, bodies which are very susceptible of crystallizing by themselves, when united with other bodies, lose this property; as the metals united with air, some of them combined with acids, &c.

The same is the case as to the *consistence*. Almost never is it the same in a compound as in the principles which compose it. Thus two fluids united with one another immediately produce a solid, as in the combination of oil of tartar with oil of vitrol; and from the union of two solids a fluid often results, as in the case of the neutral salts combined with ice, and in the mixture of the amalgam of lead with that of bismuth.

The *colour* is very often altered in combinations. Sometimes it is destroyed, as in the union of the coloured marine acid with a metal; this acid becomes white. For the most part, two bodies which had no colour assume in their union one more or less deep; as iron and copper, in most of the acids; lead, mercury, and almost all the metals, united with pure air, and in the state of metallic calces.

Frequently the most odorous bodies form compounds without *smell*; as the marine acid and volatile alkaline gases, the odour of which is strong and suffocating; but which give rise to a neutral salt, almost without odour, called *Sal Ammoniac*. Sometimes there results from the union of two inodorous bodies a compound of a very strong odour: thus sulphur and fixed alkali, neither of which has almost any odour, form liver of sulphur, which is very fetid.

We may make the same observation on *fusibility*.—Two substances that separately are infusible, or very difficult of fusion, become very fusible when they are united.



united. The union of sulphur and the metals furnishes very striking examples of this assertion. The earthy substances also confirm it.

The facts cited are but a few of those which might be adduced: There are many more which the details will present, and of which we can easily make the application.

*Ninth LAW of the AFFINITY of COMPOSITION.*

*The affinity of composition is measured by the difficulty which is found, in destroying the combination formed betwixt two or more bodies.*

CHEMISTS are acquainted with the means of separating bodies united with one another, whatever affinity or adherence there may be between such bodies; but these means are more or less easy, more or less complicated. In observing the chemical phenomena which take place here, it is constantly remarked, that the more perfect the compounds are, the more difficult it is to separate their principles, and destroy their composition. The degrees of difficulty which are felt in this separation, will serve to ascertain the degree of adherence or affinity which subsists between such and such bodies. We insist the more on this law, that those who begin to devote themselves to the practice of chemical operations, might not be mistaken about the difference of affinity that prevails between the different bodies which they combine together. The activity with which certain substances unite, naturally ought to convince us that their adhesion is very considerable. However, long experience shows that this readiness to combine, far from indicating a perfect combination, very often deceives, and gives rise to a very imperfect compound. To determine therefore, in an exact manner, the degree of affinity by which bodies unite and remain united, it is necessary to consider the difficulty which we experience in separating them, or decomposing



posing their union. The examination of the tenth and last law will elucidate this point.

*Tenth LAW of the AFFINITY of COMPOSITION.*

*All bodies have not the same degree of affinity to each other ; and by the aid of observation, we can determine the rank or degree of this force, which subsists between the different bodies of nature.*

ALL natural substances have not an equal tendency to unite with one another. Some of them absolutely refuse to combine, or at least art cannot bring them into union, as iron and mercury, although we cannot be certain that they have no affinity to one another ; others can only be combined with great difficulty, and by the aid of a very long time.

But what is of the greatest importance in this law of affinity is, that as this force is not equal in all bodies, after the knowledge of this phenomenon, we may effect in an instant the separation of two bodies whose union formed a compound. In this decomposition the greatest art of the chemist consists, and by it he exhibits miracles to the eyes of men who are not accustomed to behold them. To understand well what this decomposition is, let us suppose that two bodies adhere to one another, with a force equal to four ; as for instance, an acid and a metal. To this compound let us present a third body, which has an affinity to the acid equal to five or to six, as an alkali. What should happen ? The alkali, which endeavours to unite with the acid by a force superior to that which combines the acid with the metal, must separate this last body to unite with the acid. This is what happens ; then the metal is separated, and a new combination is formed between the acid and alkali. This operation is called *precipitation*.

The substance which falls to the bottom of the vessel in which this operation is performed, is called the *precipitate*. Four kinds of precipitates are distinguished. There



There is a *true precipitate*, if the matter separated from the compound by that which is added to it occupy the inferior part of the mixture. When selenite, or the combination of the vitriolic acid with lime, is decomposed by means of pure vegetable fixed alkali, which has more affinity with the acid than lime has, this last is separated, and falling to the bottom of the water forms a true precipitate.

There is a *false precipitate*, when the new combination formed by the precipitant, or substance added, and one of the two bodies of the compound which is decomposed, falls to the bottom of the liquor, and the body separated remains in solution. In decomposing the solution of mercury by the nitrous acid, by the addition of the marine, with which this metallic substance has more affinity than with the nitrous, the new combination of mercury and the marine acid falls to the bottom of the mixture, and there forms a false precipitate, above which is found the nitrous acid dissolved in water. This difference, as we shall mention in another place, depends entirely on the different solubility of the substances. It is easy to perceive an error in the vocabulary of some chemists in this second example of precipitates. In fact, those who have given this name to the substance separated from the compound by the precipitant, ought not to look upon the new combination which happens in this case as a precipitate: But though we should forbear calling any thing a precipitate but the substance separated by the precipitant, this name would still be a subject to deceive us, since there are many cases in which the substance separated, far from being precipitated, is raised and volatilized. Thus, when the combination of the marine acid and volatile alkali, called *sal ammoniac*, is decomposed by lime, which has more affinity with the acid than the alkali has, this last is dissipated in vapours, and there is no appearance of any precipitate in the mixture. In order to avoid this confusion of nomenclature, it would be



necessary to substitute the name of *decomposition*, in place of precipitation; but as custom has prevailed, we shall retain the names adopted, guarding against the errors to which they have given rise.

In order that the precipitates we are speaking of may take place, it is necessary that they be made in a liquor. This is called precipitation by the *humid way*, to distinguish it from that which is brought about by fire or in the *dry way*, and which is effected either by fusion or by distillation; operations to be explained in the sequel.

Modern chemists are acquainted with two other kinds of precipitates also; the distinction of which is much more just and more useful than that of the preceding. These are the *pure* and *impure* precipitates. The first comprehends all bodies separated from compounds, which enjoy all their properties, and have not been altered, either in the compounds themselves of which they made a part, or by the act of decomposition. There is a very great number of these precipitates, but still more of the impure. That the precipitates may be very pure, it is necessary that they should not have suffered any alteration, before decomposition, by the action of the bodies with which they were united, and that they have no affinity to the substance which is to separate or precipitate them. For example, when we pour some spirit of wine into a solution of vitriolated tartar in water, as the spirit of wine has more affinity to the water than the salt has, it separates the salt, which is precipitated pure; because it has not been altered by the water, and because it suffers no alteration from the spirit of wine, with which it does not unite.

But if two bodies are reciprocally altered by their union, as the combinations of the acids with the metals, then the third, as an alkaline salt, which is employed to decompose them, will separate the metal in a state very different from that which is natural to it, and will occasion an impure precipitate. The same thing happens, if  
the



the precipitant has any tendency to unite with the precipitate, as in the example already cited, of a metallic solution decomposed by an alkali; part of this salt combines with the separated metal, and renders it impure. These two causes of the impurity of precipitates, for the most part, are found united; whence it happens that the surest means of immediately distinguishing a pure from an impure precipitate, notwithstanding the absence of the essential properties which ought to characterise it, is to add a good deal more of the precipitant body than is necessary to destroy the combination of the body to be decomposed: the excess of the precipitant combines with the precipitate, completely dissolves it, and makes it disappear. Taking a solution of copper in nitrous acid, and pouring into it some volatile alkali, the copper is precipitated in the form of flocci, of a very deep clear blue. The colour of this precipitate, very different from the metallic brilliancy of the copper, clearly shows it to be an impure precipitate. Of this we are farther assured by adding some more volatile alkali. This salt redissolves the blue flocci, the liquor gradually becomes transparent and homogeneous, and assumes a very beautiful deep blue colour, which indicates the combination of the calx of copper with the volatile alkali.

The complete knowledge of these impure precipitates, which are much more frequent than the pure, is to be ascribed to the researches of M. Bayen, on the decomposition of the solutions of mercury by means of the alkalis, and of the state of the mercury precipitated in these operations.

It is easy to comprehend the theory of the decomposition of two bodies by means of a third which is put in contact with the bodies combined. As there seems to be a choice between one of the principles of the compound and the body which is added, on which the separation of the two first depends, M. Bergman has adopted a name very proper for giving an exact



idea of these decompositions. He has called them *elective attractions*.

It is not so easy for beginners to conceive what passes in the more complicated phenomena, which chemists have called *double affinity*, and which M. Bergman calls *double attraction*. It often happens that a compound of two bodies cannot be destroyed by a third and a fourth body employed separately, whilst, if we employ the compound of the third and the fourth, in order to put it in contact with the first compound, both the two are mutually decomposed. Let us make this evident by an example. Vitriolated tartar, or the combination of the vitriolic acid with the vegetable fixed alkali, cannot be decomposed either by lime or by the nitrous acid, in the cold, separately. However, if we pour into a solution of vitriolated tartar, the neutral salt formed by the union of the nitrous acid with lime or calcareous nitre, these two compounds are mutually decomposed. The nitrous acid attracts the vegetable fixed alkali of the vitriolated tartar to form nitre, whilst the vitriolic acid unites with the lime to form selenite. What is the scope of this singular affinity? We suppose it may be thus conceived. The vitriolic acid, united with the vegetable fixed alkali, cannot be separated either by the nitrous-acid cold, nor by lime; because it has more affinity with that acid, than either of these two other substances have with it. But when we present to vitriolated tartar a compound of nitrous acid and lime, at the very time this acid seeks to unite with the alkali of the vitriolated tartar, the vitriolic acid endeavours to combine with the lime: so that we may say the decomposition of the vitriolated tartar, begun by the nitrous acid, is completed by the lime. To elucidate this double affinity still farther, let us suppose that the vitriolic acid adheres to the fixed alkali with a force equal to 8; the nitrous acid, which endeavours to unite with the alkali with a less force, which we shall compare to 6, could not alone decompose the vitriolated



vitriolated tartar, if, on the other hand, the tendency of the lime to unite with the vitriolic acid, a tendency which we shall make equal to 4, did not with the preceding make up a force equal to 10; which must prevail over that of 8, with which the vitriolic acid adheres to the vegetable fixed alkali. Such is the manner in which it appears to us that a satisfactory reason may be given for the double decomposition.

It is only very lately that chemists paid attention to the double affinities, and it is very necessary that they should all be known. Those who are employed in chemical researches, perceive every moment these kinds of decompositions, that take place in mixtures, which they had not suspected to be susceptible of them. Several opportunities will offer in the history of the saline substances, in which we shall remark some of these affinities, observed by Messrs Bergman, Cornette, and ourselves.

We shall not leave the explanation of the tenth and last law of the affinity of composition, without taking notice of the ingenious method first made use of by a French chemist, of exhibiting at first sight the most constant phenomena of precipitation. Geoffroy the elder, having paid more attention than had been done before him, to the greater or lesser relations which take place between the different bodies, and to the decompositions that they occasion, in the year 1718 contrived to represent them in a table; in which he arranged, in the order of their affinities, the bodies between which he had observed them take place. Here we only announce this beautiful idea, which we shall explain in a great number of places of this work, according as opportunity shall offer. Geoffroy has given this table as an essay only, to which he himself has properly predicted there would be much to add. Many chemists have adopted and extended his plan. Rouelle the elder made several corrections upon his table, and added several columns to it. M. de Limbourg, physi-



cian at Spa, who, conjointly with M. Sage of Geneva, in an excellent dissertation on affinities, gained the premium proposed in the year 1758 by the academy of Rouen, has constructed a more extensive one. M. Gellert, in his metallurgical chemistry, has also given a new one. But nobody has advanced this part more than M. Bergman, professor of chemistry at Upsal, to whom this science is indebted for so many works. This celebrated chemist, on the plan of M. Baumé, distinguishes the affinities that take place by the humid from those by the dry way. He has constructed two tables at full length; in which he has represented the relations that exist between almost all the natural bodies. To the same learned man we owe likewise a very ingenious table; in which, by a particular disposition of chemical characters, he has found the means of representing what passes in the attractions or double affinities.

After having presented the principal phenomena of the affinity of combination, and after having established the laws which this force seems to obey, we observe that there are some cases in which these laws appear to be susceptible of certain variations. We shall not enter here into the detail of the facts on which this assertion is founded; because we will take care to remark them as often as opportunity shall present itself. We shall only say, that these appearances of inconsistency in the laws of affinity are owing entirely to some circumstances, which are capable of modifying them; such as the quantity of the substances, the temperature of the atmosphere, motion or rest, solution by fire or water, that is by the humid or dry way, the state of aggregation peculiar to each body, &c. M. Bergman has considered all these circumstances with particular attention, and has explained the different variations they may produce in the laws of affinity. From all the facts he has collected on this subject, he concludes, that all these variations ought to be regarded merely as exceptions,



exceptions, and that they are incapable of affecting the doctrine of affinities.

This is the opinion also which ought to be entertained of two kinds of affinities admitted by some authors:—The one is the affinity of intermixture; the other, reciprocal affinity. By the *first*, they understand that affinity which makes a body naturally incapable of uniting with another become capable of it, after being combined with a third, which serves as an intermedium. For example, oil cannot unite with water; but when the oil is combined with a salt, there arises a soap soluble in water by the intercession of the saline substance. It is not the saline substance which renders the soap soluble, for it has no longer all the characters of a salt in the compound; it is to the new properties of the soap that we must refer its solubility in water. This phenomenon entirely belongs to the eighth law of affinity, which establishes, that compounds have properties quite new, and entirely different from those of their component parts. *Reciprocal affinity* takes place when a compound of two bodies is decomposed by a third, and when the principle separated has the property of decomposing in its turn the new combination, so that there seems to be a kind of reciprocity in the effects. Thus, for example, we know that the vitriolic acid has more affinity with the fixed alkali than the nitrous acid has, and that it decomposes the salt formed of the nitrous acid and this alkali. Nevertheless, the nitrous acid in its turn can separate the vitriolic from the alkali, since, by heating vitriolated tartar with nitrous acid, some nitre is produced. This kind of affinity, admitted by M. Baumé, is owing altogether to a circumstance which occasions some change in the ordinary laws of this force; that is, heat. It is necessary that the nitrous acid be hot, in order to decompose the vitriolated tartar; and the nitre, which is formed in the operation, is itself decomposed by the vitriolic acid as soon as the



mixture cools\*. It ought not then to be regarded as a law, since it is only very rare. Besides, the other facts by which M. Baumé supports this affinity, as the decomposition of sal ammoniac by means of chalk, and that of the calcareous marine salt by the concrete volatile alkali, belong to the double affinities, as we shall demonstrate in speaking of these salts.

It only remains to finish what has been said of affinity, by relating, in a few words, the opinions of some learned men about the cause of this force. The first who inquired into it have ascribed it, either to the similar form of the elementary molecules, or to the physical configuration of the parts, or, lastly, to a secret relation of their intimate composition. Their first ideas necessarily agreed with the mechanical explanations which were given to the physics of the schools before this excellent science was freed from the darkness that overspread it.

The most of the modern chemists who have inquired into the cause of affinity, have found a relation between this force and the Newtonian attraction. Persuaded that nature is simple and uniform, they thought that this property of reciprocal union depended on that of attraction which exists between all bodies. They compared the small chemical bodies, between which the affinity takes place, with the great masses that compose the universe; and if the very small molecules of different bodies approach one another in order to combine, it is because they incline or gravitate towards one another. In following this opinion, and modifying it in a particular manner, some persons have supposed, that the affinity was in the ratio of the weight, and that the most weighty body was that which possessed this force in the greatest degree. This hypothesis, however, which

\* Fuming nitrous acid decomposes vitriolated tartar in the cold. According to M. Cornette, fuming spirit of salt does the same thing: But M. Bergman has observed with reason, that the fuming odorous acids, which he calls phlogisticated, have different affinities from the same simple acids, not fuming, or dephlogisticated.



which sometimes agrees with facts, as is observed in several acids, cannot apply to the greatest part of the experiments of decomposition, in particular respecting the metallic substances. In short, some chemists have been persuaded, that there is so great a relation between affinity and attraction, that they imagined it would be possible to measure and calculate this last, according to the adherence subsisting between bodies. M. de Morveau, whose opinion is well calculated to lead that of others, has made some experiments with the view of proving the assertion I have just advanced. These experiments consisted in applying to the surface of mercury, metallic plates of an equal diameter, suspended from the beam of a balance, whose other extremity carried a basin. He put weights into this last, until their weight was able to raise the metallic lamina from off the mercury; and by comparative trials on different metals, he found that their adherence to the mercury was very different, and nearly followed the degree of affinity which subsisted among these bodies: That is to say, that gold adhered with the greatest force of all to the mercury, and required the greatest weight to separate it; whilst cobalt, which cannot unite with this fluid metal, was very easily raised from its surface, to which it scarcely shows any adherence. Let us observe, that possibly there may be a subject of error in these experiments: for the well polished metallic laminæ, which are applied to the mercury, must combine with it by their inferior surface, and the portion of amalgam thus formed, necessarily becoming more considerable, as the metal unites more easily with the mercury, it is not possible to suppose that it is this combination that adds to the weight of the plate. This objection seemed to us strong enough to merit the attention of the celebrated chemist who has the praise of these ingenious experiments.

From what has been said on the opinions of philosophers respecting the cause of the force of affinity, it follows,



lows, that this cause is not known; and that it does not appear to be the same with attraction, since its laws are quite different. We shall be convinced of this truth by comparing the knowledge which has been acquired about the Newtonian attraction, with that which we begin to have of affinity. The first takes place between enormous masses only; the second between small bodies, and is altogether without power over those whose volume is considerable. The attraction of bodies placed at a certain distance from one another, appears to be changed into repulsion: Affinity, on the contrary, is never stronger than when bodies are in the point of contact. Attraction exists at very great distances: Affinity is not perceptible between distant bodies, and really takes place only when the molecules are in contact. We have already given part of this comparison in the examination of the laws of the chemical force which we are speaking of; and after all these considerations, we think that there are very remarkable differences between these two natural phenomena, to induce the learned to distinguish them from one another.

If we are permitted to give our opinion on this subject, we think that it is as impossible to discover the cause of the chemical affinity in the actual state of our knowledge, as it has been hitherto to find out that of the Newtonian attraction, magnetism, &c. and that it is much more useful to the science to continue without intermission to examine the phenomena which it presents, and to increase its laws, than to be devoted to speculations which can be only hazardous; and which, for the most part, unluckily are deceitful.

E L E.



ELEMENTARY LECTURES  
O N  
C H E M I S T R Y  
A N D  
N A T U R A L H I S T O R Y.

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LECTURE I.

*General Heads on CHEMISTRY.*

AUTHORS have differed in the opinion they give of chemistry. Some even seem to have regarded it as an art, although it is in reality a science. Boerhaave has represented it as a chain of processes and manipulations. We define it a science, which teaches us the knowledge of the intimate and reciprocal action of all the bodies in nature upon one another. In order to understand this definition well, it is necessary to consider the object of chemistry, the means it employs, the end it proposes, and its utility in life.

The object of chemistry comprehends all natural productions; for there is none of them, the nature and properties of which chemistry cannot propose to investigate. This science, then, is immense, since it has those bounds only which nature has prescribed to itself.

The means which it employs to accomplish its ends, notwithstanding the varieties which appear at first sight, may all be reduced to the methods of analysis and synthesis.

Analysis, called also Decomposition, is properly the separating and the artificial disuniting of the simple parts, of which a compound body is formed. This has been  
falsely



falsely looked upon as the grand assistant of chemistry; because, 1. It can be employed in inquiring into the properties of compound bodies only, and not at all in discovering those of simple bodies; the number of which is perhaps much more considerable than it has been as yet admitted to be. 2. Although it may be very useful in demonstrating the nature of compound substances, yet it may often lead us into error, as has been felt since chemistry made such rapid progress.

With the view of establishing this important truth, we distinguish analysis into two kinds; *the true or the simple*, and *the false or the complicated*.

By the simple or true, we mean that analysis by which we obtain the principles of bodies, without their having undergone any alteration, and such as they existed in the compound. The character of this last kind consists in this, that we can reproduce the analyzed compound, in the same state in which it existed before its analysis, by again uniting the principles obtained by decomposition. Cinnabar, for example, is a compound of sulphur and mercury. These two substances are separated by means which will be explained in the sequel; and by recombining them we form cinnabar, perfectly alike to that which had been analyzed. The false or the complicated analysis, on the contrary, gives different products, such as did not exist in the same state in the body which was analyzed. Hence we know that the principles which are furnished by this analysis, can no more form by their re-union the substance which was decomposed. All the bodies that belong to the organic substances can be analyzed in this way only; and we cannot conclude from hence, that the principles so obtained existed with the properties that they present in the bodies from which they have been separated. On this account some persons have reproached the chemists that their experiments alter bodies, and that the result of them must always be uncertain. This reproach would be well founded, if chemists were not aware, that they ought



ought not to rely on this second kind of analysis, and if this science did not furnish them other means of knowing the properties of the substances which they examine.

Synthesis, or combination, is the second assistant of chemistry. It consists in uniting the natural bodies with one another, and in inquiring into the properties of such combinations. It altogether imitates nature herself, of which it is the rival. Sometimes it produces bodies of which she cannot furnish an example. It acts by virtue of a force and a tendency which exists between natural bodies; and art only endeavours to favour or put it in play, by presenting those bodies to one another in a state proper for the exertion of this force. We can never be deceived by this method as we may be by analysis: it is at least as frequent: and it is of importance to observe upon this point, that perhaps chemistry should be designed rather by the name of the Science of Synthesis or Combination, than by that of Analysis, which seems, however, to have been almost universally adopted.

From this view of the two assistants of chemistry, three truths arise, which we present as chemical axioms.

1. The true analysis is very rarely employed, its use being confined to the treatment of some of the bodies in the mineral kingdom.
2. Synthesis is the most frequent and most useful of the means known in chemistry.
3. Analysis and synthesis are often employed together in performing chemical operations: and we will frequently observe, that in many experiments, we effect combinations, which hitherto we have regarded as decompositions.

Chemistry has for its object the knowledge of the intimate nature of bodies and their action upon one another. Under this view, it is necessary to distinguish it from physics, properly so called, whose business is merely to observe masses and their apparent properties.

The bodies which come under the operations of the chemist, may not improperly be reckoned the source of



the naturalist; and we may say with truth, *Ubi definit physicus, ibi incipit chemicus*.

The utility of chemistry is so sensibly felt at present, that the science is universally cultivated, and it would be needless to dwell upon it. The physical sciences, and particularly natural history and medicine, reap the most considerable advantages from it. The former, whose immensity might frighten the most studious and the most laborious, cannot dispense with the want of chemical knowledge: mineralogy is quite under the direction of chemistry; and in vain would we attempt to make any progress without uniting these two sciences. The best mineralogists are sensible of this important truth; and we are so convinced of it, that we think these two branches of physic ought to be united, as Haller has joined anatomy to physiology. With this view we mention the facts that mineralogy presents to us in our lectures; which, one with another, are as complete as possible; and endeavour to class the minerals after the chemical characters. We are very far from imagining, as we will show in the following lectures, that the works on chemistry are full enough to admit of giving a complete system of mineralogy; but we see with pleasure, that every year furnishes enough of new knowledge, to flatter us with hopes, that one day the efforts of the chemists will be crowned with that success to which their discoveries ought to conduct them.

Medicine derives no less advantage from chemistry than natural history does, whatever some physicians who deny its utility may say to the contrary. We live no more in that age, when some enthusiasts, proud of the miracles which they performed by their art, pretend to confine the practice of medicine to the lights of chemistry alone, and attributed diseases to acids, which it was to necessary neutralize, or to effervescences, which it was necessary to suppress. The chemical physicians of our age, more wise than those of the last, know,  
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after the example of the great Stahl, how to check the sway of chemistry, and to confine it within just bounds; but they cannot but believe that this science gives great light into the nature and properties of the animal humours, into their alterations in diseases, into the alimentary substances, medicinal and poisonous, with the prescription of formulas, &c. They imagine, that the chemical operations going on in animals, if imitated, as M. Bucquet and Rouellè have done, and as some chemists, though few, unluckily still do, will afford that light which chemistry only can furnish: and they are justly astonished every day to find practitioners, who oppose a science with which they are not sufficiently acquainted to judge of its utility, and declaim against those who cultivate it.

Chemistry extends to all the arts which do not belong to geometry. Of these Pharmacy, which, in consequence of the favours that it confers on mankind, claims gratitude from all men, and which, in consequence of the knowledge requisite for practising it, takes in most of the sciences, has such a connection with chemistry, that its operations are absolutely ruled by it; and it is impossible to be skilful in pharmacy without being a chemist.

In the mineral kingdom, the arts of brick-making, of pottery, of manufacturing the fine Dutch ware, porcelain, of lime-making, of glass-making, of forming nitre, of making salt, of assaying, of metallurgy, of gilding, of refining, of enamelling: in the vegetable kingdom, the arts of perfuming, of making starch, of making paper, of baking, of wine dressing, of brewing, of distilling, of rectifying and compounding, of making vinegar, of making soap; and in the animal kingdom, cookery, tanning, tawing, currying, making of pastes, all belong entirely to chemistry. We may with reason suppose, that were chemists to imitate the practice which workmen follow, they might bring to perfection those arts of which ignorance has retarded the  
pro-



progress: and we regret to see many more advances among those nations where the science has not been always cultivated with an equal success. We ought not to be ignorant of the outlines of the history of a science, to the study of which we wish to devote ourselves. That history, in describing the table of facts, fixes the epochs of the discoveries, guards against the errors into which those who have preceded us have fallen, and shows us the road that is necessary to keep in order to make advances in it. However, as it would be dangerous to dwell upon details that perhaps would confound our ideas of the object which we propose, we here present a brief account of the history necessary to be known, without mentioning particulars, which we find treated at great length in several well executed works.

In the history of chemistry we may fix six grand epochs.

#### *The FIRST EPOCH.*

##### *Origin of Chemistry among the Egyptians.*

THE origin of chemistry is as obscure as that of arts and sciences in general. We look upon Tubal Cain, who lived before the deluge, to have been the first chemist; but working upon metals was his only employment. He appears to be the person meant by Vulcan in the ancient fable.

We ought to assign the true origin of this science to the ancient Egyptians. The first person among them mentioned as a chemist is named, according to Abbe Lenglet du Fresnoy, *Thot*, or *Athotis*, surnamed *Hermes* or *Mercury*. He was son to Mezraim or Osiris, and stepson of Cham. He became king of Thebes. Siphoeas, the second king of Egypt, was likewise a philosopher. He lived 800 years after Athotis, and 1900 years before Christ. The Greeks have called him *Hermes*, or *Mercury Trismegistus*. Then he is the second Mercury. We regard him as the inventor of physics. He



He has written 42 books upon philosophy ; in which he does not seem to treat of chemistry, although this science has been called after him the *Philosophy of Hermes*. In Egypt there was a temple dedicated to Vulcan, and sacred to alchemy.

The Israelites learnt chemistry from the Egyptians. Moses is ranked among the chemists, only because he dissolved the golden calf, by means, as we suspect, of liver of sulphur.

Democrites of Abdera, who lived about 500 years before Christ, travelled into Egypt, Chaldea, Persia, and other countries : There, as we imagine, he learnt chemistry. Though born of a father who was rich enough to entertain at his house Xerxes and all his suite, he returned very poor into his own country, and was taken notice of by his brother Damassus. He retired into a garden before the walls of the city, where he employed himself in examining plants and precious stones. Cicero assures us, that in order not to be diverted by external objects, he scorched his eyes, by fixing them on the rays of the sun reflected from a very finely polished plate of copper. This fact is denied by Plutarch. Pliny looks upon the science of Democrites as wonderful.

Some authors rank even Cleopatra among the chemists, because she could dissolve pearls. They suppose that this art, which was known to all the Egyptian priests, had been constantly practised by those nations, until, according to the account of Suidas, Diocletian formed the design of burning their books of chemistry, with the view of reducing them more easily under subjection.

#### SECOND EPOCH.

##### *Chemistry among the Arabians.*

AFTER a succession of many ages, during which it is impossible to trace the progress of chemistry amidst the revolutions that empires have undergone, we find marks



of this science among the Arabians, who cultivated it with success. During the dynasty of Achemides or Abassides, the sciences, which had been forgotten for a long time, were revived.

Almanzor, the second calif, studied astronomy. Harum Raschid, the fifth calif, and cotemporary with Charlemagne, caused several Greek books which related to chemistry to be translated. In the ninth century, Gibber of Thus in Chorasan, a province of Persia, wrote three treatises upon chemistry, in which even now we find very good things. His best work is intitled *Summa perfectionis magisterii*.

In the tenth century, Rhases, physician to the hospital at Bagdat, first applied chemistry to medicine. His merit and his knowledge raised him to the office of grand vizier; but his debaucheries deprived him of that high preferment.

### THIRD EPOCH.

*Chemistry passes from the east to the west by means of the Crusades. The reign of Alchemy.*

THE art of making gold, a species of folly which entered the heads of chemists, made a noise for a long time, according to the authors who have written its history; but it was carried to its greatest height from the eleventh to the sixteenth century. The facts in chemistry which the Egyptians found, and the Greeks collected, and the Arabs applied to medicine, centered among the four nations who, during the Crusades, transported themselves into the east, viz. the Germans, the English, the French, and the Italians; and every one of these nations was very soon filled with men who searched for the philosopher's stone. As the immense labours to which they devoted themselves have contributed to the advancement of chemistry, we ought to know the particular men that were most distinguished among them.

In the thirteenth century, Albert le Grand, a Dominican



nican of Cologne, and consequently of Ratisbon, passed for a magician, and wrote a book full of alchemical processes.

Roger Bacon, born anno 1214, near Ilcester, in Somersetshire, studied at Oxford. He came to Paris to learn mathematics and the art of medicine. To him we ascribe several inventions, any of them sufficient to immortalise his fame ; such as the camera obscura, the telescope, and gun-powder : he had a moving chariot, a machine for flying, and a head which spoke. He was a Cordelier, and was named the *wonderful Doctor*. He was accused of magic, and was imprisoned by his brethren. At last he retired into a house at Oxford, where he laboured, it is said, at alchemy. Borrichius saw this house, which still bore his name.

Arnould de Villeneuve, who was born at Languedoc anno 1245, and died anno 1310, studied medicine at Paris for 30 years. He commented on the school of Salem. The alchemists regard him as one of their great masters. Anno 1664, Borrichius saw an alchemist in Languedoc who was descended of him.

Fourteenth century. Raymond Lully, who was born at Majorca in 1235, came to Paris in 1281, and joined himself to Arnould de Villeneuve, with whom he became famous. Robert Constantine says, that he saw one of the nobles of the Rose, who was astonished at the gold which he made in the Tower of London in the reign of Edward the Fifth, anno 1312-13. He wrote some books in alchemy, in which we find some facts respecting acids and metals.

In the fifteenth century, Basil Valentin, a benedictine of Enfort in Germany, was instructed in medicine and natural history. He finished a work on antimony, to which he gives the pompous name of *Currus triumphalis antimonii*, and which has been commented upon by Kerkringius.

Isaac les Hollandois, father and son, persons little known, composed works that are praised by Boerhaave ;



haave; in which it appears that they were acquainted with aquafortis and aqua regia.

#### FOURTH EPOCH.

*Universal medicine; pharmaceutical chemistry; alchemy opposed. From the sixteenth to the middle of the seventeenth century.*

ALTHOUGH the alchemists had not succeeded, and though the ruin of their fortune and reputation was enough to have disgusted those who inclined to apply to these researches, nevertheless we see in the sixteenth century a prodigious number of them upheld and supported by the enthusiasm of a Swiss physician, Paracelsus, who was born near Zurich in 1493. This precipitate inquirer pretended that an universal remedy existed. He added some chemical medicines to those of the Galenian pharmacy. He cured several diseases, which the ordinary remedies very weakly opposed, and especially the venereal disease, by means of mercurial preparations. He did wonders: but elated with his success, which led him far beyond the limits that he ought to have prescribed to himself, he publicly burnt the books of the Greek physicians; and, in the midst of his triumphs, died in an alehouse at Saltzbourg about the age of 48, promising almost immortality by the use of his secrets.

This foolish behaviour, extravagant as it was, encouraged the ardour of the alchemists. All of them who flattered themselves with having discovered the universal medicine, qualified themselves with the new title of *adepts*.

Alchemy was in this state at the beginning of the seventeenth century.

1. Les freres de la Rose Croix, a kind of society formed in Germany, nothing of which was known even in France but the title, and of which the members remained ignorant. These pretended freres said they possessed the secrets of transmutation, of science, and

of



of universal medicine, and of the knowledge of secret things.

2. Alexander Sethon, or Sidon, a cosmopolite, who it is said performed transmutation in Holland before a certain Hessian. The latter revealed it to Vanderlinden, grandfather to a physician of that name, who has the praise of a college of medicine.

3. A Philalete, called Thomas de Vagan, born in England *anno* 1612. He went to America, where Starkey saw him, and received gold from him. Boyle corresponded with him. It was that very adept who, in travelling to France, gave his powder of projection to Helvetius.

In the mean time, the success which Paracelsus had with chemical medicines, engaged several physicians in the pursuit of this object; and we see useful works published upon the art of preparing them. Such are those of Grollius, of Schroder, of Zwelfer, of Glafer, of Tachenius, of Lemery, and likewise the pharmacopœias published by the principal faculties of medicine. In this epoch also Glauber made a discovery of signal service in chemistry. He examined the residuum of operations, which had always been disregarded before his time, and which was called *caput mortuum*, or *terra damnata*. Some chemists, who forwarded the science after Paracelsus, were not entirely cured of the ideas which he had fixed in them: Such as Cassius, who is famous for a precipitate of gold.

Chevalier Digby, who believed in the sympathetic action of medicines; Libavius, who has given name to a preparation of tin; Van Helmont, famous for his opinions in medicine, as well as for the light in which he considers chemistry; and Borrichius, a Danish physician and chemist, who first discovered and divulged the inflammation of oils with nitrous acid, and deserves great praise for the legacy which he made of his library and laboratory, in favour of the students of medicine without fortune. At that time alchemy had



two celebrated men to oppose, who attacked it with success: The one was the famous Pere Kircher, a Jesuit, who published a great and magnificent work, which has the title of *Mundus subterraneus*.

#### FIFTH EPOCH.

*Rise and progress of philosophical chemistry, from the middle of the seventeenth to the middle of the eighteenth century.*

HITHERTO chemistry had not been treated in a philosophical manner. The chemical arts had only been described, formulas of medicine published, and the nature of metals examined, with the idea of making gold, or of discovering a universal remedy. A great number of facts were collected, but as yet no person had put them together. Towards the middle of the seventeenth century, Jacques Barner, physician to the king of Poland, arranged the principal facts then known, and joined them with reasonings in his philosophical chemistry. Bohnius also, professor at Leipzig, wrote a treatise on rational chemistry. Isachin Beccher of Spire, a man of the most profound genius, physician to the electors of Mayence and Bavaria, advanced much farther than these two learned men. In his sublime work, intitled *Physica subterranea*, he united all the knowledge which had been acquired in chemistry, and described with an astonishing sagacity all the phenomena of this science. He even predicted a great part of the discoveries made at this day; such as that of the gaseous substances, and the possibility of reducing the bones of animals into a transparent glass. He had for a commentator J. Ernest Stahl, a famous physician, whose name makes a brilliant epoch in chemistry. Born with an ardent passion for the science, he extended the doctrine of Beccher. He applied himself wholly to demonstrate the existence of the inflammable earth, which he called *phlogiston*.

Booerhave, in the midst of numberless employments, cultivated



cultivated chemistry. He composed a celebrated and very profound work upon it. The treatises of the four elements, and in particular that of fire, which he has subjoined to them, are master-pieces to which it would be almost impossible to make any addition.

The theory of Stahl has been embraced by all the chemists, and has acquired new force by the works of two celebrated brothers, M. Rouëlle, of whom chemistry was too soon deprived. M. Macquer also is one who has contributed to extend chemistry, and whose excellent works have with reason been regarded over all Europe as the most sure guide to this immense science.

#### SIXTH EPOCH.

##### *Pneumatic Chemistry at the present time.*

STAHL, whose attention was entirely employed about demonstrating the inflammable principle in all his combinations, appears to have forgotten the influence of the air in most phenomena; of which he makes the inflammable principle alone the principal cause.

Boyle and Hales, however, had already proved the necessity of paying great regard to that fluid in chemical experiments. The former perceived the difference which the chemical phenomena show in vacuo and in the open air: the latter had procured from a great number of bodies a fluid that resembled air, and in which he had likewise remarked particular properties, such as the smell and the inflammability, according to the substance whence it was procured. He considered air as the cement of bodies, and as the principle of their solidity. M. Priestley repeated a great number of Hales's experiments, and discovered many fluids which, though they resemble air, are essentially different. From the metallic calces, chiefly, he procured a kind of air much purer than that of the atmosphere. M. Bayen, a chemist justly celebrated for the accuracy of his works, examined the calces of mercury; and discovered, that they were reduced without



the addition of phlogiston, and during their reduction gave a considerable quantity of an aerial fluid. Lavoisier proved, by a great number of nice experiments, that a part of the air was combined with bodies which were calcined or burnt. Since that time he has given rise to a class of chemists, who begin to doubt of the presence of phlogiston, and attribute to the fixation or the disengagement of the air all the phenomena which Stahl thought were owing to the separation or combination of phlogiston. We must agree that this doctrine has the advantage of that of Stahl in a more rigorous demonstration, and that it is so much the more seducing at this moment, since it appears to proceed solely on palpable and confirmed facts. In this light likewise it appeared to the late M. Bucquet, who, in his two or three last courses, seemed to give it the preference. The only, and undoubtedly the wisest, part which we ought to take, is to wait until a greater number of facts shall have demonstrated completely, that all the phenomena of chemistry can be explained by the doctrine of the gases, without admitting that of phlogiston. We should take it for this farther reason, that M. Macquer, very much convinced of the great revolution in chemistry which the new discoveries might occasion, has at the same time doubted if we are able to explain them all without the help of this principle; and in the room of phlogiston, whose existence never has been rigorously demonstrated, has substituted the light, whose action and influence on the chemical phenomena cannot be called in question. Convinced of this, we shall take care to explain both of these doctrines, and confine ourselves to the simple character of an historian; using the freedom, however, to observe which of the two appears to us to have the greatest force and probability in every fact to which it will be necessary to apply them.



## LECTURE II.

## CHEMICAL AFFINITIES.

ALL the phenomena of chemistry are founded upon two forces which nature has established between all bodies, and which it is of the utmost importance to know.

These two forces, both very distinct in effects, resemble, however, one another in this, that they depend on an analogy or relation between the bodies upon which they act.

*Of the Affinity of Aggregation.*

THE first of those forces is that which subsists between bodies of the same nature, as two molecules of the same metal, or two particles of sulphur. We have a striking example of it in the manner in which two drops of water, of oil, or of mercury attract each other and mix together; and we call it *affinity of aggregation*. The effect of this species of affinity is to form a whole, of which the mass and the cohesion are changed, but of which the nature is the same with that of the parts of which it is composed. The whole is distinguished by the name of *aggregate*: the molecules which constitute it are called its *integrant parts*. Their character is to have the same nature with the whole, and to differ from it only in the bulk. The grains of sand are the integrant parts of free stone, which is the aggregate of the grains of sand.

The aggregate ought to be distinguished from the mass, whose integrant parts have no adherence among them; and from mixture, which is itself formed of several masses mixed together.

A piece of sulphur is an aggregate; the flowers of sulphur are the mass; and some sand mixed with the flowers composes the mixture.

We distinguish four species of aggregates.

1. The



1. The solid aggregate, one of which is inorganic, as marble; the other organic or fibrous, as wood.
2. The soft aggregate, as melted wax or kneaded clay.
3. The fluid aggregate, as water, oil, &c.
4. The aerial aggregate, comprehending the atmospheric air and other gases.

This distinction, which was made by M. Macquer, is very useful to guide us in chemical manipulations.

Sometimes the affinity of aggregation is strong enough to make two bodies, between which it takes place, approach and unite; as two globules of the same fluid, placed at a certain distance from one another. But for the most part it acts only by means of a disposition, which is entirely the consequence of art. Thus two parcels of lead or of silver, placed at the side of one another, never unite, unless fusion bring them into a state of fluidity.

As aggregation counteracts many chemical operations, it is often necessary to destroy it. For this purpose, we must expose a solid aggregate to a force more considerable than that which keeps its parts united and cohering: and it is indispensable that the force applied be proportioned to the degree of affinity of aggregation.

1. We divide the solid and fibrous aggregates by means of chisels, knives, files, &c. which are capable of destroying their texture.

2. We bruise the unpolished or inorganic bodies by the help of the mortar and the porphyry; whose form, hardness, and chemical nature, comprehends all that belongs to the theory of pulverisation and porphyrisation.

3. We separate fluids by filtration. In doing so, it is necessary to consider the size of the pores in filters, that they be proportioned to the density of the fluid to be filtered; the relation of this fluid with the filter; and the chemical nature of both. These considerations lead us to choose filters of wool, linen, or paper.

If art can destroy aggregation, it has the power  
likewise



likewise of reproducing it. It is sufficient for this, 1. to keep the integrant parts of an aggregate dispersed by means of a fluid; in this manner we dissolve a salt in water: 2. to elevate this fluid by degrees, until the parts are able to approach, meet, and unite. This union is generally called *crystallization*.

The theory of this operation is founded entirely upon the two principles which we are to establish, relative to the manner of restoring aggregation to bodies that have lost it. It is measured by the cohesion which the parts of the aggregate have formed with one another, and by the difficulty we feel in separating them.

### *Of the Affinity of Composition.*

WHEN the force of affinity takes place between bodies of a different nature, the result is a new body, called a *compound*. That is the reason why that force is called the *affinity of composition*.

Upon observing accurately the phenomena of this second force, we perceive that its effects are certain: therefore we consider them as laws, and think they may be reduced to the six following.

*First Law.* This affinity never takes place but between bodies of a different nature. We are even certain, that the more considerable the difference is in the chemical nature of the substances which it endeavours to combine, it is so much the stronger: of this sort are the acids and alkalis.

*Second Law.* Its power is exerted only on very small bodies. When the bodies are so divided that they disappear, the affinity of combination is then greatest. Chemists take advantage of this law, by which they can combine substances that seem but in a small degree capable of union.

*Third Law.* This affinity appears in bodies only in the point of contact. When the molecules of a body are dispersed, they only yield to the force of aggregation



tion which attracts them; but when they come in contact, combination ensues.

*Fourth Law.* It may exist among several bodies: Thus there are affinities of two, three, or four bodies; for instance of the metallic substances, several of which are frequently combined. Chemists are as yet but little acquainted with combinations of more than four bodies.

*Fifth Law.* It is necessary that one of the bodies which we combine be fluid; according to the axiom, *Corpora non agunt, nisi soluta*. The solution is not made in a mechanical way, as some physicians have explained. The solid body acts as strongly upon the fluid as the fluid on the solid. Hence the words *solvents* or *menstrua*, and bodies to be dissolved, present us with an unsatisfactory idea only, and are apt to lead us into mistake. Gellert considered the solid body as having even a more powerful action than the fluid. We have not as yet discovered a very sure criterion for distinguishing the simple suspension of a body, which is very much divided in a fluid, from true combination or solution. M. l'Abbé Rochon, of the royal academy of sciences, has discovered, that the manner in which the rays of the sun are refracted by two fluids, the one of which is only a vehicle, and the second a true combination, may make the one fluid be distinguished from the other. This fact, if confirmed, would furnish a very ingenious and very useful process to chemists.

We ought still to distinguish a kind of solution by the aid of fire, which converts one or both the solids into a state of fluidity. This last is called the *dry way*; and the former, distinguished by the name of solution or combination, the *humid way*. It were to be wished that we could substitute the word combination in the place of solution.

*Sixth Law.* The affinity of *combination* is in the inverse ratio of the affinity of aggregation. The stronger the latter, the weaker the former. This law is only a consequence and amplification of the preceding.

*Seventh*



*Seventh Law.* During its action, the temperature of the bodies changes. Two bodies, in the act of combination, grow either cold or hot. Heat is much more frequent than cold.

*Eighth Law.* The compounds which it produces have properties very different from those of their principles. The complete knowledge of this law is of great importance, since it is contrary to what has been asserted by several chemists, who think that the compounds possess the mean properties of those of their component parts. A great number of chemical phenomena, however, confirm this law as we lay it down. Two very fluid bodies, as oil of tartar and oil of vitriol, mixed together, instantly form a solid. Two solids, as an amalgam of lead and an amalgam of bismuth, triturated together, instantly become fluid. Two very sapid and even caustic bodies, as causticum commune and nitrous acid, produce a salt of a cool and bitter taste. Two bodies without colour, as oil of turpentine and oil of vitriol, form a black and charry soap. The case is the same with all the other properties.

*Ninth Law.* We estimate the influence of this law by the difficulty that occurs in separating a compound into its principles, rather than by the rapidity of their union. Nitrous acid unites with violence to mercury, from which it is easily separated by the action of fire; whilst the marine acid, which seems not susceptible of combination with this substance in its metallic state, forms with it a salt which is entirely volatilized by the action of the fire, and of which heat cannot separate the principles.

*Tenth Law.* This affinity is not equal among all bodies, and it has different degrees. Upon this law one of the most astonishing and ingenious operations in chemistry is founded, the separation of the two principles of a compound by the addition of a third, which has a greater affinity to one of the two than they have to one another. This operation ought to be called *decomposition*;



*composition*; though commonly known by the name of *precipitation*, which is not applicable to the generality of cases that occur in this decomposition. In consequence of this false denomination, we have distinguished different sorts of precipitates; true, false, pure, and impure precipitates.

It is a true precipitate when it is the substance which is separated from the compound that is precipitated. The false precipitates, on the contrary, are formed by new combination. Thus, lime precipitated from selenite by the caustic fixed alkali, gives a true precipitate; but the vitriol of mercury, formed by the addition of vitriolic acid to a solution of this semi-metal in the nitrous, is a false precipitate. But what name can be given to a substance which is separated from a compound and volatilized, as the volatile alkali disengaged from a solution of sal ammoniac by lime-water, or the caustic fixed alkali? It is evident that this word *precipitation*, which still marks the substance serving to decompose the compound by the name of *precipitant*, does not indicate the decomposition which takes place among solid bodies by cold or by fusion. It cannot be applied to those decompositions that take place without the solution growing turbid; a thing which happens in consequence of the equal solubility of the new compound and the substances separated.

By pure precipitates, we mean those which are not altered by the precipitant, in consequence of its having no action upon them; such as vitriolated tartar, separated from water by the addition of spirit of wine. Precipitates become impure by the alteration which they undergo from the precipitating substance which has affinity with them. In this manner the metallic precipitates by acids or alkalis appear under a form and under colours not natural to them, and which they owe in part to the re-action of the alkalis. The characteristic of these precipitates is, their disappearance and solution in the substance that precipitates them, when it is  
added



added in greater quantity than is necessary for precipitation. For instance, copper precipitated by volatile alkali from its acid menstrua, or iron separated from the nitrous acid by fixed alkali, which some modern chemists have falsely called *aerial*, but which is a true neutral salt, that we call by the name of *tartar*, combined with the acid of chalk, since it is formed by the union of the fixed alkali of tartar with the acid of chalk.

Chemists have distinguished several kinds of affinity of composition; as *the simple affinity*, the nature of which we are going to describe; and *the double affinity*, with which it is very difficult to be well acquainted. We see an example of this last, when a compound of two bodies which cannot be decomposed by two other simple bodies singly applied, is however decomposed by means of these two bodies united together. For example, the particular colouring principle united with the alkali called *phlogisticated*, cannot be separated from it either by vitriolic acid alone, or by pure iron. These two substances, however, under the form of martial vitriol, decompose completely this phlogisticated alkali.

It should seem that these decompositions are produced by means of a compound affinity between the four substances which come in contact in this experiment; and we can very well explain and comprehend the phenomena, if we mark the number of the particular affinities.

With regard to the reciprocal and intermediate affinities, they seem to have no right to be admitted to the rank of the first. Indeed, the reciprocal affinity, which happens when a body seems to show an almost equal affinity to two other substances, in such a manner that it can be separated from the one by the other reciprocally, as the fixed alkali which is separated by the nitrous acid from the vitriolic; it takes place only in few cases. Besides, it is owing to particular circumstances: for, in the above example, the acids must have some particular modifications in order to effect these changes,



as we shall remark in the history of the salts. We have an example of intermediate affinity, according to some chemists, when a body which could not be united to another becomes capable of union by combination with a third. In this manner oil, which cannot be united with water, becomes able to unite by the intermedium of an alkali, which converts it into the state of soap. This species of affinity is comprehended in our eighth law.

Such is the state of our knowledge of the affinity of composition. We imagine we ought only to mention facts. As to the hypothesis which we have proposed of the cause of this force, we do not pretend to account for it. We think that the knowledge of it is as obscure as that of attraction. We believe, however, that it is impossible to confound it with this last, whose laws are totally different; although some persons have believed that they are truly the effects of a similar cause.

### LECTURE III.

#### *Of the Principles of the CHEMISTS.*

**P**REVIOUS to our entering upon the examination of the different natural bodies and their chemical properties, it is necessary to know what chemists have understood by *principles*.

It is substances more or less simple, which they suppose capable to form all bodies, and which they separate in their analysis.

They are distinguished into *immediate principles*, the component or secondary parts of bodies; and into *remote principles*, their elementary or primitive parts. The first are all those that are furnished by the first analysis, which we obtain from a compound body. For this reason they are called *the immediate principles*. But as these substances are themselves compounds, they are distinguished by the name of *secondary or component parts*.

The



The primitive or remote principles, are those which we obtain from a body in the last analysis; and which, by their union, form the *immediate principles*. For instance, in the distillation of a vegetable substance, we obtain fluid or concrete salts, oils, and gases. These different matters are the immediate principles, formed, however, of other principles; for, by a new analysis, the oil yields water, air, earth, and other substances, which are primitive principles. On this account these last have been called *elements*. Their character is, an impossibility of being farther decomposed, and their serving for the formation of almost all the bodies in nature. Chemists suppose that those substances can be united in different numbers, and in different states. These unions, therefore, they have distinguished by the following denominations, which owe their origin more to their imagination than to nature, and which are only designed to set our knowledge in a proper train.

A body formed of two simple bodies is a *mixt*; and two mixts united form a *compound*; the union of two compounds produces a *surcompound*; the union of two surcompounds gives rise to a *decomposition*; and, lastly, two decompositions united form a *surdecomposition*.

We have always differed about the number and the nature of principles. Among the first philosophers, some have with Thales regarded water as the sole principle of all things. Others have ascribed this prerogative to the air, as Anaximenes has done. Empedocles united these opinions, and was the first who admitted as elements, fire, air, water, and earth. Aristotle adopted this opinion, and has been followed in it by the Peripatetics down to the 16th century. Then Paracelsus substituted five elements in place of those of Aristotle. Of these five elements, that of spirit or mercury comprehended every thing possessing volatility or odour; that of phlegm, every thing that was liquid and insipid; that of salt, every thing that was sapid and that dissolved in water; that of sulphur, or oil, every thing that was



inflammable or fluid ; that of earth, all that was dry, insipid, and fixed.

To mention this doctrine is sufficient to show its falsity and insufficiency. It is evident that Paracelsus, attached to the products of his operations, has confounded a great number of very compounded bodies among his principles.

Beccher has admitted two principles ; that of humidity, which he calls *water* ; and that of dryness, which he calls *earth*. He divided earth into three kinds ; the vitrescent, the inflammable, and the mercurial earths. The first was the most unalterable, the most pure, the principle of hardness and of fixity. The inflammable earth communicated smell, colour, volatility, and combustibility to bodies into whose composition it entered. Lastly, the mercurial earth, according to this chemist, possessed the singular property of giving to bodies, of which it makes a part, a great weight, along with an extreme volatility.

Stahl has commented on the doctrine of Beccher, and has fully demonstrated the pure vitrescent earth. The inflammable earth, which he has called *phlogiston*, is called in question by several modern chemists. With respect to the mercurial, it was quite impossible for him to find it and render its existence believed. It may be observed, that Stahl, attached entirely to the investigation of phlogiston, and to the examination of its properties, seems to have forgotten the influence of the air, which Hales, much about the same time, demonstrated to be of the most considerable consequence.

If we must call every thing which cannot be decomposed, *element*, we observe, in the first place, that the number of these substances is very great, since the metals, sulphur, and other bodies, seem to be as incapable of decomposition as the *four elements* properly so called ; which we shall prove in the article on each of them. In the second place, that the four substances named *elements*, are not all of them so, since it is possible to decompose the  
atmospheric



atmospheric air into several gases. In the third place, that we know of various kinds of earths, very different from one another, yet not the less simple.

*Of the Division of the Natural Bodies into several Kingdoms.*

SINCE the object of chemistry comprehends all natural bodies, it is necessary for the consideration of them all, to establish an order among them, that they may be distinguished, and to affix certain characters to them, by means of which they may be known.

Naturalists have divided them into three kingdoms, the Mineral, the Vegetable, and the Animal. The mineral kingdom comprehends all the hard inorganic bodies which form the mass of our globe, whose volume augments by juxtaposition or crystallization, and which yields only to the force of attraction, of aggregation, and of the affinity of combination. These are the minerals.

The vegetables are formed of fibres and vessels, which contain fluids. They are nourished by intus-susception and elaboration of the juices; and yield to particular laws, which depend on their organization, and which constitute the functions of the vegetable œconomy. These functions are, generation, digestion, nutrition, and secretion; which are very remarkable among these substances, and over which particular organs preside. Respiration, circulation, and irritability, are but very weak in them. Sensibility does not belong to them at all.

Vegetables are confined to the soil in which they are produced, until they be destroyed.

Animals enjoy all the foregoing properties in a much more remarkable degree. Circulation, respiration, irritability, sensibility, and loco-motive power, form their distinct characters. Their organization is more complicated and more elegant than that of vegetables. These exhibit always the same interior texture in their different parts; as the root, the stem, the leaf, the flower, the fruit. Animals, on the contrary, present a varied



structure in the different organs of their bodies; and moreover, all the viscera of animals are necessary for the support of life, which ceases whenever they do not lend an equal assistance; whilst every part of the vegetable, living by its proper contexture, not only can dispense, and does dispense effectively, with the aid of the other, but can even reproduce the destroyed parts. These two kingdoms seem to be confounded by several of their extremes, such as the polypes; and they have been re-united by the natural anatomists into one only, which they have called the *living or organic kingdom*.

Chemistry, as we shall point out at the end of this course, has also means of analyzing and of comparing these two kingdoms; however, we shall separate them, in order to be more explicit and methodic.

We begin with the examination of minerals, because those substances are more simple than the other kingdoms, their analysis more easy and satisfactory, much farther advanced and better known; and because almost all the principal chemical facts, which ought to form the basis of this science, are applicable to minerals. The ancients had made a particular kingdom of the four elements. It is not indeed very evident among which of the three we ought to rank them, since they act equally on all the three. However, as they make a part of the globe, and are inorganic, it appears more natural to class them at the head of the mineral kingdom, being the substances the most universally diffused, and the most simple in some points of view.

### *Of the FOUR ELEMENTARY BODIES.*

#### ARTICLE I. *Examination of the Properties of FIRE.*

COMBUSTIBLE substances, which being inflamed emit light and heat, have been universally looked upon as real fire. Philosophers have described it to be a fluid possessed of great mobility, very active, very penetrating; which is formed of subtle permanent particles endowed with continual motion, and disposed always to increase:



but none of them have been ever able to collect this fluid, to concentrate it, and examine its properties. Since this is impossible, no other resources remain, but the study of the effects which are generally ascribed to it. With Boerhaave, we admit three of these effects; Light, Heat, and Rarefaction.

### § 1. *Of Light.*

LIGHT is a body whose existence is demonstrated, and which may be collected in the camera obscura: it proceeds from the sun; it pervades the atmosphere, which it seems entirely to fill; it is that substance which makes us capable of perceiving the image of the bodies, that reflect the rays of it towards our eyes.

Its motion is very rapid, and in straight lines; it runs through 24000 leagues in a second.

So great is its elasticity, that the angle of its reflection is equal to the angle of its incidence. Hence it might be suspected, that the permanency of its rays is extreme. It is proved that it possesses weight, by the inflection which it suffers in passing by the side of a body.

When it penetrates from a rare into a more dense medium, it is refracted like all hard bodies. But Newton discovered that its refrangibility is in the inverse ratio of that of other bodies; and that, in penetrating into bodies more dense than those which it leaves, it approaches to the perpendicular, whereas other bodies recede from it.

It has different actions upon bodies according to their nature. Opake bodies reflect it. It penetrates transparent bodies; which refract it, either in the direct ratio of their density, if they are incombustible; or in the duplicate ratio of their density, if they are inflammable. Newton, who made the following experiments on light, has discovered, that in passing through the prism, it is decomposed into seven rays.

The rays are in the following order.

1. The red,—a simple and primitive colour.

F 3

2. The



2. The orange,—composed of red and yellow.
3. The yellow,—simple and primitive.
4. The green,—composed of yellow and blue.
5. The blue,—simple and primitive.
6. The indigo,—composed of the blue and violet.
7. The violet,—simple and primitive.

Light appears to be subject, as all other bodies, to the affinity of composition; however, its affinities must be very weak, since its hardness is very considerable. We know that it colours vegetables, and changes the metallic salts, when contained in transparent vessels which are exposed to it; and M. Macquer has ingeniously substituted it in place of the phlogiston of Stahl, whose existence was not demonstrated.

### § 2. Of Heat (a.)

HEAT is only an agreeable or disagreeable sensation. M. Bergman views it in the light of a particular body. M.

(<sup>a</sup>) Heat, light, fire, and phlogiston, are too often confounded together, from the vague notions of those who talk on the subject. Each of them, however, has properties of its own, distinct from the rest. Phlogiston is neither heat, nor light, nor fire, though intimately connected with all of them, and transferable into other substances by a proper management. The manner of doing this will appear evident from a review of M. Scheele's system. According to the opinion of this very ingenious chemist, heat ought to be regarded as a combination of phlogiston with pure, or what he calls *empyreal*, air (that air which alone is capable to support animal life, and to furnish pabulum for the accension of combustible bodies). He finds this conjecture verified by experiment. For instance, the earth of gold is restored to its metallic state by the decomposition of heat; the phlogiston adhering to the metal, while the empyreal air escapes into the receiver. A small quantity of this earth is made red hot in a receiver; and as the only difference between it and reguline gold consists in the absence of phlogiston, you know, when the gold is revived, that phlogiston has been found, and it could be found no where but in the heat. *Mercurius precipitatus per se* undergoes the same change, and yields the same product by the application of heat alone. In those examples, it is not possible to pretend that phlogiston penetrates the bottom of the sand-pot, the sand, and the retort, to unite with the gold earth; for then there could be



M. Macquer supposes that it is nothing but a modification of which all bodies are susceptible. To distinguish whether of these opinions ought to be preferred, it is necessary to examine the effects of heat. It penetrates all bodies without exception; it is not reflected, since

a

be no formation of empyreal air; and the calces of ignoble metals should also be revived, which is not the case. He farther observes, that light contains phlogiston in a state capable of separation. If a solution of silver in nitrous acid be poured on chalk, and exposed to sunshine, the metallic calx revives, by attracting phlogiston from the rays of light. The like decomposition obtains by presenting colourless nitrous acid to the sun's light, when it soon acquires an orange tint, and becomes fuming: a change which constantly follows the acquisition of phlogiston. Light therefore is not a simple elementary body. It rather seems to resemble a compound into which phlogiston enters as a component part. The affinity of light to heat is so great, that if the phial containing the nitrous acid be painted black, the phenomena of heat are produced, not those of light. The liquor is warmed, without change of colour or of volatility. All those circumstances seem to demonstrate, that heat and light arise from the mixture of similar ingredients, combined in various proportions. Even the various coloured light contains unequal shares of phlogiston. The violet rays part more easily with their phlogiston to revive metallic calces. When the free passage of light is not interrupted, there is no change of temperature occasioned: but when any obstacle stops the course, the opposing body is heated, or in some cases acquires phlogiston. Light therefore seems to be the matter of heat, saturated with a superabundant quantity of phlogiston. In the formation of light, we have an opportunity to trace the stages of the progress from the state of heat to that of perfect light. To this end we observe, that the heat which issues from the fire of a furnace is of two kinds; one which possesses all the properties of common heat, diffuses itself to surrounding bodies, and mounts upwards by warming the air; the other kind proceeds forward in straight lines, disturbing the air by undulations. It may be reflected from polished surfaces, according to the direction of the incident ray: with this peculiarity, that a concave mirror retains the heat, while it reflects the light; for the focus is luminous, but not warm: or while we interpose a plane of glass in its course, we see the fire, but do not feel the force of the heat. This is a curious fact, and suggests the probability of this radiant heat being an intermediate step in the transition of heat towards light. It is not perfect light, though approaching to it. Nor ought it to be thought unphilosophical, to suppose empyreal air miscible with different proportions



a hot body is not more elastic than when it is cold. It is exactly of the same nature with all other bodies, and endeavours always to put itself in equilibrio. We do not know its weight, since nothing proves that a heated body is heavier than when it is cold. It cannot be fixed in

portions of phlogiston ; because this supposition is consonant to many well known facts in chemistry, in which bodies acquire new properties by the augmentation or diminution of their phlogiston. Thus the acid of arsenic, by the addition of some phlogiston, becomes white arsenic ; and by the addition of still more, assumes the appearance of a perfect semi-metal, though apparently no states are more opposite than those of a liquid acid salt and of a solid metallic substance.

Once the intimate union of phlogiston and empyreal air has been compounded into heat, the heat becomes a substance capable of uniting with all bodies. It is, however, necessary to remark a difference in the mode of combination. Heat enters the pores of some bodies without altering their nature, as water is absorbed by a sponge, and may be expelled in the same way by compression. A rod of iron, beat on an anvil with a forge-hammer, becomes warm and red hot, because the particles of iron being more closely compacted, the heat must leave the pores ; but once it has undergone this operation, we cannot repeat it with success, until it receive a fresh supply of heat. In the other case, heat makes an ingredient of the compound, and is to be dislodged by the superior elective attraction of some third body. Thus, if we take any neutral salt, whose acid is to be detached by the action of heat alone, and expose it to a radiant heat for an hour, and allow it to cool, the case is the same as before, only instead of an acid it has adopted heat. Those which absorb most heat, not only acquire the property of dissolving in water, but also of parting with all their superfluous heat on the addition of water. On this account quick-lime becomes hot in water. The earth attracts water, and parts with its heat.

After proving the truth of these particular doctrines, Mr Scheele explains the nature of fire. He observes, that fire is a more or less heated, more or less luminous state of bodies, in which they are resolved into their constituent parts, and entirely destroyed. It must be previously heated in contact with air ; for to every combustible body a certain quantity of heat must be communicated, in order to set it in the fiery commotion. The heat penetrates the pores of bodies, and destroys their cohesion : Then the body parts with its phlogiston, provided there be a substance present which has a stronger attraction for the inflammable principle. If the heating be performed in open air, the empyreal air has the stronger attraction.



in any substance; it flies off gradually. It dilates the most part of mineral bodies; and when it is very strong, it contracts organic substances. All its properties do not demonstrate the existence of a body; and we think, after this, that heat is only a modification similar to motion.

tion. Immediately after this, the inflammable principle must come out to unite with the empyreal air, and thus be set at liberty. From this union heat is compounded; and scarcely is this heat generated, when the combustible body is still more expanded by it than in the beginning, and its phlogiston more laid open. The more the heat is increased, the more minute are the particles into which the combustible body is dissolved. The empyreal air meets more surfaces, consequently comes in contact with more phlogiston, and according to its nature forms an union with a greater quantity of it, which causes radiant heat. At this very moment the constituent parts of the combustible body are so much disunited by the still increasing heat, that the empyreal air, continuing to pour upon it in streams, attracts the phlogiston in still greater quantities: and hence the most elastic substance, light, is composed; which, according to the quantity of combustible matters, shows various colours.

Dr Crawford's system of heat proceeds upon principles very different from those which Mr Scheele has advanced. Heat, he observes, has a tendency to diffuse itself all around, and to bring all bodies to the same temperature. In this state it is sensible upon the application of a thermometer. But during the communication of heat from one body to another, a great quantity often appears to be lost. Thus, when you suspend a piece of ice in a warm room, a great influx of heat is requisite to dissolve it, and even then the water is not raised one degree above the freezing point. It would therefore appear, that a large portion of heat is absorbed by the ice, to enter as a constituent part in the formation of water; in short, that water cannot exist without heat as an ingredient; and that all bodies contain it in their composition, though it may not sensibly affect the temperature. To heat under this form, he gives the name of *absolute heat*; and to heat which is diffused, the name of *relative or sensible heat*.

In order to measure the proportional quantities of absolute heat which different bodies contain, it is necessary to remark, that when equal quantities of a homogeneous fluid, at unequal temperatures, are mixed together, the mixture is found to be an exact mean between the two extremes. This remark is more fully explained in the note upon thermometers: But when the fluids are of different kinds, the temperature of the mixture approaches nearest to that which contains the largest proportion of absolute heat. Nor does the quantity



tion. Bacon supposed that it was owing to the collision of the last molecules of bodies on one another. M. Macquer, who admits his opinion, thinks it well supported by the following facts.

1. The motion which is constantly produced from heat,

Quantity of heat seem to be proportioned to the density of the fluid. Mercury, which is the densest of all fluids, contains less heat than water. The truth of this may be proved by various experiments. If vessels of mercury and water be placed before a fire, the mercury will reach its temperature before the water. If both be raised to the same temperature, and a solid body immersed into them, the water will impart a larger quantity of heat than the mercury: or if equal quantities of water and mercury be mixed together, the temperature will come out nearer to the heat of water. This kind of measurement furnishes a mode of estimating the proportional quantities of absolute heat in different bodies; so that if water be employed as a standard, we may be enabled to compare them in this respect. Dr Crawford actually did so; and the result of all his trials was, that bodies which contain a large portion of phlogiston, admit a small quantity of absolute heat: on the contrary, that bodies which have a great capacity for absolute heat, contain but little phlogiston; or if bodies be deprived of their phlogiston, and reduced into another form, then their capacity for heat is increased. Thus, when regulus of antimony is deprived of its phlogiston, and reduced by calcination to the state of diaphoretic antimony, it nearly triples its capacity for heat. The same change takes place between crocus martis and iron. In short, the fact is universally true, whatever be the nature of the substance. Aerial vapours are affected in the same manner. Air spoiled by phlogiston possesses very little heat; on the contrary, dephlogisticated air shows a most prodigious quantity. Upon these facts Dr Crawford formed a conjecture, that phlogiston and heat were two distinct substances, whose presence in the same body at one time is quite incompatible; and that whenever the one enters, the other is expelled. He illustrates this doctrine from the phenomena observable in metallic substances. Metals are calcined in consequence of a double elective attraction, which induces the metal to part with its phlogiston to the air, while the air in return communicates heat to the metallic calx. In confirmation of this, we know that the quantity of metal calcined bears an exact proportion to the bulk of the air. The appearance of combustion of inflammable substances is of the same nature. All inflammable bodies contain a large quantity of phlogiston in their composition, which adheres but loosely. Dephlogisticated air contains absolute heat, and has a strong attraction for phlogiston. In the act of combustion



heat; as we observe betwixt two solids, as stone and iron; betwixt a solid and a liquid, as lime and water; betwixt two liquids, as water and oil of vitriol; between two gases, marine-acid gas, and alkaline gas.

2. That it is always in proportion to motion.

3. The bodies which are the most susceptible of motion, are those which are the most quickly heated.

From

combustion the inflammable body is consumed, impregnating the air with phlogiston, while its own residuum possesses a much greater capacity for heat. Accordingly you find the combustion of sulphur contaminate the air, and present the vitriolic acid impregnated with more absolute heat. On some occasions a most intense sensible heat is produced; on others, it is moderate. The difference arises from the nature of the vapours which the inflammable bodies emit. When the vapour is inconsiderable, and the residuum is unable to absorb the whole heat which the air deposits, the remainder must be diffused around in the form of sensible heat, by a kind of chemical precipitation: but when the vapours of the inflammable body are able to absorb the whole heat which the air contains, then the sensible heat is extremely small. In the combustion of spirit of wine, the aqueous vapour absorbs almost the whole absolute heat of the air, so that the heat of the flame is hardly to be felt. But in phosphorus the heat is most intense, because there is nothing but a small quantity of acid to carry it off. The appearance of flame he attributes to the extrication of a large quantity of sensible or moving heat; and through the whole essay, fire seems to be employed as a term synonymous to absolute heat.

The opinion which M. Lavoisier entertains upon the subject of inflammation is materially different from the sentiments of the other two gentlemen, and goes to the total subversion of all Stahl's discoveries concerning phlogiston. M. Lavoisier observes, that inflammable bodies burn in one species of air only; to which he gives the name of *pure air* or *air eminently respirable*. In all other kinds of air, combustion is impracticable; and whenever it takes place at all, a portion of the air is lost, and the inflammable body acquires an addition of weight, which exactly corresponds to the quantity of air missing. One grain of Kunckel's phosphorus requires 16 cubic inches of air for its combustion, and acquires  $1\frac{1}{2}$  grains of additional weight by its conversion into the acid of phosphorus. A similar change obtains in the combustion of sulphur; nor is it possible to set sulphur on fire, unless there be a constant circulation of pure air. He observes also, that the same circumstances are requisite in order to effect the calcination of metallic substances, and that every calx



From this theory it is easy to conceive, 1. Why a body when long heated becomes luminous: the reason is, because the light is then moved in direct lines towards our eyes. 2. Why a body may be hot without being luminous: in this case the motion is too small, or

is heavier than the metal from which it was produced. In every case, therefore, a loss of air is observable; which can have gone no where but into the calx, or into the remains of the combustible body. Accordingly M. Lavoisier endeavours to recover it from them in its primitive purity. He chose to make his trials upon mercury, as this metal calcines easily, and may be revived without addition. During the calcination the mercury absorbs a quantity of pure air, which increases its weight, and remains united to it so long as the mercury retains the form of a calx. Upon the application of an intense heat, this air is expelled of the same purity in which it entered, and exactly in the same quantity. By this separation the mercury is revived. From all those appearances, M. Lavoisier infers that mercury precipitate *per se*, is a combination of mercury with pure air. He applies the same hypothesis to explain the conversion of sulphur into vitriolic acid, and thinks himself able in some cases to disengage all the air from its confinement. This separation takes place when the metallic salt formed by the union of mercury with vitriolic acid is exposed to heat in a retort. Some volatile sulphureous vapour first arises: this is followed by a quantity of pure air, while the mercury is revived completely. The production of all the elastic fluids must therefore depend upon the decomposition of the vitriolic acid, since the mercury remains unchanged; so that M. Lavoisier discovers the integrant parts of vitriolic acid by means of this process. The volatile sulphureous acid, which rises first, is nothing but a portion of the vitriolic acid, deprived of some pure air which still adheres to the mercury. According to this doctrine, mercury and sulphur are simple substances; and not a mixture of phlogiston with some material basis, as Dr Stahl supposed. But M. Lavoisier nowhere perceives the smallest vestige of phlogiston, nor does he admit of its existence; and all the phenomena which are said to indicate the motion of phlogiston from one body to another, he explains upon other principles. In place of admitting that inflammable bodies burn during combustion, M. Lavoisier asserts, that pure air is the only combustible body in nature; that the bodies commonly said to be combustible acquire weight, while the pure air is decomposed into its integrant parts. In all cases of combustion, this air unites with the bodies commonly called *combustible*. In most instances it forms an acid. With sulphur, vitriolic is formed; with phosphorus, phosphoric acid; with arsenic, arsenical



or the form of the molecules of the body is not suited to reflect the rays in direct lines. 3. How a body may be luminous without heat, when the form of the molecules is such that they can reflect the rays, as the phosphori. 4. That the light, by its motion, may even excite heat; and that if the body of rays is quickly united, as we observe takes place in the focus of convex lenses, the heat will be the most intense which human power is able to produce; whilst those rays, when dispersed thro' the atmosphere, will only produce a feeble heat in consequence of their extreme tenuity.

## LECTURE IV.

### § 3. *Of Rarefaction.*

THE third effect of fire, which falls next to be considered, is the rarefaction of bodies. At first view this rarefaction seems to suppose the entering of some substance into the small cavities of the rarefied bodies; in that

cal acid. It must therefore contain some acid-making principles in its constitution, which communicates acidity to all bodies, and is the only basis of acidity. This is the basis of M. Lavoisier's hypothesis: He conjectures, that pure air is composed of this acid-making or oxygenous principle united to the matter of heat; that in every instance of combustion, the oxygenous basis unites with the simple body, while the matter of fire is set free and becomes sensible. M. Lavoisier has the modesty to offer this theory as a conjecture, which he is not yet able to support by any positive demonstration. In some parts it is not so completely made out, as to be quite intelligible to the reader without an appearance of inconsistency. With regard to the production of aerial acid, in one place he says that it arises from the combination of pure air and charry matter; in another, from the combination of pure air with inflammable air; and in a third, with the matter of heat. When he says that the volatile sulphureous acid and pure air proceed from the decomposition of vitriolic acid, he never attempts to produce vitriolic acid by their union; besides, in this distillation, some aerial acid is produced, which M. Lavoisier does not account for. What degree of credit this new system shall meet with from the public, time alone can determine; in the mean time it was thought necessary to give a short sketch of it in a note, as M. Foncroy makes frequent allusions to it in the course of his lectures.



that case the substance would act as wedges, which would disjoin and separate their molecules. But on reflecting that a body rarefied by heat, has acquired no absolute weight, and that its specific weight is diminished, we very well conceive that rarefaction consists only in a simple separation of the parts of the hot body, whose pores are then enlarged, so that they contain more void and fewer solid parts in a given space than before.

Boerhaave, who has considered the effects of fire as a natural philosopher rather than a chemist, has established three laws of rarefaction.

*First Law.* That all bodies are dilated by heat. This law is not so general as he has imagined; since all organic matters are contracted, and clay cracks, by the action of the fire. Some bodies too are expanded by cold. Mr Leurs has made the same observation on gold.

*Second Law.* Bodies are dilated in all their dimensions. The elongation of a bar of iron when heated, the pyrometer, and the ring into which a cylinder of metal when it is red hot can no longer pass, are decisive proofs of this law.

*Third Law.* Dilatation is in the direct ratio of the rarity of bodies, or the inverse of their density. In order to establish this third law, Boerhaave has compared the effect of heat upon three solid bodies only, but very different from one other, such as wood, stone, and metal. M. Buffon, however, repeating the experiment on a great number of different solids heated, has proved that heat expands them in the ratio of the alteration which they suffer by fire; that is, the stones in the ratio of their calcinability, and the metals in the ratio of their fusibility. Boerhaave, who extended this law even to the fluids, has determined its influence upon air, spirit of wine, and water only. If he had taken mercury to compare its rarefaction, he would not have made the law so general as he has done. This metallic substance,



substance, though much more dense than spirit of wine or water, expands itself more than these two fluids. This proves that it is neither the inflammability nor the fusibility of fluids which determines the degree or the celerity of their rarefaction by heat.

Besides the laws of rarefaction which heat produces, it is essential to know,

1. That bodies, in passing from the solid to the fluid state, always produce cold; as the salts when they are dissolved in water, and ether when it evaporates.
2. That fluids, which are susceptible of passing to a concrete state, grow warm as they become solid: thus water which is plunged into a vessel of ice, never produces so great a degree of cold as spirit of wine plunged into the same vessel (*b*).

4.

(*b*) The degrees of heat are measured by an instrument called the *thermometer*; which is made in this way. A small quantity of some unelastic fluid is confined within a glass tube, where the fluid, rising or falling with every increase or diminution of heat, indicates the change with great accuracy. Those variations are rendered more perceptible by means of a bulb blown at one end of the tube, which augments the mass of matter, while the area of the tube, in the direction of which all expansions are determined, continues invariably of the same size. Such a form is of great advantage, as the augmentation of bulk would oftentimes be altogether insensible, were the fluid permitted to expand equally in every direction. We have an example of this in a mass of iron or other solid body, whose alteration of size, when condensed by the cold of snow, or dilated by the red heat of a furnace, requires some mechanical contrivance to make it obvious. It is indeed true, that solids do not expand so much as fluids, and are upon both accounts less proper for the construction of thermometers. Every degree of heat has a corresponding point on the tube of the thermometer, at which the fluid remains stationary, and to which it always returns in equal heat. Those points are marked from the phenomena which occasion them, as the heat of melting snow, the heat of boiling water. The interval between these two points is divided into a scale of equal parts; the number of which is variable according to the pleasure of the constructor: and provided we be thoroughly acquainted with the extremities of the scale, we can readily compare thermometers of all constructions with one another. Here a question occurs, Whether or not such degrees of a scale indicate equal differences of heat?

They



§ 4. *Of the Action of Heat considered chemically.*

THE utmost expansion which heat produces, is entirely to separate the molecules of bodies, to diminish the force of their aggregation, and consequently to facilitate that of their combination according to one of the laws of affinity. By this effect then, heat is very useful to the chymists who employ it with success.

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They clearly mark equal degrees of expansion, with which general effect of heat most authors have confounded its absolute quantity. But heat and expansion are two very different things, and ought to be distinguished from each other. The investigation is extremely curious, and may be brought to the test of experiment in the following way. Two equal quantities of water of different temperatures, will upon mixture give an exact arithmetical mean between the extremes. It is impossible they can do otherwise. For as the hotter has all the heat of the cooler, and so much more, it must part with a portion of the excess; and the difference being distributed over a double mass, will lose one half of its heat, and give a mixture of mean temperature. If the one quantity of water be double the other, the excess being distributed over three times the mass, will reduce the difference to one-third; and so on of other proportions. When a series of these mixtures is made, and thermometers are immersed into each of them, we find that the expansions of the fluids do not correspond with the heats of the mixtures.

All fluids expand in an increasing series; that is, by equal increments of heat, their expansions are the greater as the scale rises high. Water is very remarkable in this respect. The expansion of mercury approaches nearest to the arithmetical progression of heat. M. de Luc of Geneva, who made many ingenious experiments upon this subject, found that oil stood next to mercury in the regularity of its expansions. Oil varies as much from mercury as mercury does from the regular increments of heat; and upon this principle he constructed a scale of an equidifferential thermometer to measure equal degrees of heat; but as the detail of the process is too long to insert here, I must refer to the original writings of the author. These remarks show what service thermometers are qualified to perform, and what we ought to expect from them. The next object is to ascertain a fixed and determined point of heat, which shall be invariably the same in all thermometers, and may serve to adjust them to one another. The heat of melting snow is commonly employed for this purpose; and provided the thermometer be immersed in the water which surrounds melting snow, it will always rise to a certain height, as the heat is constantly the same.

But



The action of heat, considered under the last point of view, that is, as tending to diminish aggregation, and to favour combination, is modified in four ways, according to the nature of the bodies upon which it is

VOL. I.

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exerted:

But the heat of boiling water, the other standard point, is not so unalterable, being affected by the pressure of the atmosphere, which is continually varying. These variations admit of corrections, of which M. de Luc has given a table; and when all circumstances are taken into account, the boiling-point may be found with great accuracy. In this way thermometers may be made at the most distant places, which shall perfectly tally with each other. We have already seen that mercury expands with more regularity than other fluids; and for that reason deserved to be preferred, as approaching more nearly to a true measure of heat. It can also be more perfectly purged of air, which circumstance alone is of great consequence: for little bubbles of air collecting at the commencement of the tube, prevent the regular rise of the liquor; besides, the presence of air promotes the formation of vapours. Then mercury is adapted for measuring great degrees of heat better than any other fluid. Next, though itself the densest fluid, it conforms readily to the variations of heat. Lastly, it can always be had uniform, so that all the intervals between two points will correspond in a mercurial thermometer; which is not the case with those made with spirit of wine, and with some other liquors. But with all those advantages mercury cannot measure the same intense cold with rectified spirit of wine, which never has been frozen. And, with regard to extreme heats, all thermometers on this construction are entirely useless. Sir Isaac Newton endeavoured to supply this defect by calculation. He exposed a mass of red-hot iron to a stream of cold air; and marking the progress of cooling when an oil thermometer could be applied, he computed the extreme heat it had endured when first taken out of the furnace. Yet however ingenious this method may appear to philosophers, it was inapplicable in practice, and would be liable to error, if the progression of cooling in the higher and lower degrees of heat were not the same. Nothing is more desirable than a practical measure of the higher degrees of heat, which are necessary in so many arts in which it is often essential to ascertain the intensity of the heat with great precision. This is the case in all the manufactures of baked earthen-ware. The quality depends on the violence of the fire. M. Wedgwood, who was sensible of the importance of this, proposes to employ the contraction of clay to measure the heat. He finds that the clay he employs, of which he gives an accurate analysis, begins to contract in a red heat; and that by the strongest fire he can raise, it contracts one-fourth of its original dimension in an unbaked state. The clay is formed into small parallelepipeds, cut to  
one



exerted: 1. Where it does not alter them in any shape, it only dilates them. Bodies of this nature are unalterable

one size by means of a gage. They are next fired in a low red heat; after which they are fit for use. One of them is exposed to the heat intended to be measured, and the intensity estimated by the degree of contraction. A scale is applied to measure the contraction; and as it is the property of clay never to expand after contracting from heat, we have reason to confide in the measurement. Mr Wedgwood divides his scale, from the heat at which clay begins to contract, to the greatest which he was able to produce, into 160 degrees. He found copper melt at 27°, silver at 28°, gold at 32°, cast-iron at 130°, iron run down among the fuel 150°; yet we find that all those degrees are called a white heat merely without any discrimination. It would be needless to say more upon this improvement, till farther experiments shall confirm its use; and even with it in perfection, we shall still want some contrivance to supply the interval between the common thermometer and this new one. We shall finish this account of thermometers, by subjoining the following TABLE of the real quantities of heat, corresponding to the variation of the mercurial thermometer, whose scale is divided into 80 equal parts, between the points of boiling water and of melting snow.

| Mercurial Thermometer. | Real Heats. | Real differences of the heat, corresponding to the variations of the mercurial thermometer, of 5 in 5 degrees. |
|------------------------|-------------|--|
| Boiling Water          | 80          | 80,00  |
|                        | 75          | 4,72   |
|                        | 70          | 4,72   |
|                        | 65          | 4,79   |
|                        | 60          | 4,81   |
|                        | 55          | 4,81   |
|                        | 50          | 4,89   |
|                        | 45          | 4,89   |
|                        | 40          | 4,97   |
|                        | 35          | 5,00   |
|                        | 30          | 5,08   |
|                        | 25          | 5,10   |
|                        | 20          | 5,10   |
|                        | 15          | 5,18   |
|                        | 10          | 5,20   |
|                        | 5           | 5,31   |
|                        | 0           | 5,43   |
| Melting Snow           |             | 80,00  |



terable and apyrous, as rock crystal ; but they are very few in number. 2. Where it destroys the aggregation, and converts them from a solid into a fluid. This phenomenon is named *fusion* ; the bodies which undergo it are fusible. There are different degrees of fusibility, from that of platina down to that of mercury. This fusibility, when urged to extreme, is volatilisation. A body is volatilised when, by a great rarefaction, it is converted from a liquid state to that of an aeriform fluid. Being then lighter than the atmospheric air, it ascends. 3. Bodies susceptible of this property are called *volatile* ; those which do not possess it, *fixed*. Many degrees of heat intervene between absolute fixity and absolute volatility. It is necessary to distinguish this real volatility from that which is but apparent, and which happens only in consequence of the motion communicated to bodies by the current or flame of vapours, as that of flowers of zinc. If heat act upon a body composed of two principles, the one of which is volatile and the other fixed, it produces a separation by volatilising the first. This body will be decomposed, but without alteration ; for we can restore it by uniting the two principles. This will be a true and simple analysis. The bodies upon which heat produces this effect are capable of decomposition, without suffering alteration. 4. If the bodies which we heat are composed of several volatile and fixed principles, the volatile principles unite, the fixed combine also ; but the decomposition is such, that the products united anew with the residuum cannot reproduce the first compound. This, then, is a false or complicated analysis. The bodies upon which heat acts in this manner suffer an alteration in their decomposition. In consequence of this various action of heat, chemists employ it to perform calcinations, fusions, distillations, sublimations ; the theory of which is founded entirely upon the different manner in which heat acts. As chemists employ different degrees of heat according to the preparations which they intend to make, they

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have



have carefully distinguished these degrees from one another. They fix them above and below boiling water. The inferior degrees are measured upon the thermometer: the superior degrees by some known phenomena.

*Degrees of heat inferior to boiling water.*

THE first degree extends from 5 to 8 of Reaumur's thermometer. This heat favours putrefaction, vegetation, slow evaporation, &c. The second degree fixed at 15 continues to encourage putrefaction; it raises the spirituous fermentation in the sweet liquids. The third degree extends from 25 to 30, the acetous fermentation is fixed, the exsiccation of plants.

The fourth degree raised to 45 is called the *mean degree of boiling water*; it disorganises animal matters, it volatilises their essented oils, &c.

Boiling water extends from 80 to 85 degrees of the same thermometer.

*Degrees of heat above boiling water.*

THE first degree reddens glass, consumes organised matter, fuses sulphur.

The second degree fuses the soft metals; such as lead, tin, bismuth, and the fusible glasses.

The third degree fuses the metals of a moderate hardness, as zinc, regulus of antimony, silver and gold.

The fourth degree bakes porcelaine, fuses the refractory metals, such as cobalt, copper, iron, &c.

The last degree, and the strongest of all, is the burning glass, which in an instant calcines, scorches, and vitrifies all bodies that are susceptible of these changes.

§ 5. *Of Phlogiston.*

BECCHER, surpris'd at the property which some bodies possess of producing fire in action by repeated motion, or by the contact of bodies in ignition, imagined that it depended upon a particular principle, which  
he



he called *inflammable earth*. Stahl has greatly enlarged this doctrine, and thought that this was the pure fire inherent in all bodies. He has given it the name of *phlogiston*. As it was as impossible for him to separate this principle, and detach and examine its particular properties, as it was for the philosophers to demonstrate the nature of the fluid which they called *fire*, he supposed the existence of phlogiston to be proved by the phenomena of combustion, and thought that the property which he constantly found in combustible bodies were owing to it: he ascribed a perfect identity to it in all bodies in which it exists; and he believed that the combinations into which it entered derived from it smell, opacity, or a deep colour, volatility, fusibility, and above all combustibility. Thus the inodorous, fixed, refractory, and incombustible bodies, acquire smell, volatility, fusibility, and inflammability, when they were combined with phlogiston.

Of this sort is sulphur, which, according to Stahl, is formed of this substance and the vitriolic acid; and such are the metals composed of a particular earth and phlogiston. The principle is separated during the calcination of the metals, and passes into the state of free fire.

We cannot but be sensible that there are many objections to be made to this doctrine.

1. Without seeking to deny it from the impossibility of demonstrating phlogiston, which can no longer be refused, since M. Macquer has substituted light for it, we observe, that the properties attributed by Stahl to phlogiston, do not appear in many bodies in which he admits this principle. Charcoal, and particularly that of the resins, which he looks upon as phlogiston almost pure, possesses neither smell, volatility, nor fusibility; it even possesses but a small degree of combustibility. The diamond, which is very infusible, very fixed, transparent, and free of odour, is perhaps the most combustible body known, since it consumes entirely and without residuum.



2. It often happens, that bodies, in losing phlogiston, acquire the properties which we generally ascribe to its presence, and which were even scarce perceptible before it was dissipated. The metals in their calcination, for the most part, assume a much deeper colour, as cobalt, mercury, lead, iron, copper.

3. In admitting with M. Macquer the light instead of the phlogiston, we do not see how it can be disengaged without making its properties apparent, particularly its clearness and brightness, by which it is always distinguished; nevertheless all the metals are susceptible of losing their phlogiston, without suffering a red heat.

4. The presence of the light in any of the bodies which Stahl looked upon as containing phlogiston, has not been demonstrated in a decisive manner.

These objections, to which we might have added many more if our object permitted us, and which we propose to illustrate hereafter, give to pneumatic chemistry, which several chemists, and particularly the late M. Bucquet, have adopted, an advantage over phlogiston, though perhaps it would be dangerous to esteem this doctrine as demonstrated, and to reject the doctrine of Stahl. In order to give a general idea of this new theory, which we call *pneumatic*, it is enough to add, that it is absolutely the inverse of that of Stahl.

1. According to this doctrine, the phlogisticated bodies of Stahl are substances which have a very great tendency to unite with the air; a tendency which in general constitutes combustibility.

2. All the instances in which Stahl thought the phlogiston disengaged, display only combinations with pure air: Such are combustion and calcination.

3. All those instances, on the contrary, in which the doctrine of Stahl supposes the phlogiston to form a combination, show the disengagement of the air according to the pneumatic theory. Such are the reduction of the metals, the decomposition of the acids by combustible bodies.



4. All the bodies which Stahl supposes to be compounds containing phlogiston, are looked upon, according to this doctrine, as simple substances, which have a great affinity with pure air. In the history of the air, of the acids, and particularly of the metals, a more particular illustration of this subject will be given; and we will take great care in comparing fully these two theories, in order to explain the advantages and disadvantages of each.

## LECTURE V.

### ART. 2. *Examination of the properties of Air.*

AIR, according to philosophers, is an invisible, ponderous, elastic, and spongy substance. It encircles our globe to a certain height, and is called the *atmosphere*. Notwithstanding its invisibility, its existence is proved from the resistance which it gives to the motion of bodies by its weight, and from the currents which we observe in it. For understanding it properly, we think it necessary to examine its properties, physical and chemical.

#### § 1. *Physical properties of Air.*

AIR is invisible, in consequence of its perfect transparency. The atmosphere, formed of an enormous mass of air, appears blue. The air is fluid; its masses are removed, and form the winds. Its fluidity is so essential to it, that no degree of cold has ever been able to destroy it. The air has taste: new-born animals, and the skin covered by the epidermis, are singularly sensible of its contact; habit by degrees renders this feeling imperceptible.

The air has weight. This is proved by these phenomena.

1. It resists bodies in motion; and this resistance increases in the duplicate ratio of the velocity of the body moved.

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2. We can weigh it in a balloon, and compare its weight with that of other bodies.

3. Its weight supports water at the height of 32 feet in the common pumps. The ancients ascribed this phenomenon to the horror of a vacuum. Torricelli, who has the merit of this nice discovery of the air's weight, demonstrated that fluids are supported at different heights according to their density, and that mercury is suspended at 28 inches. Paschal, in repeating the experiment in a pit and upon a mountain, has confirmed this theory; and proves, that according to the height of the atmosphere, the mercury mounts or descends, and varies about an inch in 100 toises. This is the theory of the barometer.

Air is elastic and compressible. Philosophers demonstrate this,

1. By the air-gun.
2. By the balloon.
3. By the fountain of compression.

It may be reduced by compression to 128th of its bulk.

The air possesses spunginess or expansibility: it always fills the same space of a pneumatic bell, although it is much diminished by the action of the piston. To explain this, the same quantity of air occupies more or less space in proportion as it is compressed or rarefied. This property makes the air, after being compressed, assume a greater volume than that which it had previous to its compression, as actually happens in the air-gun.

## § 2. *Chemical properties of Air* (c).

THESE were the only qualities which occupied the attention

(c) The air of the atmosphere is composed of various elastic fluids, every one of which possesses specific properties, which distinguish it from the rest. A thorough knowledge of those properties enables us to separate the different airs from one another, in order to examine them apart. When we do this, we learn that the qualities,



attention of natural philosophers. Some chemists, at whose head Van Helmont, Boyle, and Hales, ought to be placed, having perceived that in the analysis of many bodies some air escaped, have thought that this substance was combined and fixed; from whence the name

lities, which are commonly ascribed to the general mass of air, do in reality belong to one particular species, and are applicable to it only. We learn, for example, that one-fourth of the air of the atmosphere contributes to support animal life: the remainder is destructive and instantly kills. The useful portion of the air therefore deserves our attention, to ascertain the essential properties of it with accuracy. On account of the exclusive power to assist the respiration of animals, M. Lavoisier calls it *eminently respirable air*. On account of its ability to support the combustion of inflammable bodies, M. Scheele affixes the name of *empyreal* or *fire air*. Dr Priestly, from theoretical principles, chooses the term *dephlogisticated air*. The property of this air to promote the combustion of inflammable bodies, is by far the most striking to our senses. To be convinced of this, it is only necessary to immerse a small taper into a vessel filled with this air, when the wick will instantly blaze like a flambeau: the flame becomes larger, the light more vivid, and the heat more intense. By means of this air, bodies which had ceased to flame resume their luminous state; even those which were apparently extinguished, rekindle without the application of heat. It is indeed impossible to set a body on fire without the presence of some empyreal air, though it does not seem material whether this air be quite pure, or mixed with other air unfit for combustion. If it be pure, the flame is luminous and the combustion rapid; if it be impure, the flame is dull and the combustion slow: But in all cases an equal quantity of materials is consumed, the superior vivacity of the inflammation serving to compensate for the shortness of the time. This fact is well illustrated by experiments made on Kunckel's phosphorus. One grain of phosphorus requires 16 cubic inches of empyreal air for its complete inflammation; and provided this quantity be placed within reach, the phosphorus will burn completely away. The same experiment proves, that the whole air is absorbed by the phosphorus, which gains an accession of  $1\frac{1}{2}$  gr. in weight, just what 16 cubic inches of this air ought to weigh: So that empyreal air seems capable of entering into the composition of solid bodies. Perhaps this doctrine will be more clearly established, by considering the phenomena presented in the calcination of metals. In all cases of calcination, the calx proves heavier than the original metal from which it was prepared. In the case of *mercurius præcipitatus per se*, the absorbed air can be expelled by heat of its



name of *fixed air* first came, which has been given to that which is obtained in chemical operations. These first philosophers regarded this fluid as air. But Dr Priestley has found that several bodies possess the physical properties of this fluid, and yet differ from it in many respects. It is necessary then actually to have recourse

its former purity, and in full quantity, without sustaining loss. It is also remarkable, that the quantity of empyreal air present determines the quantity of metal calcined. The use of this air is equally important in the respiration of animals. Experiments show, that small animals live longer in this air than in any other; and those whom curiosity has induced to breathe empyreal air, find an uncommon hilarity of spirits after a few inspirations; so that no doubt remains of empyreal air being one of the great engines in the chief operations of nature.

There is another kind of air very different from this in all its characteristic properties. It destroys animals, extinguishes flame, and prevents the calcination of metals. This air is called *fixed air*, and more recently has been distinguished by the name of *aerial acid*, from a certain resemblance to the common acids in the effects which it produces, though it has never yet been obtained in a concrete form. But whatever may be its true constitution, we find it of great importance in the œconomy of nature. Many of the hardest bodies, all animal and vegetable substances, contain a large quantity of this air. Limestone, and the alkaline salts, owe nearly one half of their weight to its presence in their composition; and when it is expelled by heat, they both of them become caustic. It is emitted in great abundance from the crevices of subterraneous cavities, where it forms what is called the *choak damp of mines*.—This choak damp floats at the bottom under the common air, on account of a more considerable specific gravity, and in this way forms a distinct stratum. Fermenting liquors also emit large quantities of it. It is the separation of this air which communicates the sparkling appearance to all liquors, and to some mineral waters. The impregnation gives an acid taste to water, which instantly flies off when it is uncovered, on account of the volatility of the air. It is the presence of this air which enables water to dissolve the earths and metals, a property that water instantly loses when the air is dispelled. The specific gravity, the attraction for water, for alkalis and earths, distinguish this aerial fluid from all others. Whether it be a true primitive substance, or only a compound of empyreal air with some other principle, is a question not proper to discuss here.

The air next in order may itself be set on fire, and is therefore very justly termed *inflammable air*. Like all other inflammables, it burns



recourse to other properties, in order to distinguish air from the aeriform fluids. The chemical properties are the only means by which its characteristic difference can be established.

Upon inquiring what may be the distinct properties of

burns only when it is in contact with empyreal air. When pure or mixed with fixed air it cannot be kindled. From its elastic nature it expands over a wide space, and may have every particle contiguous to a sufficient quantity of empyreal air. In this situation a spark of fire pervades the whole mass in a moment, so that the flame bursts forth at once with a violent explosion. This air is most remarkable for its levity, the specific gravity of the common atmospheric air being above ten times greater.

Inflammable air admits of considerable varieties, according to the nature of the substances from which it is produced, and gives different residuums upon combustion; all of which are acid, as far as has been hitherto observed. Inflammable air produced from charcoal yields aerial acid; produced from solutions of metallic substances in the vitriolic, nitrous, or marine acids, it yields those respective acids. Æther converted into vapour in a vacuum, gives a permanent elastic vapour which is inflammable. The atmosphere which floats round the fraxinella is inflammable from the admixture of some essential oil: and M. Scheele is of opinion, that every inflammable air is composed of a very subtle oil. Inflammable air has of late been employed in the construction of air-balloons; though, till the invention be carried to greater perfection, we cannot pretend to say how far the application of its levity will prove useful to mankind.

The residuum which remains in the atmosphere after combustion is extremely noxious to animals. M. Lavoisier thinks it a primitive substance of an unchangeable nature, and gives it the name of *atmospheric mephitic*. Dr Priestley, on the contrary, takes it to be a combination of phlogiston with pure air; upon which account he calls it *phlogisticated air*. It is quite useless, and has been the subject of few experiments.

The different kinds of air hitherto mentioned, exist copiously in nature without preparation; those which remain to be considered, are all of them artificial productions.

The *nitrous air*, whose properties have been the most noticed, arises from the decomposition of nitrous acid. It may be produced by the distillation of nitre, by the dissolution of some metallic substances in nitrous acid, and by some other processes; but in all cases the air is exactly of the same quality. This air is a transparent fluid, not to be condensed by cold, nor to be absorbed by water.

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of air, we find in it two properties very capable of characterising it, and which seem to belong to it exclusively: The one is its favouring combustion; the other its supporting animal-life, by serving for respiration. It is extremely difficult to give a proper definition of  
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It may therefore be preserved in close vessels on the surface of water for a great length of time. But the moment atmospheric air gains access, it loses all transparency, parts with some heat, and becomes yellow. This singular phenomenon receives different explanations, though it is universally agreed that the change is owing to the empyreal air contained in the atmosphere. Dr Priestley imagines that the empyreal air deprives the nitrous air of some redundancy of phlogiston, when it is reduced to the state of nitrous acid. M. Lavoisier thinks that both airs unite to form nitrous acid. Nitrous air is more a matter of curiosity than of use.

Besides nitrous air, there is a *nitrous acid* air; which seems to be the nitrous acid converted into vapour, which is very quickly absorbed by water, though it cannot be condensed by cold.

The vitriolic and marine acids undergo similar changes. But the volatile alkali may be converted into an air which more resembles true nitrous air, as seemingly it arises from the resolution of the alkali into its constituent parts; volatile alkali distilled upon black manganese, or upon colcothar of vitriol, yields a peculiar kind of air. The same air is generated by the explosion of aurum fulminans, though the nature of it is not well understood, from the small number of experiments which have been made on the subject. Another species of volatile alkaline air is produced by heating a mixture of sal ammoniac and quicklime. This air forms different neutral salts by the admixture of the vapours of the nitrous and marine acids. It is the *volatile-alkaline* air spoke of by Dr Priestley; in whose works some observations will be found concerning its chief properties.

It only remains to make a few remarks on the nature of *hepatic air*. Hepatic air is produced from mixtures of sulphur with different substances by the effusion of the mineral acids. Nothing answers better than a mixture of sulphur and iron, distilled in a retort, preserving the residuum for this use. Hepatic air is distinguished by many properties. It does not precipitate lime-water: it is absorbed by water in considerable quantities, which acquires a hepatic smell and sweetish taste from it. A burning candle introduced into a vessel containing hepatic air is immediately extinguished: but if two-thirds be common air, the hepatic air kindles, filling the glass with a white thick smoke. This air then smells like volatile spirit of sulphur; and a white powder is deposited which consists of sulphur.

This



combustion; it is a collection of phenomena, which certain bodies called *combustible* exhibit, when heated with the concurrence of air; the principal of which are, heat, motion, flame, redness, and the total change of the burnt matter. We may perceive a great deal of difference among all the combustible bodies:—Some, as the oils, burn briskly with a shining flame; others are burnt almost without any perceptible flame, as several metals and well prepared charcoals; others consume with a slow motion, scarcely apparent, and without burning sensibly, but always with heat, as several metallic metals. Combustion takes place in all these cases: The body which has been burnt cannot be set on fire anew, and it is called by the general name of *cinder*, *charcoal*, or *calx*, according to its nature. The residuum which remains after combustion, is sometimes heavier than it was before it was burnt. This happens in all fixed combustible bodies. All those, on the contrary, whose inflammable matter is volatile, take fire with more rapidity than the former, and their residuum has lost the greatest part of its weight: of the last kind is wood, &c.

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This abstract of the doctrine of the gases was made out for the convenience of the reader, as many of the articles are more particularly mentioned by M. Fourcroy, when he treats of the substances from which they are produced.

We shall conclude this treatise with the following table, which exhibits the specific gravities and also the absolute weights of a cubic inch of the various elastic fluids, under a mean heat of the barometer and temperate degree of heat, which are the results of M. Fontana's experiments.

| Names of elastic fluids. | Their specific gravities. | Weight of a cubic inch in grains. |
|--------------------------|---------------------------|-----------------------------------|
| Common air               | 152                       | 0.385                             |
| Dephlogisticated air     | 160                       | 0.442                             |
| Phlogisticated air       | 140                       | 0.377                             |
| Fixed air                | 220                       | 0.57                              |
| Inflammable air          | 10                        | 0.035                             |
| Nitrous air              | 157                       | 0.399                             |
| Marine acid air          | 243                       | 0.654                             |
| Vitriolic acid air       | 300                       | 0.778                             |
| Alkaline air             | 70                        | 0.2                               |



So long as a combustible body is not volatile, combustion always adds to it absolute weight, as is observed in the metals.

One of the most important phenomena of combustion is, that it can never take place without the concurrence of air, and that it never does take place but in proportion to the quantity and purity of this fluid. This absolute need of air in combustion has surprised philosophers; and every one has proposed his opinion on the subject. Boerhaave believed, that by the application of air to the surface of combustible bodies, it assisted the separation of their principles. On this hypothesis, we do not understand why the same air is not always sufficient for combustion. M. de Morveau believed, that that depended on its too great rarefaction: although the fluids which have the same elasticity, and all the properties of air, cannot produce combustion. Stahl thought that this phenomenon was only the separation of fixed fire or of phlogiston: but he neglected the influence of the air; and his theory came short in this important point. By ingenious experiments upon the calcination of metals in determined quantities of air, M. Lavoisier has proved, what John Rey the physician had long before perceived, that air is absorbed during calcination; that the calcined metal acquires as much weight as the air loses; that the metallic calx is a combination of the metal with air, since we can reduce the calx of mercury by disengaging this fluid with the assistance of heat. Other facts have carried him still further. He has observed with Priestley, that the air remaining after calcination and combustion, can no longer serve for new calcinations: that it extinguishes combustion; suffocates animals; in a word, that it is no longer air; and that it is diminished exactly according to the quantity of it which had been absorbed by the combustible body. On the other hand, air obtained from metallic calxes is three or four times purer than that of the atmosphere: it alone can serve for



combustion; it accelerates and renders it much brisker than atmospheric air does. M. Priestley has called this fluid *dephlogisticated air*: we give it simply the name of *air*; because in effect it serves eminently for respiration and for combustion: to make use of the expression of M. Lavoisier, it is more air than common air. The atmospheric air, as these fine experiments show, is a fluid composed of about three-fourths of mephitic gas and one-fourth of pure air. This theory supposes that combustion is the combination of pure air with the combustible bodies, and the reason of this increase of weight. It seems to stand in need of nothing to render it more complete; although M. Macquer, who was very sensible how much these facts elucidate the nature of combustion, does not think that the action and separation of phlogiston in this grand phenomenon ought to be entirely rejected. He thinks that light, which he has substituted, as we have seen, for the phlogiston of Stahl, is combined in combustible bodies; that its separation is the first cause of combustion; but that it can never be disengaged but by the concurrence of air, because air is the precipitant of light, and it unites to combustible bodies in proportion as the light it separates from them is volatilized. Although we could make several objections to the theory of this celebrated man; as for example, to the considerable increase of metallic calxes, the reduction of several of these calxes without the concurrence of the light, the brilliant and deep colour which some of them assume in spite of the separation of this colouring principle; we think, however, that the respectable authority of so great a master constrains us not to reject phlogiston entirely. Besides, we are only the historian of opinions, and we think that several facts are wanting in the doctrine of gases to render it sufficient for explaining all the phenomena of chemistry without the concurrence of the inflammable principle. In short, whatever be the cause of combustion, our object in it is not the less answered;  
and



and we have proved that air is the only body that can serve for combustion, it cannot take place without the contact of the air. The air which has served a certain number of times for the support of this important function, is no longer proper for respiration: it kills animals, and extinguishes candles; it shows marks of a kind of acid, which we know by experiment; and it wholly resembles the air remaining after combustion, which is called *mephitic gas*, *phlogistic gas*, &c.

## LECTURE VI.

### ART. 3. *Examination of the properties of WATER.*

**W**ATER is an element, since it cannot be decomposed, and since it is to be obtained from the analysis of many bodies.

It is transparent, fluid, very moveable, and shows the following properties: A taste very well known to the drinkers of water; a fluidity susceptible of changes, and which is not its most natural state; specific gravity 850 times greater than that of air; an elasticity more or less remarkable according to its different states; a force of affinity very considerable.

It is found in almost all the bodies in nature, although art has not been able to combine it with several substances with which nature unites it every day.

Water is presented to us in three forms; in the form of ice, of fluidity, and of vapours. Its history comprehends that of mountains of ice, of lakes, of seas, of great rivers, of small rivers, of brooks, of clouds, of hail, of snow. It is also found in subterraneous cavities: it is one of the great agents of nature; it serves to form the mountains, to fill the vallies, to shake the caverns, and undermine the rocks, to hollow the cavities, to give rise to springs and fountains, to dissolve salts, to crystalize mineral substances, to purify the air. In order to have a full knowledge of the properties of water, it is not sufficient to consider it in general; it  

I

must



must be examined in its three different states, then it will be perceived what advantages may be reaped from this examination for the purposes of life.

§ 1. *Of Water in the state of Ice.*

Ice appears to be the natural state of water, since the natural state of a body, at least considered chemically, is that in which it has the strongest possible aggregation. The formation of ice presents phenomena of importance to be known.

1. A heat of some degrees is produced in the water that freezes; because it is a liquid body which becomes solid. A thermometer plunged into water that is frozen, stands at some degrees above 0; although another set in the open air when cold enough to make water freeze, be always at 0 or under it.

2. The access of the air favours the production of ice: water much confined freezes but very slowly.

3. A slight motion also accelerates this formation.

4. Ice is more bulky than the water before it froze, and bursts vessels of glass in which it is formed. It seems to be the disengagement of the air, which is the cause of the dilatation. Ice well formed is distinguished by the following properties.

1. Its form is either regular, and shows crystals like needles, which, according to the observation of M. Mairan, are joined at an angle of 60 or 120 degrees; or irregular, when it is formed rapidly and in a lump.

2. Its solidity is so great, that it can be reduced into powder, and carried off by the wind.

3. Its elasticity is very great, and much more remarkable than that of water in a state of fluidity.

4. It has a very strong taste approaching to causticity.

5. It is lighter than fluid water on which it floats.

6. Its transparency is interrupted by bubbles of air.

7. It melts at some degrees above 0, and with a great cold



8. It has a great power of combination with light, with air, and with the salts.

§ 2. *Of fluid Water.*

FLUID water possesses different properties.

1. Its taste is weaker.
2. Its elasticity is less. This was denied until M. l'Abbe Mongez demonstrated it by repeated experiments, the very same that had been used to call the truth of it in question.
3. Its state of fluid aggregation renders its force of combination more powerful: on that account it is called the great solvent of nature.
4. It appears not to combine with light, which only passes through it.
5. Heat dilates it, and converts it into a gas. This transition from a liquid state to that of an aeriform fluid constitutes its ebullition. Water boils at different temperatures according to the weight of the surrounding atmosphere, as Farenheit has discovered. When the air is very weighty, it requires more time and more heat, because the atmosphere which compresses it retards its rarefaction more. The same thing happens to all fluids; which, according to M. Lavoisier, may boil from two causes; the one is rarefaction by heat, the other the taking away of the weight of the atmosphere. Thus mercury may be made to boil *in vacuo*. Water boils *in vacuo* between 80 and 84 degrees of Reaumur's thermometer; it boils at 40 according to Huygens and the Abbe Nollet.
6. If water be heated in close vessels, with a distilling apparatus, it is collected in vapours, which when condensed form distilled waters. This is one means of separating it from the earthy and saline matters, which almost always alter it, and which at the end of the process remain at the bottom of the vessel. The chemists who require very pure water for their experiments, employ this method of purification. Distilled



water has an insipid taste; it occasions a sensation of weight in the stomach: by agitation with air, it acquires a brisk taste, and may then be drunk. Distillation does not change water (<sup>d</sup>). Boerhaave distilled it 500 times, and he observed no sensible alteration. It is not converted into earth, as some have imagined; but the small residuum which it leaves after a great number of distila-

(<sup>d</sup>) Although M. Fourcroy asserts the unchangeable nature of water upon the authority of M. Lavoisier, yet as the very accurate experiments of M. Margraaf on the same subject infer a different result, it may be proper to give an abridgement of them here.

The water employed was collected at some distance from any town, after the rain or snow had continued to fall for more than half a-day, which removed all suspicion of extraneous impurities. The retorts in which it was distilled were rinsed with distilled water; and after these precautions, he found that 100 measures, of 36 ounces each, yielded 100 grains of earth, which he judged to be calcareous. He then added 30 drops of a solution of fixed alkali to the water distilled into the receiver, which caused the deposition of a few grains more of calcareous earth; and by evaporation, some crystals of saline matter presented, part of which resembled nitre, and part marine salt.

The water from the melted snow afforded a similar product; only the proportion of marine salt was seemingly greater; and in both cases the salt was tinged of a yellow colour, from the impregnation of a small quantity of oily matter.

M. Margraaf continued to prosecute these inquiries with still greater exactness. As some suspicion had arisen of the earth being occasioned merely by the glass, he examined every part of the retort with the most scrupulous accuracy. He poured in distilled rain water, and excluded all access of external air, to prevent dust from mingling with the product. The distillation was repeated 30 times; and at the end of each distillation the water became turbid, though the introduction of any foreign matter was impossible. After this the retort was separated; and in place of being diminished in weight, it had rather increased. There was no erosion, no exfoliation, no inequality, but the surface was still smooth like new glass. M. Margraaf also found that exposure to the sun for some months, or agitation in a close vessel, was adequate to separate the earth. It was further remarkable, that more violent coction was requisite at the end than at the beginning of the operation; and that the deposition was copious, according to the force of the boiling. This earth proved infusible when exposed to the most violent fire under a muffle: part of it was soluble in nitrous acid, showing



distillations, is part of the glass vessels, the surface of which is by degrees destroyed, as M. Lavoisier has demonstrated.

§ 3. *Of Water in the state of Vapour.*

WATER in the state of vapour is distinguished,

1. By the appearance of a white cloud which it forms.
2. By its state of dilatation: it occupies 1400 times the space of fluid water.
3. By its weight, which is much less.
4. By its elasticity and springiness; which are so great, that it produces terrible explosions when it is confined; and in mechanics it may be employed to advantage to put large bodies in motion.
5. By its affinity of composition, which is so much the stronger as its aggregation is weaker.
6. By its manner of acting on light, which it seems like the prism to decompose.
7. By its union with the air this kind of combination forms dew; upon which the late M. le Roi the physician composed an interesting work.
8. By its action on burning bodies, which it seems to favour, as is observed in the eolipile, the enamelers lamp, wet fuel, oils set on fire which water cannot extinguish, and the flame of which it even augments. From these phenomena Boerhaave looked upon flame as chiefly formed of water.
9. Lastly, by its condensation into fluid water when it is exposed to a temperature above 0; and into small flakes, which form dendrites upon the windows when it suffers a sudden cold below the freezing point.

§ 4. *Ap-*

all the marks of calcareous earth. The remainder was fusible by the addition of an alkali.

These experiments of M. Margraaf afford strong presumption of the existence of an earth in the purest water; which is more evident to those who set a just value upon the accuracy and precision with which M. Margraaf conducted all his observations.



§ 4. *Application of these facts to the uses of Life.*

AFTER all these reflections upon water, it may be easily perceived, that it must vary from a great number of circumstances, and that all waters cannot be equally proper for drinking. The knowledge acquired upon this subject furnishes means of distinguishing waters that are fit for drinking, and of correcting such as are not so.

The drinkable waters may be easily known by the following characters.

1. They have a brisk and sharp taste.
2. They have no smell.
3. They boil easily.
4. They make ready pot-herbs well.
5. They dissolve soap without forming lumps.
6. They deposit nothing or very little by tests.

The methods of correcting those which have not these qualities are,

a. Agitation, which favours the deposition and separation of heterogeneous matters.

b. Boiling; which disengages gaseous substances, and separates selenite.

c. Exposure to the air. This fluid by combining with water gives it a brisk taste, lightness, and other properties.

d. Filtration; the tendency of which is to separate mechanically the foreign matters that change it.

e. Motion in canals and cascades, which facilitates its combination with the air.

f. Attention to pools and ponds, in order to free them from plants and insects; the putrefaction of which renders the waters fetid and unwholesome.

## L E C T U R E. VII.

### ART. 4. EXAMINATION of the PROPERTIES of EARTH.

#### § 1. *Of Earth in general.*

THE name of earth was given very anciently to every hard, dry, insipid substance which entered into the composition of the globe. The ancient philo-



sophers reckoned it an element. Paracelsus looked upon every thing as earth which remained fixed after chemical operations. Beccher, Stahl, and Boerhaave, have only admitted the vitrifiable earth as an element; they supposed that all the rest could be melted into glass.

Several earthy substances different from one another are at present known, the vitrifiable, argillaceous, and weighty earths. It is not then an identical substance, a simple element. Earths have been confounded also with saline matters; such as magnesia, gypsum, lime, the bare bones, the ashes of vegetables, metallic calces, and other substances.

The history of earth, then, comprehends that of several substances, which, as will be pointed out more fully hereafter, possess common characters with it.

§ 2. *General distinction of Earth into three sorts. General division of the Minerals.*

WE are acquainted with three sorts of earths only which differ from one another. The first, upon which the fire has no action, and which is not altered either in its hardness or transparency, we mean that which is called *vitrescent earth*. The second, which by its hardness and infusibility resembles the first; but which, however, differs very much from it in this, that the action of the fire deprives it of its transparency and hardness, and reduces it into white, opaque, and friable earth, which shows the beginning of a sensible alteration, we call it *quartz earth*, because it makes the base of the quartz.

These two first kinds of earth cannot be acted upon by any of the menstrua which combine with the third, as we are just going to see. They only enter into fusion by the addition of alkaline salts, and then form glass, which has for a long time determined the naturalists to design them by the name of *vitrifiable earths*. The third kind of earth is less hard than the foregoing; it never strikes fire with steel, however strong its ag-  
grega-



gregation: it acquires so great a hardness by the action of a well conducted heat, that it equals that of the two first kinds; and in water it becomes capable of forming a paste, which receives all sorts of forms. This earth, called *argillaceous*, unites with the acids, and with them forms particular salts.

M. Bucquet admitted a fourth kind of simple earth, some of the characters of which resemble those of clay; but which, he says, does not form alum with the vitriolic acid, as the latter does. It was called by the name of *false clay*; but this clay not being as yet known, we do not look upon it here as a particular kind. In the following lectures it will be noticed, that, according to M. Bucquet, this earth existed in some stony matters.

After having thus treated of earths in general, we come next to consider them in particular; but this examination making part of the history of the mineral kingdom, we should stop a moment on the nature and difference of the bodies which form it.

The name of *mineralogy* has been given to that part of natural history which treats of minerals: We examine them first, because they are more simple than vegetables and animals, and because their properties are more early understood. We divide all the minerals into three great classes. The first comprehends the earths and stones. In the second, we place the saline substances. The third contains the inflammable or combustible matters.

We will go through each of these classes after one another. Let us previously cast a rapid glance on the structure of our globe.

### § 3. *General reflections on the Globe and its Alterations.*

As the minerals, and in particular the earths and stones, serve to form the mass of our globe, it is necessary, previous to the examination of the properties of these bodies in particular, to consider, in a cursory manner,



the structure and the alterations of the world which we inhabit.

The terrestrial globe, considered in general, presents at first sight a singular irregularity, both externally and internally. It appears thick set with mountains, and hollowed with cavities. Its surface is very unequal: its bowels are either solid or hollow; either containing a single mass of matter, or formed into beds or layers; or, lastly, irregularly mixed with different substances. A more accurate examination shows order and a regular arrangement in the world: the great mountains are continuous; the middle-sized ones correspond in their juttings out and angles: the substances which they contain are laid in horizontal or inclined beds; the earths are always external, the stones more deep, the bitumens in large masses, the metals in veins.

From these general observations, naturalists have drawn conclusions upon the history of the globe; these have been called the *theory of the earth*. The authors who have written on this subject may be divided into two classes: the first contains the systematics, of whom we will say nothing; the second comprehends the observers. The latter distinguish three worlds in the globe. The ancient world: this appellation they give to the high mountains, which are formed of a hard matter, almost unalterable. The middle world, which shows marks of alterations, to which an epoch cannot be assigned. The new world, which undergoes alterations even to our own eyes, and of which consequently the epochs may be known. The alterations which the world has undergone, and which it undergoes every day, may be ascribed to four classes of agents.

1. The first of these agents is heat. It fuses, volatilizes, mixes, combines, calcines, vitrifies. It produces volcanos, which may be divided into three orders. The first order comprehends those of which there remain no traces but in their products: Of this sort are those of Auvergne. The second order presents mouths

or



or craters of extinguished volcanos; as those of Vivarais. In the third order, the volcanos which still burn may be placed; as Vesuvius. Particular characters distinguish the products of volcanos; the form, the absence of water and organic substances, the very coloured and often very opaque crystals, the volatilized, fused, and vitrified substances.

2. Water is the second agent which alters the globe; it is likewise the most general. The seas, the rivers, the torrents, the rains, are so many agents that in their own way change the surface of the earth. The motion and currents of the first deposit the matter in beds, which form the mountains of the second and third order; the waters of the heaven waste others of them; those which are filtrated dissolve the salts, and deposit them in crystals, in stalactites. The substances produced from water are known by their form and by their nature; they contain organic matter; they present transparent and very regular crystals.

3. The air acts by its currents, which occasion the winds; it displaces and raises up the sand: confined in the subterraneous cavities, and suddenly rarefied by heat, it bursts asunder every obstacle, and makes caverns shake; it opens up mouths, through which the matter thrown out by the volcanos are discharged.

4. The saline substances constitute the fourth class of agents which alter the globe. Their action is not so general as that of the three first; they combine with the earths and with the metals; they burn inflammable substances.

## MINERAL KINGDOM.

### *First Class of Minerals—EARTHS and STONES.*

THE earths and stones, which we confound together because they differ only in their aggregation, are characterised by their absolute insipidity, hardness, dryness, very little tendency to combination, insolubility  
in



in water, a perfect infusibility when they are pure, or fusibility greater or lesser, always corresponding with their combination or mixture with other substances.

As our object is to treat of the natural history of stones and earths, it is necessary to establish distinct characters between them. For this end we offer two divisions of these substances.

The one, which we call the *natural division*, is entirely founded on the physical properties; such as the form, the hardness, the transparency or capacity, fracture, vitreous or lamellated, the colour, the polish, the property of striking fire with steel. The knowledge of the earth and stones by their apparent qualities, is absolutely necessary, before we consider their chemical nature. For this purpose, let us employ this first method, which is that of the naturalists.

The other division is drawn from the chemical properties. We are sensible we cannot gain an intimate knowledge of the earths and stones by it at first sight; and that, in order to ascertain their chemical nature, it is necessary to destroy their form and all their physical properties: So we do not propose it as a method adapted to render us intimately acquainted with these substances; but rather as a collection of chemical facts, which it is of very great importance to collect.

*Natural Division of Earths and Stones by the aid of Characters which the eye may distinguish.*

MANY minerologists have offered methods of distinguishing the earths and stones by their physical properties; but the great number and obscurity of their divisions have already embarrassed those who study them. M. Daubenton, who is so justly celebrated for the extent and utility of his discoveries in natural history, being well apprised of these difficulties, thought proper to give to the earths and stones distinct characters, simple and easy to be known, and upon the whole making a contrast between them, in such a manner that it is impossible



able to confound these substances with one another. He has presented his division and his characters in form of a Table to the Royal College in his course of Natural History. As we know nothing more methodical, more clear, and at the same time more complete in this kind, we think it proper to give here the principal divisions of this naturalist.

SANDS, EARTHS, and STONES.

THESE substances do not dissolve in water as the salts do, have no smell like sulphur and the bitumens, nor brilliancy like the metallic substances.

FIRST CLASS.

*Stones which strike fire with steel.*

*Vitreous quartzzy stones.*

| Genera.  | Species.   |
|--|--|
| 1. Free-stone and sands.<br>Granulated fracture, the grains detached and vitreous. | 1. Free stone.<br>2. Sand.   |
| 2. Crystal.<br>Crystalline substance, vitreous fracture.                           | 1. Transparent.<br>2. Semitransparent.<br>3. Opaque.   |
| 3. Cats-eye stones.  | 1. Sparkling spar.<br>Sparry fracture, rhomboidal form.<br>2. Aventurine.<br>Reddish.<br>3. Cats-eye.<br>4. Fishes-eye.<br>5. Girasols, stained red and blue.<br>6. Girasols pale. |

Genera.



## Genera.

## Species.

4. Semitransparent stones.  
Vitreous fracture, semi-  
scaly.

1. Agates.  
All colours except the  
milky white, the fine red,  
and the green.
2. Chalcedony.  
Of all colours.
3. Cornelian.  
Fine red.
4. Sardonyx.  
Orange.
5. Flints.  
Grey, light, black.
6. Prase.  
Green.
7. Jade.  
Polished, greasy.
8. Stone-flint.  
The transparency of  
wax.

5. Opaque stones.  
Vitreous fracture, some-  
times scaly, sometimes  
dull.

1. Millstones.  
More or less porous.
2. Flinty.  
Concentric layers.
3. Jasper.  
Vitreous fracture, often  
dull, without concentric  
layers.

*Vitreous lamellated Stones.*

## Genera.

## Species.

6. Gem crystals.

M. Daubenton places  
here the stones called *pre-  
cious*, of which he reckons  
twenty species; in which he  
places the diamond, and  
which he disposes according  
to the colours of the prism.

*Stones,*



*Stones which contains calcareous and quartzzy Earths.*

| Genera.   | Species.   |
|---|--|
| 7. Azure stones.<br>Opaque, and of a fine blue. | <div> <div></div> <div> 1. Oriental.<br/>2. Pale blue. </div> </div> |

*Stones which contain calcareous, quartzzy, and aluminous Earth.*

| Genera.  | Species.  |
|--|---|
| 8. Zeolite.<br>Generally in diverging rays, and soluble into a gelly by acids. | <div> <div></div> <div>Sparkling.</div> </div>  |
| 9. Schorl.   | <div> <div></div> <div> 1. Crystallized.<br/>2. Sparry. </div> </div>   |
| 10. Argillaceous stones.<br>Fracture fimilar to that of dried clay.            | <div> <div></div> <div> Hard schiftis, leafy-like fracture. M. Daubenton places in this species the stone of coma and trap. </div> </div> |

SECOND CLASS.

*Stones which do not strike fire with steel, and which do not effervesce with acids.*

| Genera.   | Species.  |
|---|---|
| 1. Soft clays.<br>They are ductile and dry, and are polished between the fingers. | <div> <div></div> <div> 1. Absolutely infusible.<br/>2. In part fusible.<br/>3. Entirely fusible. </div> </div> |
| 2. Argillaceous earths.<br>According to the 10th genus of the first class.        | <div> <div></div> <div> Soft schiftis.<br/>Leafy fracture. </div> </div>  |

*Stones of an uncertain nature.*

|   |   |
|---|---|
| 3. Talc.<br>Polished laminæ and glittering without sparry fracture. | <div> <div></div> <div> 1. In great leaves.<br/>2. In small leaves. </div> </div> |
|---|---|

4. Stea-



| Genera   | Species   |
|--|---|
| 4. Steatites.<br>Soft to the touch like<br>tallow.                             | { 1. In layers.<br>2. Compacted.<br>3. Lapis ollaris.                 |
| 5. Serpentine.<br>The polish and the colours<br>of marble.                     | { 1. Opake.<br>2. Semi-transparent.                                   |
| 6. Amianthus.<br>Filaments not calcinable,<br>flexible, lighter than<br>water. | { 1. In flexible filaments;<br>2. In hard filaments.<br>3. In leaves. |
| 7. Zeolite.<br>According to the eighth<br>genus of the first clafs.            | { 1. Sparry.<br>2. Compacted.<br>3. Blue.                             |
| 8. Sparry fluors.  |   |

As these are true salts, the history will be found in the article on these substances. M. Daubenton should look upon these substances as stones, since they have neither solubility, odour, nor brilliancy.

*Gypseous Substances.*

9. Gypsum.

It is just like the sparry fluors; it is a true salt, but with the apparent properties of stones. They will be treated of in detail in the history of the Saline Substances.

T H I R D C L A S S.

EARTHS and STONES which effervesce with Acids.

*Calcareous Substances.*

ALL these substances have been hitherto looked upon as stones, and indeed they have neither taste nor apparent solubility. However, as they are truly composed of two saline substances, we insert their history in the article of the *Salts*. But as the object of the Naturalists is very different, they ought to range them among the stones.

*Pro-*



*Products of Volcanos.*

## Genera

## Species

## Lavas.

Volcanic matters, that is to say, formed by volcanos.

- |   |   |
|---|---|
| { | 1. Weighty scorizæ.   |
| { | 2. Basaltes.  |
| { | Compact, sparkling, granulated fracture, grey or black, with brilliant points, without leaves like those of schistes. |
| { | 3. In glafs.  |

## 2. Volcanized matters.

That is to say, altered by the heat of the volcanos, indicated by roasting, by calcination, fusion, or vitrification.

## 3. Mixed products.

That is, formed by the mixture of the two preceding, together or separately.

## LECTURE VIII.

*Chemical Division of the EARTHS and STONES.*

**W**E divide the earths and stones, considered chemically, into three sections. The first contains the simple earths and stones; the second, the compound earths and stones; the third, the mixed earths and stones (*a.*)

The simple earths and stones very pure, are insipid, dry, hard, insoluble, and infusible. If any of them seem to differ from these characters, particularly in having a sort of fusibility, it is always owing to the mixture of some strange matters. Chemical analysis cannot separate those when very pure into several substances.

The compound earths and stones ought to be looked upon as combinations of different simple earths with the

(*a*) This division, which entirely belongs to M. Bucquet, is undoubtedly very far from the scrupulous exactness which the chemists might desire. It is even very faulty in several points, as we shall observe; and we only present it as a work begun by this chemist, and which requires a long set of experiments before it be amended.



the saline and metallic substances. These combinations have been made in the great laboratory of nature by means of water or fire. Their chemical characters are the following: they are fusible, give different glasses by the action of the fire, and which admit of separation into several simple substances by the action of the solvents, particularly of the acids.

The mixed earths and stones are distinguishable by the eye: they seem formed by the irregular assemblage of different stones, or of simple and compound earths. We know, that to make an analysis of them, we must separate the different matters which are irregularly mixed, and examine apart these substances from one another; after that, chemical experiments may indicate their nature with certainty.

#### § I. *Simple EARTHS and STONES.*

*We divide them into four Orders.*

##### ORDER I. *Vitreous Stones.*

THEY are of an extreme hardness and a perfect transparency; their fracture is vitreous; they strike fire with steel: heat alters neither their transparency nor hardness.

This first order contains two genera; rock crystal, and the precious vitreous stones.

##### GENUS I. *Rock Crystal.*

Rock crystal presents all the characters of vitreous stones in the most remarkable degree. It is distinguished from the following genus by its fracture, which is like that of glass.

It may be divided into its different species.

##### 1. *From the form.*

Species

1. Isolated hexædral crystals, with two hexædral pyramids; they occasion a double refraction, according to M. l'Abbe Rochon.
2. Hexædral crystals united in one or two points.
3. Threc.



## Species.

3. Three-sided crystals, twelve-sided, flattened, &c.  
They are always hexædral, with surfaces varied and irregular.
4. Rock crystal in a lump from Madagascar; it occasions only a simple refraction.

2. *From the Colour.*

5. Red rock crystal.
6. Smoky crystals.
7. Black crystals.

3. *From accidental Varieties.*

8. Hollow rock crystal.
9. With water.
10. Set crystals.
11. Round crystals, flint of the Rhine.
12. Crystals encrusted with metallic calxes.
13. Crystals en geodes.
14. Crystals containing amianthus.
15. Crystals containing schorl.
16. Crystals encrusted with pyrites.

Their formation by water is proved,

1. By their transparency.
2. By the form of the small crystals.
3. By two inclosed crystals.
4. By the substances alterable by the fire which they contain.

It is cut to make vases and jewels.

GENUS II. *Precious Vitreous Stones.*

THE precious stones which we place here have all the characters of rock crystal, and particularly its perfect unalterability by the fire. Although this seems to invert the natural order, and though M. Bergman declares that he found in these stones several substances combined, their hardness, their transparency, the manner in which they are acted on by the fire, make them ap-



proximate to rock crystal (*a*). They differ, however, in a very considerable hardness, a more lively and pretty colour, a lamellated fracture. The chemical difference which subsists between all the precious stones, in particular in their manner of being altered by the fire, has induced us to separate them from one another, and to refer

(*a*) Mr Fourcroy here alludes to an essay of M. Bergman, which presents a most beautiful instance of chemical analysis, and which clearly explains the nature of all the genus, except the diamond. Many difficulties occurred to be surmounted before the investigation could be made complete. The great value of the materials rendered it expensive to obtain specimens in sufficient quantity: their great hardness renders them difficult of being reduced to a powder fit for experiment: while common crucibles cannot be employed, as the alkaline salts made use of to promote the fusion act upon them, as well as upon the subject of essay. Heat alone, without the addition of some powerful flux, has no effect in altering the appearance of the gems. Vitriolic acid extracts a portion of iron and calcareous earth, but leaves the remainder totally infusible in the fire: the other acids do the same thing; and the fact favours the conjecture, that all the gems are formed of a peculiar kind of earth, different from any to be found in other stones. But when some very pure mineral alkali is employed to loosen their texture, they may then be resolved into simple earths. M. Bergman took one part of any gem in powder, and two of fixed alkali: this he put into a small coppel of iron, with the cavity well polished, to diminish the chance of scorification. He placed this coppel on a bit of tile in an air furnace, and covered it with an inverted crucible. He carefully avoided the blast of a bellows, which calcines the iron, and adulterates the product. An incipient fusion is sufficient to open the texture of the gem; and when the fusion is made complete, the melted button adheres to the surface of the iron, and never can be entirely detached. After this operation, the acids dissolved a much larger portion than before, and left the remainder insoluble by the longest digestion, and infusible by the strongest heat. It was, however, convertible into glass by the addition of an alkali, and showed all the signs of a pure siliceous earth. The solution, in the marine acid, was next subjected to experiment: he first added some Prussian alkali to separate the iron; then he filtrated the solution, and added some mild alkali to precipitate the earthy matters. This precipitate was washed, and some vinegar poured upon it, which dissolves the calcareous earth and magnesia, but leaves the argillaceous earth untouched. The remainder at this time was dissolved in vitriolic acid, and gave pure and perfect alum. The matters dissolved



refer them to the orders of the stones with which each of them seems to have the greatest relation.

These four precious stones, which we distinguish from the rest by the name of *Vitreous*, are,

Species

1. The oriental topaz.
2. The hyacinth.
3. The oriental sapphire.
4. The amethyst.

M. Daubenton always esteemed this last as a crystal of quartz.

I 2

OR-

solved by the vinegar were then thrown down by the addition of some mild alkali. The precipitate was washed, and was known to contain nothing but terra ponderosa, calcareous earth, and magnesia. The vitriolic acid dissolves all these earths. With magnesia it forms Epsom salt, soluble in twice its weight of water; with terra ponderosa, the gypsum ponderosum, not to be dissolved in 1000 times its weight of water; with calcareous earth, common gypsum, soluble in 500 times its weight of water; and by the addition of acid of sugar, an insoluble salt is formed, which falls to the bottom of the vessel. After this very accurate mode of examination, M. Bergman found that all the gems were composed of those kinds of earth, the argillaceous, the siliceous, and the calcareous; and that all of them owed their colour to the admixture of a small proportion of iron. The results of all his experiments were, that of 100 parts employed in the analysis,

|                       | Argill. | Silic. | Calc. | Iron. |
|-----------------------|---------|--------|-------|-------|
| The emerald contained | 60      | 24     | 8     | 6     |
| Sapphire              | 58      | 35     | 5     | 2     |
| Topaz                 | 46      | 39     | 8     | 6     |
| Hyacinth              | 40      | 25     | 20    | 13    |
| Ruby                  | 40      | 39     | 9     | 10    |

When we consider the composition of those beautiful jewels, on which mankind has at all times set so high a value on account of their brilliant colours, we find reason to admire the simplicity of nature in all her operations. It is wonderful to discover all the gems composed of four simple ingredients, united in various proportions. It is still more wonderful that human art is able to imitate the external appearance of them all, by the employment of different materials. The basis of artificial jewels is the same in all, but the colouring matter is different in each of them. Gold gives red, lead yellow, cobalt blue, iron green, manganese purple. This branch of manufacture is more particularly explained in the Lecture upon Glass.



ORDER II. *Quartz Stones.*

THEY have less hardness and transparency than the first, their fracture is vitreous, they strike fire with steel; heat makes them lose their hardness and transparency, and reduces them into a white and opaque earth. We rank four genera of stones in this order.

GENUS I. *Quartz.*

It unites all these characters.

## Species

1. Transparent quartz crystallized into hexagonal pyramids without very evident prisms, or with very short prisms.
2. Transparent quartz in a mass.
3. Opake or milky quartz.
4. Flat quartz.
5. Rotten quartz.
6. Coloured quartz, a prism of amethyst.
7. Yellow quartz with lamellated fracture.

Topaz

{ of Saxony.  
{ of Brasil.

These topazes have all the characters of quartzes.

GENUS II. *Flint, Agate.*

The flints and the agates form small round masses, most often opake, sometimes semitransparent, hollow, or solid, differently coloured, and disposed in beds in chalk, as the flints, or in clay, as the agates. Their fracture sometimes is scaly.

## Species.

1. Grey flint.
2. Yellow flint.
3. Red flint.
4. Horned flint, for firelocks.
5. Brown flint of Egypt.
6. Transparent, shadowed flint; German agate.
7. Red agate, cornelian.
8. Red pale agate, fleshy.

9. Brown



9. Brown or yellow agate, sardonyx.
10. Agate onyx, disposed in concentric layers.
11. Agate — disposed in horizontal layers, which depends on their cutting.
12. Figured agates.  
Dendrites.  
Anthropomorphite.  
Zoomorphite.  
Uranomorphite.
13. Agatelike parsley, marked with small green points.
14. Agate of four colours, elementary agate.
15. Grey agate, grey chalcedony.
16. White agate, white chalcedony.
17. Chalcedony in beds.
18. Chalcedony in stalactites.
19. Chalcedony rolled up, cacholong.
20. White agate, shining with different rays.  
Cats eye of the lapidaries.  
Cats eye.  
Oculus mundi.
21. Natural aventurine.
22. Opake.
23. Girasol.
24. Oriental agate.

The formation of the quartz, agates, and flints, is owing to water; as is proved by, 1. Their form. 2. Their layers. 3. Their masses. 4. The water which they contain. 5. The organic substances which are mixed with it, as in the mass of agates.

The history of the geodes also proves this formation; these are the stony boxes filled with crystals; some flint and quartz are found with it disposed in beds.

### GENUS III. *Organic matters made of Flint and Agate.*

THE organic form still distinguishable, joined to the characters of the quartz earths, distinguish them from the three other genera of this order.



## Species.

1. Petrified wood still fibrous and susceptible of polish.
2. Wood whose species is distinguishable on account of its texture ; fir.
3. Wood and madrepores silicified.
4. Shells become agates.
5. Carpolites. These have been falsely looked upon as petrified fruits : they are small ludus helmontii, become flint.
6. Entrochites.
7. Fruit-stone become silicious. It strikes fire with steel, does not effervesce with acids : it seems to be formed of cornu ammonis cut perpendicularly to their volutes.

There are two opinions on petrification. Some imagine that the organized matters have been entirely changed into stone ; others suppose that the vacuums left in the soft earths by animal-substances, or the intervals of the fibrous texture of vegetables, have been filled by the earthy matter which is gradually deposited. There is nothing certain of the causes of this phenomenon. It is observed that vegetable matters almost always become quartzzy ; whilst animal matters for the most part become calcareous, and rarely quartzzy ; and that vegetable almost never pass with their texture to the calcareous state.

GENUS IV. *Jasper.*

THE jasper has all the characters of quartzzy stones : It is not fusible ; it loses its aggregation by the fire. It is a very hard stone, capable of a fine polish, opaque, variegated with different colours. Its fracture is vitreous and dull. It is rarely found arranged in beds. It more often forms considerable masses or veins in the rocks. It is also found in small or rounded masses. The most part of the specimens of jasper are mixed with quartz and chalcedony, some contain calcareous spar.

The species of jasper have been very greatly multiplied



plied by the naturalists. They may be reduced to the following.

Species.

1. White jasper.
2. Grey.
3. Yellow.
4. Red.
5. Brown.
6. Green.
7. Veined.
8. Stained.
9. Green, with red points.  
Bloody.
10. Flowered.

Toys, and chiefly cups and seals, are made with the jasper. The ancient engravings are almost always on these stones.

#### GENUS V. *Free Stone.*

FREE stone is opaque, of a granulated fracture, much less hard than the quartz and flints; it is in enormous masses, more or less hard, of a more or less fine and compact grain.

Species

1. Free-stone crystallized in rhomboids. M. de Laffone has demonstrated, Memoirs of the Academy 1777, that their form is owing only to the chalk which is united to them.
  2. Free-stone in the form of colliflowers, balls, &c.
  3. Free-stone in stalagmites.
  4. White free-stone.
  5. Grey free-stone.
  6. Red free-stone.
  7. Black or brown free-stone.
  8. Veined free-stone.
  9. Figured or herborised free-stone.
  10. Free-stone whose aggregation is destroyed; sand.
- The sand presents the following varieties,

I 4

1. Quick-



## Varieties.

1. Quick-sand.
2. Cornered sand.
3. Sand rounded by water.
4. Sand pure and white.
5. Micaceous sand ; glarea.
6. Yellow and argillaceous sand ; sand of the founders.
7. Martial sand, yellow.
8. ——— black.
9. Blue sand, coppery.
10. Sand of tin, violet.
11. Golden sand.

## LECTURE IX.

ORDER III. *Argillaceous* EARTHS and STONES.

*They are fat, flexible, adhering to the tongue, leafy, often coloured, disposed in large masses and in beds.*

THEIR aggregation is not so strong as that of the quartzey earths ; they have a greater force of combination : we also often find them altered. Heat makes them contract, and renders them so hard that they imitate the quartzey stones : water reduces them into a paste ; divides and purifies them. They unite to it, and retain it so strongly, that they cannot be deprived of the last portions.

A part of their substance unites with the acids.—Some chemists have thought that clay was only the siliceous earth altered by the vitriolic acid : But this opinion has not been directly proved.

On the two properties of making a paste with water, and of hardening by heat, the arts of making tiles and bricks, pottery, Dutch and porcelain wares, depend ;—the details of which belong to the history of these earths.

The naturalists have described a great number of species of these stones. They have confounded with them many false clays, as well as compound stones, as the serpentine, the zeolite, the trap. We ought to give the name of clay only to those earths which turn hard



hard with the fire, can be washed with water, and form alum with the vitriolic acid.

M. Macquer, who has examined a great number of them, has not found any absolutely pure: it is to the mixture of different combustible and metallic substances that the colour and fusibility of several among them are owing.

We distinguish four genera of them.

GENUS I. *Soft and ductile Clays.*

They may be kneaded when they come out of the quarries, and they dry with the air.

Species.

1. White clay, pipe clay.
2. Sandy clay.
3. Flexible clay, blackish, for the white potteries.
4. Clay with mica; kaolin, in part fusible, for porcelain.
5. Metallic clay, fusible; terra figillata, Armenian bole.
6. Pyritous clay, fusible, blue, green, marbled, for common potteries.

GENUS II. *Dry friable Clays.*

Tripolis.

Species.

1. Dry, grey, leafy clay; fuller's-clay.
2. Red tripoli; some regard it as a volcanic production.
3. Grey tripoli.
4. Black tripoli.
5. Rotten stone, of a grey olive.

GENUS III. *The Schistus.*

The schisti are leafy stones, which peel off in laminæ; they are very mixed and fusible.

Species.

1. Black, slender.
2. Fissile schistus; slate.
3. Black, hard schistus; sheet slate.
4. Red, brown schistus.
5. Schif-



Species.

5. Schistus, with vegetable and animal impressions.
6. Very hard schistus.

#### GENUS IV. *Felt Spar.*

It is formed of rhomboidal laminæ: its fracture is sparry; it gives sparks with steel; on that account it is called *sparkling spar*. It is harder than the schisti, and is fusible. M. Bucquet looked upon it as an argillaceous earth, coloured with iron. M. Monet says, that it is composed of quartz, clay, magnesia, and a little calcareous earth. M. Daubenton has placed it among the quartz, vitreous, and cats-eye stones. This naturalist told me, that there he found a felt-spar crystallised in prisms. The difference of the opinions of the nature of felt-spar is owing to its not being well known. A farther examination will determine its place.

Species.

1. Prismatic felt-spar.
2. White felt-spar.
3. Red felt-spar.
4. Green felt-spar.
5. Blue felt-spar.

#### ORDER IV. *False Clays.*

These are clays only of a leafy texture, fat appearance; Some harden with the fire.

They differ from them in this, that they do not make a paste with water, and the most part fuse. They produce with the vitriolic acid a salt in needles, which is not altered by the air, which is soluble in four or five parts of water, and which does not bubble on the fire: in a word, which is not alum. These characters have been given by M. Bucquet, who had examined several of these stones: As for the rest, as they are only but very little known, they may be ranked after the clays.

#### GENUS I. *Lapides Ollares, hard.*

Their texture is a little leafy; their appearance fatty; and they take but a bad polish.



## Species.

1. Grey lapis ollaris of Sweden.
2. Green ; colubrine of Sweden.
3. Yellow.
4. Brilliant green ; jade. The nephritic stone, and that of Otaheite, were, according to M. Bucquet, varieties of jade. We should observe, that jade is very hard, and strikes fire with steel. It is undoubtedly after Mr Pott that M. Bucquet placed it among the lapides ollares.

5. Dirty green lapis ollaris ; colubrine stone.
6. Serpentine. Stone of a deep green colour, and as if blackish, streaked with stains or black veins, like the skin of serpents. We have put it at the end of the lapides ollares, on account of its appearance : however, it appears to be compounded.

GENUS II. *Tender Lapidés Ollares.**Steatites, or Smeclites.*

## Species.

1. White steatite, compact ; chalk of Briançon.
2. Clay of Briançon, brilliant ; talc of Venice among the druggists.
3. White steatites of Norway.
4. Red marbled steatite of Norway.
5. Reddish steatite of Norway.
6. Green steatite, compact, of Norway.
7. Green and red steatite of Norway.
8. Green-leaved steatite, tender colubrine of Norway.
9. Black steatite ; stone-cutters stone.
10. Grey and brilliant steatite ; plumbago molybdæna, and very improperly mineral of lead. It is reduced into powder : it is formed into a liquid paste with a solution of fish-glue. This paste is run into small cylinders of hollow wood, which are cut at an end to make crayons.



GENUS III. *Talc.*

It is formed of polished and shining laminæ, of a gelatinous transparency, which adhere to one another like leaves: with a violent fire it fuses into a coloured glass.

## Species.

1. Talc, in large transparent spangles; Muscovy glass.
2. Talc, in very small argentine spangles; cat silver.
3. Talc, in very small golden spangles; cat gold. These two species are used to dry writing, under the name of *silver* or *gold dust*.
4. Talc, rounded into the form of pebbles.
5. Talc, in black spangles.
6. Talc, in mixed brilliant spangles.

GENUS IV. *Amianthus, Asbestus.*

This kind of stones is formed of fibres or filaments, placed parallel at the side of one another: these filaments are either stiff or flexible; they differ in their length, disposition, colour, and thickness. The ancients span them, and made a cloth called *incombustible linen*, in which they burnt the dead, and collected the cinders. With a strong fire the amianthus is easily fused into a coloured and opaque glass.

## Species.

1. Hard and grey asbestus in parallel filaments; woody asbestus.
2. Asbestus, hard and green, in parallel filaments.
3. Asbestus, hard and green, in bundled fibres.
4. Asbestus, in starred fibres.
5. Asbestus, in soft fibres.
6. Hard amianthus, in parallel and greenish fibres.
7. Hard amianthus, in parallel and white fibres.
8. Amianthus, in white brilliant bundles.
9. Amianthus, in hard yellow bundles; amianthus not soft.



## Species.

10. White flexible amianthus ; soft amianthus.
11. Grey amianthus.
12. Mountain flesh.
13. Mountain leather.
14. Mountain cork.

## LECTURE X.

§ 2. COMPOUND EARTHS *and* STONES.

THE eye cannot distinguish them from those of the first section. With respect to their character of composition, they are formed of a homogeneous matter, almost always coloured, often opaque, sometimes transparent. The most of them are regularly crystallized. Their form, their colour, serve to distinguish the genera. They are all very fusible, and produce glasses of a different nature. Their fracture is sometimes vitreous, sometimes flinty. They are substances in which nature has combined together earths, salts, and metals.

M. Bucket divided these stones into two orders : In the first he comprehended the earths and stones composed by water ; to which he gave the characters peculiar to the products of this element. In this order he ranked two genera, viz. the ochres and the zeolite. In the second he placed the schorl, the macles, the trap, the azure stone, the fusible precious stones, the crystals of volcanos, the glasses of volcanos, the pumice stones. He thought these eight genera of stones formed by the action of fire. We think we ought to relate the ideas which this celebrated chemist had formed on the nature and division of the stones ; but as the distinguishing character of these two orders is not yet founded on numerous and conclusive proofs, as M. Bucquet himself had proposed them only by way of hint, we shall here relate the history of the genera, one after the other, without following this division.



GENUS I. *Ochres.*

The ochres are less diffusible through water than the clays; they are friable, and stain the fingers; they are coloured by metallic substances. When we urge them with the fire, their colour loses its intensity: they fuse with a violent heat. It is used in painting.

Species.

1. Yellow ochre; ochre of rue.
2. Red ochre, bloody, red crayon.
3. Green ochre, earth of Verrone.
4. Brown ochre, earth of ombre.

GENUS II. *Zeolite.*

The zeolite, for the first time described by M. Cronstedt, is a stone formed of needles, which diverge from a common centre. It does not strike fire with steel, nor effervesce with the acids: it fuses like borax with a gentle heat; it bubbles up, and gives a transparent glass. If it is distilled in a retort, we obtain a good quantity of water. The residuum, according to M. Bergman, contains siliceous earth, argillaceous earth, and magnesia. M. Bucquet, who made a very complete analysis of it, found in it very little siliceous earth, and a particular earth which is neither argillaceous nor calcareous; which forms with the vitriolic acid a crystallizable salt, in small brilliant spangles, like those of sedative salt. These two earths are crystallized together by the aid of the water, which makes up more than one-eighth of it; for M. Bucquet extracted a gross and a half of water from an ounce of white zeolite of the island of Feroe. The property of making a jelly with the acids is not peculiar to it, since it is found in the azure stone, tin, several minerals of iron. We are unacquainted with its origin and formation: it is found in abundance in volcanic productions. We know five species of it.

Species.

1. White zeolite, in transparent bundles.
2. ———, in compact bundles.

3. Red



## Species.

3. Red zeolite.

4. Green zeolite.

5. Blue zeolite.

The red, green, and blue, have not been examined; and they have only the transparency of the zeolites.

GENUS III. *Schorl*.

Schorl is a deep-coloured stone, being violet, black, or green, rarely white, very brittle, and strikes fire with steel. It easily fuses into a black and opaque glass. It contains, according to M. Bucquet, some clay and earth combined. M. Daubenton places it among the stones which contain the quartz, aluminous and calcareous earths. He found in the heart of the schorls bubbles resembling those we observe in the flags of glass-houses. We are not well acquainted with its origin. Some persons think it a volcanic production, because it is frequently found where volcanos have been: But it is also found among matters that have been overflowed with waters.

## Species.

1. Violet schorl, crystallized.

2. ———, in fibrous masses.

3. Black schorl, in prisms with four, six, eight or nine faces, with pyramids with two, three, or four sides; as also the violet schorl.

4. Black schorl in masses.

5. Green schorl, in lamellated masses.

6. White schorl, bluish.

7. Electric schorl, of a yellow reddish; tourmaline.

GENUS IV. *Macles*.

By this name we understand prismatic stones, opaque, of a dirty colour, often of a very regular form: Their analysis made by M. Bucquet approaches to the schorls. They are a compound of clay and iron.

## Species.

1. Three-sided macle, whose impression bears the figure



figure of a cross. M. Daubenton thinks it a petrification, and does not range it among the stones. Are they not perhaps petrified vertebræ?

2. *Lapides cruces*, macles of Brittany; hexaëdral prisms, joined and laid across by the middle like branches of a cross. They are found in the leaves of yellow mica: The two branches never cross at a right angle.

#### GENUS V. *Trap*.

The trap is a hard stone, of a fine grain, of a leafy and angular fracture like the steps of a stair. It is of a deep green colour, inclining to black, often ochry: It is very heavy; strikes fire with steel: it fuses into a blackish glass. It is always covered with a kind of rind softer than its own substance. It is formed of clay and iron, which, according to M. Bucquet, is to the clay in the proportion of 25 lb. in the 100; so that it might be regarded as a mineral of iron. M. Daubenton places it among the hard and sparkling schisti. We know only one sort of trap, which has been just described.

#### GENUS VI. *Azure Stone, Lapis Lazuli* (b).

Its colour, the fineness of its grain, and its analysis, which has demonstrated it to contain iron, occasion its being ranked at the end of the preceding. There are three species of it.

#### Orien-

(b) *Lapis lazuli* is much esteemed for the use it is of in preparing the pigment called *ultra-marine*. This pigment affords the most beautiful blue colour which painters have ever been able to obtain, besides enjoying the farther advantage of being extremely durable. On these accounts it is in great reputation, and sold at a considerable price from the trouble of preparing it. The stone itself is of a deep mazarine blue, interspersed with yellow veins, which shine like spangles of gold. This beautiful diversity is owing to the presence of some martial pyrites. The colour of the stone was supposed to depend upon the admixture of copper, until Mr Margraaf clearly proved the existence of iron, and that no copper entered into the composition. It is imported from Cyprus and Persia by the Venetians; and Pere du Halde says, that lapis lazuli is to be found in great abundance in the kingdom of China.



## Species.

1. Oriental azure stone.
2. Azure stone, of a pale blue, and often purple.
3. Armenian stone, variegated with white and pale blue.

Mr Daubenton, who ranks it among the first class of the stones which strike fire with steel, made it an article apart, under the title of *Stone which contains calcareous and quartzey earths*.

GENUS VII. *Crystals, fusible Gems.*

The chemical differences which are found between the different species of precious stones, or stone gems, have led us to separate them from one another, and to refer each of them to the sections and orders to which they seem to belong; those which we place here are manifestly compounded. M. Bergman has found several substances in them; such as the siliceous earth, clay, lime, magnesia, and metallic calxes. All these stones are fusible, and composed of laminæ; their fracture is lamellated.

## Species.

1. Aqua marina.
2. Emerald.
3. Chrysolite.
4. Ruby.
5. Vermilion.
6. Granate.

GENUS VIII. *Crystals of Volcanos.*

We give this name to the species of regular stones, transparent, coloured, and like to the gem crystals, but which do not seem to have their hardness and brilliancy. They are found in the cavities, formed by the union of small brilliant particles of the same nature, agglutinated. They are found in the neighbourhood of volcanos; but we do not know if they are formed by the fire. Of them we admit three species.



## Species.

1. Volcanic crysolite, in crystals with many sides of a golden green.
2. Volcanic hyacinth, in crystals with many sides of an orange yellow.
3. Volcanic granates: they greatly resemble isolated granates, but they are irregular, and set in brilliant stones, or kinds of lavas, like the two preceding.

GENUS IX. *Pumice Stones.*

The most part of pumice stones appears to be an assemblage of vitreous filaments, twisted like threads upon a clue. It is a real combination of different substances, fused by the volcanic fire. We may distinguish four species of pumice stones, each of which presents a great number of varieties.

## Species.

1. Pumice-stone, white, fibrous.
2. ————, coloured, fibrous.
3. ————, cellular and light.
4. ————, cellular and compact.

GENUS X. *Glass of Volcanos.*

The glasses fused and thrown out by the volcanos are formed of earthy and saline matters, coloured by iron or some other metallic substance: They are true chemical combinations, made by nature in the dry way.

## Species.

1. Greenish, cellular glass.
2. Blackish glass, cellular or in agglutinated fibres.
3. Black glass, very fine and transparent; agate of Iceland; lapis obsidionalis of the ancients.

## LECTURE XI.

§ 3. *Mixed EARTHS and STONES.*

THE character of the stones of this section may be easily known. We need only to inspect the mixture of the different matters of which they are formed, particularly



ticularly when we compare them with those of the two preceding sections. We have already fully remarked, that in order to analyze them, we must separate the different substances which compose them by the hammer; then we find in them the simple stones combined with the compound stones. If we expose these stones entire to the action of the fire, they all fuse, more or less easily, into a glass of different colours, in proportion as the mixture is more or less perfect, and the nature of the subjects which constitute this mixture.

It appears that nature has formed them by the approximation of the different substances found in them, and that this approximation has been made by water or fire. This is the reason why M. Bucquet was induced to divide this third section into two orders, like the preceding: the first order comprehends the stones mixed by the water; and the second, those by the fire. This division is founded on many more facts than that of the second section; we therefore admit it with more confidence.

#### ORDER I. EARTHS *and* STONES *mixed by* WATER.

##### GENUS I. *Flint Stone or Rock Stone.*

By this name the naturalists understand a stone of a middle hardness, between that of soft stones and flint. M. Daubenton has placed it among the vitreous stones, because it gives some sparks with steel, and has a vitreous fracture sometimes a little flinty. Flint stone has a semitransparency, resembling that of wax; it is dull and without any brilliancy; it has also a small appearance of tallow: its grain is very fine and very compact; it is found in large masses, often in beds differently variegated, applied to one another. M. Bucquet gave it as a chemical character its fusing into an opaque glass: its mixture is nothing near so apparent as that of the following genera; it seems to possess the characters of the compound stones, wherefore we place



it at the head of the third section; it may be an intermediate state between these two divisions (\*).

The form of its layers, the matters which it frequently contains, and particularly the masses of it in the heart of the earth, shew that it owes its formation to water.

Species.

1. Grey flint stone.
2. Reddish flint stone.
3. Greenish flint stone.
4. Brown flint stone.
5. Black flint stone.
6. Stained flint stone.
7. Veined flint stone.

#### GENUS II.

The pudding-stone is a mixture of flints united by a cement of a different nature. This cement is either of the nature of free stone, or is argillaceous, or ochry: it is sometimes hard and like flint.

Its formation is not equivocal; it is owing to the water; it is constantly found at the sea shore, or in places which have been covered by the water, and which they have for some time left.

Species.

1. Pudding-stone, sandy.
2. ——— ———, ochry.
3. ——— ———, argillaceous.

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(\*) It is necessary to observe, that these characters, drawn from the action of the fire on these stones, are founded on the experiments made by M. le Duc de la Rouchefoucault and by M. Bucquet, in an excellent fusing furnace, properly constructed in the laboratory, which the distinguished lover of chemistry just now mentioned destines for inquiries the most proper to advance the knowledge of the science. I have examined the greatest part of the results of this work, which will one day be communicated to the public; it will confirm the elegant set of experiments made by M. d'Arcet, and will add to them several facts, which will serve as proofs of the chemical characters, with which, according to M. Bucquet, I propose to class the stones.



Species.

4. Pudding-stone, filiceous.
5. ——— mixed with agate, susceptible of finest polish.

### GENUS III. *Granate*.

THE granate is formed of three stony matters, in fragments more or less large, united to one another. These three substances are, quartz, felt spar, and mica.

It strikes fire with steel on account of the quartz and felt spar which it contains; its fracture is irregular, and in coarse grains; it is fusible, but in different degrees, according to the respective quantity of the three matters which form it. It is capable of receiving more or less lively polish, according to the fineness of its grain and the hardness of its principles. Some sorts are altered and spoiled by the air. This makes the ancient granates be distinguished from the modern. The species of granate have been greatly multiplied. We reduce them to the following.

Species.

1. White granate.
2. Grey granate.
3. Red granate.
4. Brown granate.
5. Green granate.
6. Black granate.
7. Dull and friable granate: it has been altered by the air.

### GENUS IV. *Porphyry*.

THE porphyry is a stone thick set with stains, upon a red or some other coloured bottom; it strikes off a good deal of fire with steel. It differs from the granate in its greater hardness, and in its being susceptible of a much finer polish; it seems formed of felt spar and shorl, united by cement of jasper.

The paste which forms the foundation of the porphyry is very fine and compact. The different fragments interspersed in it, are in general much smaller



than those of the granate. It is fusible, and gives a coloured glass: We may reduce all the species to the seven following.

Species.

1. Porphyry, red, with great stains.
2. Porphyry, red, with small stains.
3. Green porphyry with great stains.
4. Green porphyry with small stains.
5. Black porphyry with great stains.
6. Black porphyry with small stains.
7. Coarse porphyry, of a dirty red, almost without stains, a sea shell: it approaches to the nature of free stone.

GENUS V. *Ophite*.

PLINY gave the name of *ophites* to the stones stained like the skin of serpents: M. Bucquet looked upon them as species of porphyry; but harder, more ancient, and of a much more intimate mixture. The ophite strikes fire with steel; its fracture is fine and semi-flinty; it fuses with fire. The principal sorts which we have had occasion to see are the following.

Species.

1. Ophite of a deep green, with large white stains.
2. Ophite of a deep green, with oblong stains of a pale green.
3. Ophite like the former, whose stains are very small, little appearing; some savage nations cut it for coin. We have given it the name of *thundering stone*.
4. Brown ophite, with irregular oblong stains of a rosy white.

The origin of the ophites is very obscure. We do not well know whether they are owing to the action of water or of fire. As they have some analogy with the porphyry, we have placed them after this stone.



## LECTURE XII.

ORDER II. EARTHS and STONES mixed by the FIRE.  
*Volcanic Products.*

WE have no doubt of the origin of the substances which compose this order, since they are always found about volcanos, or in those places which have been formerly burning. Besides, they present all the characters of products of fire. By joining the genera which it contains to those we have described among the compound stones, we shall have a complete view of all the volcanic products. We do not comprehend under this name all the substances found about volcanos, and which are not altered by fire like the most part of the stones which we have already described; particularly the granite, the clays, as also several saline substances: they present nothing particular; and it would be only a useless repetition to insert here their history.

GENUS I. *Volcanic Cinders* (<sup>b</sup>).

We have given the improper name of *volcanic cinders* to the earthy powdery matters which are found about

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vol-

(<sup>b</sup>) Volcanos, in the time of eruption, eject a vast variety of substances. Some of those are the products of fusion by fire; others are common natural bodies, which have undergone no change by any subterraneous operation. Such were the shells which mount Vesuvius threw out in the eruption of the year 1631. But when the heat has been more intense, the original structure is completely destroyed, and the volcanic matter is thrown out in the form of ashes, lava, and pumice. The quantity of ashes is sometimes so prodigious, as to overwhelm a whole country in ruin by a single eruption. In this way the towns of Herculaneum, Pompeia, and Stabia, were buried under a mass of ashes and calcined matter in the year 79.

The nature of these substances is very particularly described by M. Bergman. They consist of a spongy powder, more or less dark in the colour, and which is sometimes attracted by the magnet. It commonly goes by the name of *Puzzolane earth*, 100 parts of which contain 55 of an impure flint, 20 parts of clay, 5 of calcareous earth, and 20 of iron. The proportion is not quite uniform in all speci-



volcanos. It appears, that they owe their origin, either to substances mixed and rejected by the volcanos, or to the lavas altered by the contact of the air or of water. M. Bucquet looked upon them as combinations of clay and iron. They often are attractable by the magnet. We know two species of them.

Species.

1. Rapillo, of a blackish grey, found about the craters.
2. Puzzolane. This substance, which has got its name from the city of Puzzoli, where it was employed very anciently, is an argillaceous earth, charged

specimens. From this analysis Puzzolane earth seems to be a ferruginous clay, altered by the action of the subterraneous fire. Architects make great use of Puzzolane earth in the construction of buildings under water, on account of the property it possesses of concreting into a solid stone soon after the mixture with quicklime. The tufa of the Italians is this substance, compacted into a coherent mass in the course of many years.

True pumice-stone consists of slender, parallel, fragile fibres, and being full of cavities, very much resembles the texture of a sponge, and is so light as to float on the surface of water. Acids dissolve 8 or 10 parts in 100, chiefly magnesia, with a small admixture of calcareous earth; the remainder is entirely siliceous. This proportion of ingredients approaches nearly to the composition of albestus; from which it is probable the pumice has been formed.

*Lava* is the name given to the ignited currents of liquid matter, which flows from volcanos. The extent of ground which they sometimes cover is quite incredible. An eruption of lava came from mount Hæcla in Iceland 90 miles long by 40 broad. The accounts of this inundation which have lately arrived, bear great marks of authenticity. The appearance of lava varies according to the violence of the fire to which it has been exposed. That subjected to the most intense heat is fused into perfect glass: Some is reduced into a semivitrified mass, and the remainder is left porous from the want of sufficient fluidity to permit the escape of the air. But whatever may have been the state of liquefaction, the proportion of the component parts is the same in all, being 69 parts of flint, 22 parts of clay, and 9 parts of iron. The colour of lava is in general black or dark grey, although shapeless pieces are sometimes found transparent and tinged with colour, and which in brilliancy and hardness almost equal the gems. Every kind of lava is hard enough to strike fire with steel.

The three substances mentioned commonly compose the matter which is ejected; the other substances are more accidental.



charged with iron, and of different colours, according to the state of this metal. There is grey, yellow, red, brown, and black Puzzolane. It fuses into a black enamel: It is very useful to make a kind of mortar, which has the property of hardening in the fire. M. Foujas de Saint Fond found it in Vivarais. He thinks that these earths are formed by the alteration and destruction of the porous lavas, and even of the basaltés. This observer has, in his researches upon Puzzolane, detailed the processes for formation in the water and with the air with this substance.

#### GENUS II. *Lavas.*

This name is given to the substances fused and semi-vitrified by the volcanos. They are most frequently thrown out on the sides of the mountains with which the inside is filled. The matters form burning rivers, which sometimes flow to a very great distance, and ravage and destroy all the places over which they pass. Their heat and size are so considerable, that they cool only very slowly, and only in several years. When they cool, they split and separate into masses, which sometimes present regular forms. Cabinets contain a great number of varieties of these stones. They are in general composed of a paste of a more or less deep grey, of a grain and hardness very varied; in which crystals on irregular fragments of schorl, granates, glass, &c. are found, which constitute a true mixture. It is impossible to fix the general characters of the lavas, as they all differ in their grain, their coherence, their hardness, their colour, &c. In general they are all very fusible, and give a kind of black enamel, resembling the glass of volcanos. M. Cadet has found in them clay, iron, copper, and quartz.

1. Ten



## Species.

1. Tender lava, of different colours, with crystals of black schorl.
2. Tender lava, of different colours, with crystals of green schorl.
3. Tender lava, of different colours, with crystals of white schorl.
4. Reddish lava, with blackish crystals.
5. Yellowish and saline lava.
6. Tender lava, with crystals of granate.
7. Cats-eye and porous lava.
8. Porous grey lava; Volvic stone.
9. Tender blackish lava, with white crystals.
10. Grey lava, a little compact, set with twelve-sided crystals, opaque, or with granates altered by the fire.
11. Ancient lava, of a blackish grey, set with deeper stains.

GENUS III. *Basaltes.*

Nothing is less accurate in the books of the naturalists than that which they have described by *basaltes*. Under this name several have confounded the schorls, the granates, with the true basaltes. We cannot find any where a good definition of this word. Some have thought them volcanic products; others supposed them formed by water. From the observations of M. Desmarets, we think we ought to adopt the first opinion. For a distinct character of the basaltes, we may give their regular form, a perfect opacity, so considerable a hardness that they strike fire with steel; a grey cindry colour, inclining a little to black, and a manifest mixture of small vitrified fragments, generally more coloured. The basaltes are fusible.

In this genus there are stones of an enormous size, and collected into very considerable masses, whose formation seems to refer to the greatest antiquity.—

1. These are they which form the Giants Causeway



in the county of Antrim in Ireland: 2. The rock of Pereneire, before St Sandoux in Auvergne, very well described by M. Desmarets. These stones are symmetrically arranged at the side of one another. Their analysis has as yet not been very completely made, so as to be able to say any thing certain about their nature. It seems that they are only lavas crystallized by a slow cooling.

Species.

1. Basaltes in polygonal prisms, very long, and without a regular pyramid.
2. Basaltes in short prisms, and truncated, with three, four, five, or seven sides.
3. Basaltes in short prisms, polygonal, terminated by a superior concavity and by an inferior convexity; articulated basaltes.

#### GENUS IV. *Scoriæ of Lavas.*

The fused matter, which constitutes the lavas, is a mixture formed of several heterogeneous substances, of a different density and weight. Its slow cooling gives occasion to the separation of these substances, according to the order of their weight. This is the origin of the formation of the scoriæ of lavas. They are bodies often spongy, which have not undergone so complete a fusion as the lava, and which have been raised to the top of it by their lightness. As for the rest, they seem to be of the same nature, and differ only in a less perfect mixture. In them are found crystals of schorl and of granates, as in the lavas.

Species.

1. Weighty volcanic scoriæ, of a compact texture.
2. Volcanic scoriæ, black and cellular.
3. ———, ———, and spongy.
4. Volcanic scoriæ, black.
5. Volcanic scoriæ, yellow and ochry.
6. Volcanic scoriæ, reddish.

GENUS



GENUS V. *Volcanized Substances.*

We give, along with M. Daubenton, the name of *volcanized substances* to those altered by the action of the fire. The three genera hitherto examined are entirely formed by the volcanos; but those which compose this fourth are still very distinguishable, for being able to be referred to the two preceding sections. They have only been either calcined, baked, or semivitrified: Such as,

1. Schorl. It has lost its polish: It frequently shows round bubbles like flags, which indicates a vitrification.

2. Quartz. It is friable and opaque, or full of flaws, and also a little transparent.

3. The granite. It is less hard, and as if calcined.

4. The grenat. Exposed to a gentle fire it becomes white opaque, sometimes hard, often so very friable as to fall into powder as soon as touched. The twelve-sided form which it preserves, or the cavity which it leaves in the stones which have enveloped it, always distinguish it. Some authors have called it *impure* or *unripe grenat*.

## SECOND CLASS of MINERALS.

## SALINE SUBSTANCES:

CHEMISTS have given the character of *saline* to every substance which possesses taste and solubility in water. But as these two characters are found in many substances which are not saline, recourse must be had to other properties, in order to design this second class of minerals. We believe that the four following properties may be admitted as distinct characters of the saline substances: taste, solubility in water, a more or less remarkable tendency to combination, and a perfect incombustibility.

These four properties, however, do not prevail equally in all the salts; of consequence, before examining these substances in particular, we must fix our ideas upon the



characters which we assign to them, that we may clearly distinguish all their varieties.

§ 1. *Of Taste, considered as a character of the Saline Substances.*

TASTE is nothing but a sensation excited upon the organ of taste by the sapid body. This property has been looked upon as so peculiar to saline substances, that several philosophers have ranked among them all the bodies which have taste: However, it is not far from being the same in all. Some have a very strong taste, so strong as to corrode and destroy our organs; then it receives the appellation of *causticity*, and the bodies which have it are called *caustic*. The taste of others, although sensible, and capable of producing remarkable changes in the animal œconomy, is, however, far from being able to derange and alter the texture of parts. This middle taste commonly leaves on the tongue a varied impression, which has been called by several names, as *bitterness*, *astringency*, &c. Lastly, some salts appear absolutely to want taste, or only to possess it in a very small degree.

All these sensations, more or less perceptible, appear to be only different degrees of the same property. If, then, we want to penetrate into the knowledge of their cause, we will do it with more certainty and more facility, by investigating that taste which is the most pungent. The name of *caustic* has been given to those substances, the taste of which is so strong as to redden our organs, because their action resembles much that of active heat. Chemists have entertained different opinions on the cause of causticity. Lemery thought that it was owing to the introduction of fire into the pores of the caustic substance. M. Baumé adopted the same opinion. But as the fluid called *fire* by Naturalists, has not been at all understood, we cannot admit this system.

Meyer, an apothecary of Osnaburg, endeavoured to  
prove



prove by a set of experiments, that the cause of causticity consisted in the union of a mixt or of an acid, which he called *causticum*, or *acidum pingue*, and which he supposed to come from fire. According to this chemist, when this acid was combined in lime, it passed from it into the alkalis. He has by no means demonstrated the presence of this substance; and besides, Dr Black, by conclusive experiments, which have since been repeated by every chemist, has proved, that in the reciprocal action of lime and the alkalis, decompositions take place, of which Meyer had not the slightest idea.

M. Macquer thought that causticity consisted only in the effort which the sapid body makes to combine with our organs, and in the very act of this combination. This sublime theory, to which it would be impossible to add any thing after what has been said by this learned man under the article *Causticity* in his Chemical Dictionary, strictly corresponds with every fact relative to the taste of saline matter. It is founded in an essential manner on the four following observations.

1. The most sapid substances are those which have the greatest tendency to combination.

2. Those which have not that quality have but a weak taste.

3. A caustic body, whose tendency to combination is satisfied, at the same time loses its taste.

4. A caustic body which exerts all its force on our organs, combines with their proper substance, destroys them, and accordingly loses its causticity. Nothing is better demonstrated in physic than the cause of taste, after the relation of these facts.

We think it necessary to add to the knowledge acquired upon taste in general, that it is of great importance to physicians to distinguish the degrees, as well as the slightest varieties, of this property, upon which they can establish the principal virtues of medicines and the action of certain poisons. With these views, we propose in our course a division of tastes, according to the



the sensibility of our different organs, upon which this property, which is much more extensive than has hitherto been believed, exercises its action. The first class of tastes comprehends the bodies which act on the skin, corrode and destroy it; it includes all the caustic bodies. The second class comprehends the substances, the action of which is scarce sensible on the skin, but affects the more delicate organs, whose epidermis is not so thick; such as the mouth and tongue. The third class comprehends the bodies, the taste of which has no effect on the skin and tongue, but acts upon the very fine and very sensible membrane of the stomach and intestines; such are several emetics and purgatives, which have no taste in the mouth, but commonly act with great violence on the organs of digestion. The fourth and last class comprehends tastes the most inconsiderable and the least sensible

which we have just mentioned; but the action of which, however, is very remarkable upon the organs of sensibility, that is to say, on the brain and the nerves. These are the calming and narcotic medicines, which never possess any action but by means of the most attenuated and volatile parts, those which constitute their odour.

§ 2. *Of Solubility in Water, considered as a Character of Saline Substances.*

SOLUBILITY in water has been looked upon by chemists as one of the grand characters of saline matter. However, it is not more essential to it than taste is, and both depend absolutely on the same cause. It is found so considerable and so extensive in some salts, that they cannot be freed from the last portions of water but by the most tedious and intricate processes. Others possess it in a moderate degree only; which may be calculated exactly, as has been done in a great number of saline substances. Lastly, there are some of them in which we find almost no solubility at all, and which by this difference vary much from the former. From this property,



property, however, Stahl was led to regard the salts as intimately combined with water and with an earth. This ground theory, adopted by M. Macquer, and supported by every thing which chemistry can furnish from facts suited to confirm it, in the article *Salt* in the Chemical Dictionary, ought only to be looked upon as a sketch, very far from a perfect demonstration, and which modern discoveries even seem to invalidate, as will be shown in some of the following Lectures.

§ 3. *Of the tendency to Combination, considered as a character of Saline Substances.*

IF we consider the whole class of saline substances with which the mineral kingdom presents us, we will soon perceive, that in all the productions of nature there is not a more powerful agent than some of those substances. Their tendency to combination, or their affinity of composition, is so great, that they are capable of destroying the aggregation, which is often very strong, of a great number of bodies; so that they reduce them into very fine molecules, and sometimes into fluid substances.

Such is the action of the most part of the mineral acids. In the same manner chemists employ them every day to great advantage, and have given them the name of *solvents* or *menstrua*: But in taking a view of the mineral salts, we are soon convinced that the same thing holds with respect to this third character as with the two first; that is to say, that it presents numberless varieties, and that it is found in degrees very different from one another. In short, there are several saline substances which have no remarkable taste, nor very considerable solubility, nor strong tendency to combination. Analysis, or the method of decomposition, then, is the most certain means to discover their nature, and to refer them to their true class. However, though these three first characters are very imperceptible in some salts, yet when compared with the same pro-



properties observed in the earthy or combustible bodies, we will always find in them a more considerable power, and we will then be able to determine their distinction; particularly if we have recourse to the examination of the fourth character, which we are just going to mention.

§ 4. *Of the Incombustibility considered as a character of the Saline Substances.*

It is more difficult to determine this fourth character than the three first. As yet no chemist has considered these substances under this point of view: Several have even supposed that some salts, among others nitre, possess a true combustibility. To be certain that they are deceived in this point, and that all the saline mineral matters are perfectly incombustible, it were necessary to be much more advanced in the history of the properties of these substances. However, as we suppose this character to be one of the most obvious and most essential to be known among the salts, it is proper here to present a brief account of the doctrine which we propose to deliver on this subject, and which shall be clearly elucidated, and absolutely put out of doubt, in the details which we are to give upon the saline substances in particular.

It is demonstrated by the nice experiments of M. Lavoisier, that, after combustion, combustible matters leave for a residuum an acid of a particular nature.

Combustion is nothing else, as we have explained more fully, but a combination of pure air with combustible bodies. Every body which has burnt, that is to say, which has combined with pure air, enters into the class of incombustible bodies; or, what is the same thing, its tendency to combine with pure air is satisfied, and it is no longer capable of uniting with it. These principles being once proved, if on the one hand it is found that several salts are the residuums of several combustible matters, and if on the other hand all



the salts appear to contain pure air, and to resemble consumed bodies, it is known why they can be no longer combustible. These analogies are founded upon a great number of facts, as we shall explain more fully afterwards; and it is clear they demonstrate that the salts are very compound substances, and formed mostly by the union of certain combustible bodies with pure air. After what has been said, it is very easy to understand how this character of incombustibility comes to be the most certain and the most constant attendant of saline substances. With respect to the demonstration of these important truths, we hope to render it complete, by the details which will form the particular history of every one of these substances.

§ 5. *Of the division of the mineral Salts.*

THE number of salts which the mineral kingdom comprehends is very great. Several of them are the production of nature, which forms salts by the action of fire, of water, of air, and by the destruction of organic bodies: But the greatest part owe their formation to art. For the sake of treating the history of them methodically, we think it necessary to divide them into orders, genera, and species, as we have done to the stones.

We comprehend all the saline mineral substances in two orders.

The *first* contains the saline substances, which are called *simple*, and go under the name of *primitive salts*.

The *second* contains the secondary salts, compound or neutral.

ORDER I. *Simple or primitive saline Substances.*

We give the name of *primitive* to those salts which were formerly called, and which chemists still call, *simple*. But as it has been demonstrated by accurate experiments, that the most part of them are manifestly compounded, we are of opinion, that the title of *simple* can



can no longer be applied to them with justice. The word *primitive* seems to design them with more exactness, because they constitute the neutral salts, which we call *secondary*. We divide this order into three genera.

GENUS I. *Saline earthy Substances.*

By this name we design three substances, which hitherto have been looked upon as earthy matters, but whose characters in fact resemble those of salts. This mixture of saline properties, so remarkably blended with several earthy properties, less observable than the first, induced us to place those substances before the salts; to make them serve, to speak so, as a chain between these last and the earths, from which they differ by a much stronger tendency to combination, as will be seen in the examination of their properties.

It is of importance to observe, that in the examination of those saline earthy bodies, we suppose them, like the primitive salts, to be pure and detached, without even mentioning the means of making them so, that we may not render the elementary order complex which we propose to follow. In the history of the neutral salts, under the article of their decomposition, we shall describe the means which chemistry furnishes for separating those simple or primitive salts, and obtaining them pure.

This first genus contains three species of saline earthy bodies.

Species I. *Terra Ponderosa.*

THIS earth received its name from Gahn and Scheele, two Swedish chemists, because, with the vitriolic acid, it forms a salt of a very considerable weight, which has been ranked down to their time among the stones, and which we will examine in proper time. This earth never exists pure, but always combined. It was discovered by the chemists we have mentioned, who looked upon it as a



particular substance. Margraff and Monnet supposed it to be of the nature of the absorbent or calcareous earth. Its properties have never yet been well examined, at least as a detached and pure substance. Its combinations have been more studied; and chiefly in the salts which it forms with the acids, and in its very singular affinities, whereby it differs from the other analogous substances.

The terra ponderosa, obtained by means which shall be more explained hereafter, is in the form of a powder of an extreme fineness and very great whiteness. It has no perceptible taste upon the tongue. It is not yet known whether it can be changed by the light. It does not enter into fusion by the most violent fire: It gives a blue colour to the crucible, and receives itself a slight taint of the same. Exposed to the air, its weight augments, and it combines with the aerial acid contained in the atmosphere. It dissolves in water, although with considerable difficulty, and is obtained crystallized in pellicles on the surface of that fluid by a slow evaporation: water charged with it, gives a green colour to the tincture of the flowers of violets (*a*). This substance fuses with the earths, but with very great difficulty.

These general properties of the terra ponderosa, pure and separate from other bodies, have been pointed out by M. Bergman in his Dissertation on Affinities, and by M. d'Arcet in his Course of Chemistry in the Royal College. As yet few chemists have been employed about this. M. Macquer has made no mention of it in his Dictionary of Chemistry. The history of its combinations with the acids, of which we will treat in the article on the neutral earthy salts, will add to these properties.

(*a*) By the tincture of violets, we mean a solution of their colouring matter in water. This tincture, when fresh, ought to be preferred to the syrup, which does not by far possess the same delicacy. With regard to other experiments, the syrup may be employed in all the cases in which the saline matters we wish to examine possess a certain force: We will likewise mention it often in place of the tincture.



properties, and complete all which we at present know of the history of the terra ponderosa.

Species 2. *Magnesia of the salt of Epsom, pure or caustic.*

THE magnesia of the Epsom salt, which is likewise found in the mother-waters of the saline substances, of the saltpetre hillocks, and in a great number of stones, is a powdery white substance, which never exists pure in nature. Dr Black is one of the first chemists who has properly distinguished it from lime. This substance, when obtained by the means which we shall know more completely afterwards, is in the form of a white powder, very fine and dry. It has no sensible taste on the tongue; but it has an effect on the stomach, since it is purgative. It gives a green colour, though a very slight one, to the tincture of violets.

According to the observation of M. d'Arcet, it does not fuse, though exposed to a violent fire. M. Macquer has observed, that it resists even the focus of the lens of the Infanta's Garden. Morveaux had the same result, after burning magnesia for two hours in the most violent fire of Macquer's furnace. M. Butini, a citizen of Geneva, who lately published some very nice inquiries into the magnesia of the Epsom salt, observed that this substance, when strongly heated, contracts, and that its particles condense so much as to be able in consequence to attack and corrode the surface of iron. When heated in a retort, it only loses the water which it may contain; but it acquires in these experiments a very remarkable phosphoric property.

When exposed to the air, it suffers no change, till after the expiration of a very long time. M. Butini kept in a dry chamber ten grains of calcined magnesia, on a porcelain dish covered with paper: About two years after, its weight had only increased an eighth of a grain.

It possesses little solubility in water, and but in a very insignificant manner; for four ounces two gros of pure



water, allowed to remain for three months in a bottle, with a gros of calcined magnesia, and boiled with this substance, gave to M. Butini, after evaporation, a product estimated at a fourth of a grain only.

The action of magnesia, on pure earths, is not well known. A mixture of magnesia, clay, flint, and lime, melts with the fire. In medicine it is used as an absorbent and as a purgative. It ought to be preferred to the ordinary magnesia in the case of acidities; because the aerial acid which the latter contains, is disengaged by the action of the acids in the *primæ viæ*, and produces flatulency and pains. It preserves meat a long time, and even freshens putrified bile. M. Bergman ascribes to it the property of rendering camphire, opium, the resins and gum-resins, soluble in water, and of forming very useful tinctures, although the caustic magnesia is not soluble in water. These preparations are unknown in France.

### LECTURE XIII.

#### Species 3. *Quicklime.*

**L**IME is a substance which possesses more coherence than the two preceding substances do. It is generally found in the form of a stone of a whitish grey colour. Its taste is urinous, and strong enough to inflame the skin. In this state it gets the appellation of *quicklime*. It renders the syrup of violets green, and the colour which it gives to it is much deeper than that which the syrup receives from magnesia. Lime exposed to an intense heat, such as that of a glass-house, fuses into a yellow and transparent glass.

Exposed to the air it swells, splits, and turns into powder; it is called *lime slacked by the air*: its weight is augmented; it has attracted water and a little aerial acid from the atmosphere; it has no longer a very strong taste.

Lime dissolves in water; it requires 85 parts of this  
fluid



fluid to retain it in solution. If a little water be put on very good lime, the union of these two bodies is accompanied with a considerable heat, crackling, and boiling. The lime splits, mixes with the water, and renders it turbid and white. It is then called *milk of lime*. This water when filtrated, passes clear and transparent, and is called *lime-water*.

Lime-water has a warm urinous taste, and changes the syrup of violets to green. If it be evaporated, we extract the lime in form of a powder, or of a white pellicle. If it be exposed to the air, it is covered in a few hours with a saline pellicle, which is termed *cream of lime*. This substance is never formed but at the surface; which is owing to the evaporation of the water, and to the combination of the lime with the aerial acid which is contained in the air. Lime-water produces a great number of these pellicles. It furnishes them until the water be entirely evaporated.

Lime fuses with vitreifiable earths, and serves as a flux to them. If it is mixed with sand, the lime, by absorbing the water, unites with the fragments of this earthy substance, and forms with them a hard matter which is called *cement*, and is used to build with. The true means of getting a cement which is very hard and unalterable by the air, is to add to the lime the smallest quantity of water necessary to slack it.

This was the process of the ancients.

Lime melts with the terra ponderosa and magnesia: It produces then white and opaque glasses, species of enamels. Lime is employed in a great number of arts. In medicine, lime-water is administered with success in ulcers of the bowels. It has been esteemed as a powerful lithontriptic; but an extensive experience has shown, that it does not always succeed, and that a too long use of it produces in the fluids an alteration approaching to scurvy or putridity.

#### GENUS II. *Alkaline Salts.*

THE alkalis ought to be treated of before the acids,  
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because they appear to be more simple and less capable of decomposition, and because they approach in some of their characters to the nature of the saline earthy substances. They have a urinous taste, which is burning and caustic: they change the syrup of violets to green; they produce heat in their union with water; they absorb the water contained in the atmosphere, as well as the aerial acid of the air; they dissolve the earths; they have a great tendency to combination, and unite with almost all the bodies in nature. Three kinds of them are known.

Species 1. *Vegetable fixed Alkali.*

THE vegetable fixed alkali has got this name from being found in very great quantity in vegetables; although it is found very frequently in minerals also. It has likewise been called *alkali of tartar* and *salt of potash*; because great quantities of it have been extracted from these two substances, which is known by experience. The vegetable fixed alkali was not known in its state of purity before the time of Dr Black.

This salt, when pure, is in a dry and white form; its taste is so strong as to redden the skin and open issues: It gives the syrup of violets a deep green colour, and much more perceptible than that which lime occasions. The contact of the light, colours it by length of time. Exposed to the fire in close vessels, it liquefies as soon as it begins to redden: if it be run then upon a metal plate, it forms a white glass, which is brittle and opaque. It cannot be decomposed by this agent: it is not volatilized but by an extreme heat, such as that of a glass-house; and for that reason it is called *fixed*, a name which is only relative.

Exposed to the air, it powerfully attracts its humidity: It runs into a liquor, and passes into the state of a neutral salt, by absorbing the chalky acid from the atmosphere. For this reason it effervesces with the acids; which does not happen when it is pure, the  
state



state in which we here suppose it to be. If then we wish to preserve it in the state of purity, it is necessary to hold it in vessels accurately shut, and which it fills entirely. The vegetable fixed alkali dissolves very readily in water; it then produces a great degree of heat, and a fetid lixivial odor exhales. Its solution is colourless; it leaves no precipitate when it is very pure. If we want to separate it from its solvent, it must be evaporated to a state of dryness, in close vessels, because it attracts the aerial acid from the air, and becomes effervescent.

It combines with the vitreous and quartz earths in the dry way, and brings them into fusion: it forms then a transparent body known by the name of *glass*. This substance varies according to the quantity of sand and fixed alkali that constitute it. If two or three parts of salt to one of earth be employed, we get a soft brittle glass, which attracts humidity from the air, becoming opaque and fluid. This glass dissolves in water by the assistance of the superabundant alkali that it contains. This solution is called *liquor silicum*. In time it deposits a part of the earth contained in it, in white semitransparent tufts, mucilagenous in appearance, and so light that they precipitate but slowly. The acids separate the alkali from it, and cause this earth to be deposited, which is called *terra silicea*. Several chemists think that the earth of flints is not like the quartz earth, and that it has been altered by its union with the alkali. They think that it approaches to the nature of argillaceous earths; that accordingly it can be united with the acids like this last, and form with them the same salts as it does. This opinion is not yet entirely demonstrated, although it is certain that the quartz earth is altered in some manner.

The art of making glass is entirely founded upon chemical properties, that substance being nothing but a combination of the fixed alkali with the quartz earth. The purity of these two substances, their pro-  
por-



portion, their complete fusion by the means of a very strong and long continued fire, are the three circumstances necessary to have a glass transparent, hard, and without bubbles of air, and especially a glass unchangeable by the air. We will, in the sequel, become acquainted with different substances which are mixed with the two first, in order to increase their fusibility, and to give to the glass weight, transparency, and several other properties relative to the use for which it is destined.

The vegetable alkali seems even to be susceptible of combination with the terra ponderosa, magnesia, and lime; but these combinations have not been examined. It unites with the acids, and forms with them particular salts, which we will examine in the second order.

Although we have not yet been able to decompose the vegetable alkali, many facts, which shall be mentioned in the sequel, tend to prove that it is not a simple substance. Stahl, who, from many views, looked upon the simple salts as formed by the union of water and of earth, thought that the fixed alkali differed from the acids only in containing more earth. In this manner he accounted for its dryness. It is probable that the vegetable alkali, like all other salts, is formed of a combustible substance combined with air, since M. Rouelle has observed, that more fixed alkali is extracted from burnt vegetables, than from these bodies in their natural state. It frequently acts also as the acids do, in which much pure air is found. It calcines the metals, and consumes combustible matters. As for the rest, we only propose this idea as a supposition; which should not be received for a demonstrated truth; but which agrees with several facts, which it very well explains.

The vegetable alkali is employed in surgery to red-den the skin, to produce in it an inflammation and a sup-puration; which when continued gives rise to an issue. It is employed in the arts for the preparation of soap.

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Species 2. *Mineral fixed Alkali.*

THE name of mineral fixed alkali has been given to a saline substance, which presents the same general characters as the preceding, and which is found in great quantity united with another salt in the waters of the sea, and in those of several fountains. Sometimes, however, it is found in vegetables, but much less frequently than the preceding. This salt has also been called *marine alkali*, because it makes a part of the marine salt; and the *alkali or salt of soda*, because it is most frequently extracted from this substance.

The mineral fixed alkali, when very pure, has a taste as strong and as caustic as the vegetable; it changes the syrup of violets to a green equally well. It is in a dry and solid form; it fuses in the fire when it begins to redden; it is volatilized by a violent heat; it attracts humidity and the aerial acid from the atmosphere; it raises a degree of heat in its union with water, and disengages a fetid lixivial odour. From this solution it can only be obtained pure in close vessels. It combines in the dry way with vitrescent earths, and forms glass. The glass makers have even supposed it to possess a greater fusibility, and a greater adherence to these earths, than the vegetable; and for that reason they employ it in preference to this last in the manufacture of glass. In like manner, what we have said on this art in the last article, may be applied to the mineral alkali. Lastly, this alkali combines, in the same manner as the vegetable, with the acids, and with a great number of other bodies which shall be mentioned in the sequel.

There is no other remarkable difference between the apparent properties of these two alkalis: they can be truly distinguished, then, in their combinations only. Each of them united to the same acid, affords neutral salts very different in all their properties; which is so much the more singular, as it is absolutely impossible to assign to them any distinct character when they are in  
their



their state of purity. M. Bergman has indeed added a distinguishing proof of these two salts, with which it is very important to be acquainted, viz. That their affinity with the acids is not the same; the vegetable fixed alkali has a stronger relation with these saline substances than the mineral has, because it is able to decompose the neutral salts which are formed of this last. This object we will resume in the examination of the secondary salts. This beautiful discovery has astonished us the more, that, with the design of finding a distinct character in the two fixed alkalis, and without knowing M. Bergman's dissertation on their elective attractions, about seven years ago we had proposed to M. Bucquet this very question on the difference of the affinities of these two salts, which we then only suspected. This illustrious professor had even promised to investigate this subject, when we very soon learnt that M. Bergman had got before us in this important inquiry.

Species 3. *Volatile Alkali.*

THE volatile alkali is distinguished from the two preceding by a pungent and a suffocating odour, and a remarkable volatility. It is with this salt, as with fixed alkali; we did not know it in its state of purity, before the publication of Dr Black and Dr Priestley's ingenious experiments. For the volatile alkali, a kind of imperfect neutral salt was taken, solid and crystallized, which has some of the properties of the volatile alkali, but which differs from it in this, that it is truly composed of two saline substances. The character of effervescing with the acids, which is ascribed to the volatile alkali, belongs only to this salt in its neutral state. That kept in chemical laboratories under the name of *volatile caustic alkali*, is not even this salt in its natural state; it is only it dissolved and diluted with water. Dr Priestley demonstrated, that a permanent gas may be extracted from it by means of a gentle heat; and that the water deprived of this gas, by little and little loses its alkaline pro-



properties. This aeriform fluid is the pure volatile alkali, and is distinguished by the name of *alkaline gas*. The properties of this subject must be examined, that those of the true volatile alkali may be known, as M. Macquer has very well observed.

The alkaline gas resembles air when it is contained in a glass vessel: It possesses its transparency and elasticity; but it is heavier than air is. It has a penetrating odour; it has an acid and caustic taste; it quickly gives a deep tinge to the blue colour of the violets; it extinguishes burning bodies, and kills animals; it makes the flame of a candle, before it is extinguished, increase a little in size; it gives its disk a yellow pale colour, which proves that it is itself partly inflammable; it is absorbed by the porous bodies, as charcoal, sponge, &c.

Air does not combine with the alkaline gas; it only makes it disperse.

Water readily absorbs the alkaline gas. If it is in the state of ice, it instantly melts, and produces a very intense cold; whilst, on the contrary, this gas is heated by water in a state of fluidity. Water saturated with this gas, exactly resembles that from which it has been extracted by heat. We call it the *volatile alkaline spirit*; as we call the spirit of marine salt, the *solution of the marine acid in water*.

The alkaline gas has no sensible action on the earths, nor on the saline earthy substances. It has a very powerful action on the acids, and upon several neutral salts, as we shall show hereafter. The alkaline spirit has the same properties as the gas, which it contains dissolved, but in a less remarkable degree; because the aggregation of the gas being much less strong than that of the liquid, according to one of the laws of affinity, the tendency to combination ought to be much stronger in the gas than in the alkaline spirit. The volatile alkali has been looked on as a combination of the fixed alkali, and of an inflammable substance. We know indeed



indeed many instances in which this last salt, heated with inflammable matter, produces volatile alkali; but it is not known whether the fixed alkali enters completely into the combination of the volatile alkali, or if it only furnishes a particular principle, which, in combination with a proportion of the combustible matter, produces this salt.

The volatile alkali diluted with water is employed in a great number of diseases. It is an aperient and a powerful detergent; it has a strong action on the skin; it is used in the bite of a viper, in the maladies of the skin, in the venereal disease, and many other complaints.

As it is acrid and caustic, it ought only to be employed with great circumspection. Applied externally, it is a strong discutient; it is capable of dispersing many tumours, particularly those formed by clotted milk, and by the inspissated lymph. It readily cures burns; it is often employed, and with success, in chilblains; it is used frequently, and under different names, as a very active stimulant in syncope, asphyxies, &c. In these last cases, the use of it ought to be very carefully managed. It is not prudent to make it be swallowed in diseases, without diluting it with much water, and giving it in a very small dose. Dangerous excoriations have been observed to have been produced upon the canal of the œsophagus, and upon the membranes of the stomach, by giving it internally without precaution. The use of it then, internally, ought never to be allowed, without the advice of a knowing physician, who, by having a great knowledge of the animal œconomy, and of the chemical actions of this salt, may proportion the quantity and strength of the dose to the vigour of the patient (*b*).

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(*b*) M. Cornette, of the Academy of Sciences, a chemist very celebrated for a great number of well executed works upon several saline matters, upon the acid soaps, upon the art of manufacturing nitre, &c. lately acquainted me, that he discovered that the volatile alkali is very combustible. This fact should not appear wonderful, after what we have said above of the action of alkaline gas on a lighted candle.



## LECTURE XIV.

## GENUS III. ACIDS.

THE acids are distinguished by their sour taste. When they are diluted with water, they redden the blue colours of vegetables. The greatest part of them are in the form of gas. They unite with rapidity to the alkalis. They act more powerfully than these last do on combustible substances, and most frequently reduce them to the state of consumed bodies. As combustible bodies, and especially the metallic, contain a great quantity of pure air, which may be extracted from them; and as in their combination with an acid, this saline substance passes itself into the state of a combustible body, we may conclude, that this genus of salt is much less simple than has been believed, and that in general it is formed of inflammable matter combined with pure air. All the phenomena of chemistry establish the certainty of this grand theory.

We know seven sorts of *Mineral Acids*, viz.

- |                  |                    |
|------------------|--------------------|
| 1. Chalky acid.  | 5. Aqua regia.     |
| 2. Marine acid.  | 6. Vitriolic acid. |
| 3. Sparry acid.  | 7. Acid of borax.  |
| 4. Nitrous acid. |                    |

We shall examine each of these in their order.

Species 1. *Acid of Chalk.*

We give the name of *chalky acid*, with M. Bucquet and Lavoisier, to the aeriform fluid, called at present by the English *fixed air*, by Mr Bewley *mephitic air*, and by Mr Bergman *aerial acid*.

This acid has not always been regarded as such. The principal properties of it only have been glanced at by Paracelsus, Van Helmont, and Hales. It is to M. Priestley, Bewley, and Bergman, that we owe the certain



certain knowledge of its acidity. The name of *chalky acid* is given it very properly, because chalk contains it in great quantity, and because there is no body with which it has so strong an affinity as quicklime.

The chalky acid has all the physical characters of air. Like it, it is invisible and elastic; when confined in a glass vessel or flask, it cannot be absolutely distinguished from this fluid. It exists in the atmosphere, and in certain subterraneous cavities. It is combined with a great number of natural bodies; such as mineral waters, and several neutral salts. The spirituous fermentation disengages it in great quantity.

The specific gravity of the chalky acid is double that of the air. Like all fluids, it may be poured from one vessel into another; it may be also drawn by the cock of a great cask after wine. It has a sharp acidulous taste. It kills animals instantly, because it is unfit for respiration: It turns the tincture of turnsol to a bright clear red. This colour is lost by the action of the air, in proportion as the acid evaporates. It does not alter the colour of violets, because it has only a very slight tendency to combination.

The force of affinity is in general weak in this acid: It is not changed by the contact of the light.

Heat expands it like air, without producing any change on it. It mixes with pure or dephlogisticated air, but without alteration; and it forms a mixture very like the air of the atmosphere. It combines with water but slowly. These two fluids, if they are agitated, and their contact increased in any way, unite and form the acid spirit of chalk. The colder the water is, the more of the acid is dissolved. This saturation has its fixed point. The acid spirit of chalk is specifically lighter than water; it has a sharp acidulous taste; it reddens the tincture of turnsol. It may be decomposed by heat, which disengages the acid, as it does the alkaline spirit. This acid spirit of chalk is found in abundance in nature;



ure; it constitutes the acidulous waters, and those which contain gases, as those of Piermont, of Seltz, &c.

The chalky acid has no action upon siliceous earth: it unites with clay, magnesia, and terra ponderosa, and forms with them different neutral salts, which we shall examine more particularly hereafter.

When mixed with lime dissolved in water, it produces a constant phenomenon, which always distinguishes this acid. As soon as it touches that fluid, it occasions a white cloud, which very soon thickens, and becomes a copious precipitate. The cloud is owing to the chalk that is formed by the union of the lime with the chalky acid. This new salt being almost insoluble in pure water, separates and falls to the bottom of the fluid; lime-water then is a test to distinguish the nature and quantity of this acid. After the formation of this precipitate in the water, if a new quantity of the chalky acid be made to pass through, the sediment redissolves by the excess of the acid, and disappears. This is a second character proper to this acid. The spirit of chalk poured into lime-water produces the same effect. The chalky acid unites itself with rapidity to the three alkalis: If we put into a vessel full of gas extracted from chalk, or taken from a cask of fermenting beer, a little of a solution of pure and caustic fixed alkali, divided upon the sides of the vessel, and cover the mouth of the vessel with a moistened bladder, the bladder falls down by little and little; a vacuum is made in the vessel from the absorption of the chalky acid by the alkali; a heat arises during the combination of these two salts; and at the same time we perceive, upon the sides of the vessel, crystals elegant dendrites, which become more and more thick. We call this salt *tartar* with the chalky acid, if we have employed the alkali of tartar; and *soda* with the chalky acid, if we have employed that of soda. These two true neutral salts were formerly called *salt of tartar*, and *salt of soda*. The contact of the alkaline gas,



and of our aeriform acid in a close vessel, instantly produces some vacuum, also a brisk heat, and a white and thick cloud, which adheres in regular crystals, or simply in a crust, to the sides of the vessel. This is a true neutral imperfect salt, which we call *ammoniac* with the chalky acid. The chalky acid may be combined with a great number of other bodies, which we will see according as we advance. We have not yet been able to decompose this acid: We suspect, however, that it contains some pure air, combined with an inflammable gas. We give this as a hint only, until we know the facts upon which it is founded.

It has the property of preserving animal substances and of retarding putrefaction, and of restoring those that are beginning to putrefy. From this property Macbride thought that it unites with the putrefying body, and restores to it the acid which it lost during putrefaction. According to him, this last phenomenon is entirely owing to the natural decomposition of the organic substances, and the dissipation of the chalky acid, which he called *fixed air*. In like manner he has pretended, that this acid is indispensably necessary to compensate the loss which is occasioned in animals, and to re-establish the fluids which are altered by motion and heat. He allows it to exist in fresh vegetables, particularly in those which are susceptible of fermentation, as the decoction of malt and the must of raisins. In like manner, he supposes that they are all good in the diseases which depend on the motion of the humours, as the scurvy.

The acid spirit of chalk is also prescribed in putrid fevers; and several observations have affirmed its success. The English employ it, it is said, in respiration in a small dose, and mixed with common air, in diseases of the lungs.

It has been strongly recommended as a lithontriptic, or solvent of the stone in the bladder; but no fact well attested has yet demonstrated in France its efficacy in this



this terrible malady. The public papers have announced several cures of the cancer effected in England by the application of the chalky acid. We can affirm, that we have seen it employed several times, and have employed it several times ourselves, without success. With the first applications, the cancerous ulcer seems to assume a better appearance. The sanies, which generally flows from it, becomes white and purulent; the lips of the sore take a red colour and consistence: but these flattering appearances do not long continue, and the ulcer very soon returns to its former state, and soon becomes worse and worse. It is a pity such promising hopes should be frustrated.

Species 2. *Marine Acid.*

THE *marine acid*, or *spirit of salt*, is the name in laboratories, of a fluid that flows like water, which has a very strong taste, capable, when concentrated, of corroding our organs, and which raises on the tongue only a sour and stiptic taste; it is much diluted. This fluid, quite pure, ought to be absolutely free of colour. That which is red, or like the juice of citrons, owes its colour to some combustible substances, and often to the addition of some iron which changes it. This acid is extracted from marine salt, as shall be mentioned in its history. If it is strong, it exhales a vapour or white fume when it is exposed to the air: It has a pungent penetrating odour, which, when very weak, resembles that of citrons a little; then it is termed *smoking spirit of salt*. These fumes are more or less abundant, according to the humidity of the air. When we open a vessel containing this acid, if we apply our hand to its neck, a manifest heat is felt, owing to the combination of the acid in vapour with the air of the atmosphere. The spirit of salt strongly reddens the syrup of violets, and all the blue colours of vegetables; but it does not destroy them.

The spirit of salt, however concentrated, and how-



ever fuming, is not the pure and uncombined marine acid, but this acid united with much water. Dr Priestley has put this truth out of all doubt, in assuring us, that we may volatilize this acid in gas, and in this state obtain it permanent above mercury. The properties of this gas then must be examined if we want to know those of the marine acid without mixture, and in its state of perfect purity.

The marine acid gas is obtained by heating the fuming spirit of salt in a retort, the neck of which is received under a vessel full of mercury. The gas which is much more volatile than water passes into the vessel. It presents all the apparent characters of air; it is heavier than it; it has a penetrating odour; it is so caustic that it inflames the skin, and frequently occasions strong corrosions; it suffocates animals: it extinguishes the flame of candles, enlarging it at first, and giving a green or blueish colour to its disk: it is absorbed by spongy bodies.

Light does not seem to alter it in any sensible degree. Heat rarefies it, and augments its elasticity prodigiously. Pure air, and the air of the atmosphere, by coming in contact with marine gas, make it assume the form of fumes or vapour, and heat it slightly; which proves that there is a combination. The greater the humidity of the air, these vapours are the more apparent.

The marine gas combines rapidly with water; ice melts in it instantly, and absorbs it readily. Water in its union with this gas is pretty strongly heated. When saturated, it cools, and exactly resembles the spirit from which the gas was extracted by means of heat: it emits white vapours; it has no colour; it reddens the syrup of violets. The marine gas has no action on the earths except clay, with which it forms a marine salt with clayey base: It combines with the saline terreneous substances, and forms with them the marine salt with base of terra ponderosa, the marine salt with base of magnesia, and the marine salt with that of calcareous earth.

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When combined with the vegetable fixed alkali, it constitutes the febrifugal salt of Sylvius; with the mineral alkali, it forms the marine or culinary salt. The marine gas mixed with the alkalis raises a great heat; it forms a white cloud: the mercury mounts in the tubes; and the internal sides of the vessel are very soon hung with crystals, which are sal ammoniac.

This gas acts in general upon combustible bodies in a more powerful manner than the chalky acid, but much less than the following acids.

The intimate nature of the marine acid is not well understood; we have not yet been able to decompose it. Beccher thought that it was formed by the vitriolic acid united with a mercurial earth, because he observed that this acid had much affinity and combined intimately with those bodies in which he admitted this principle to exist; such as arsenic, mercury, and some other substances. We only suspect that it is formed of an unknown combustible body, combined with pure air, which may be obtained from some bodies altered by this acid. It is known also that it has more affinity with all bodies than the aerial acid has; and though, with regard to the other acids, its affinity is less strong, yet it is susceptible of several variations.

The marine acid is employed in some of the arts, and particularly in the art of assaying. In medicine it is administered, very much diluted with water, as a diuretic. It forms the base of the remedy of the *Prieur de Chabrières*. It is supposed that the baths for the feet, boasted of in the gout by some persons, but which have not always equally succeeded, are formed with this acid dissolved in water. It is used externally for producing eschars, and destroying altered parts, in the disease of the gangrened throat, the aphthæ of the like nature, and other diseases.

### Species 3. *Sparry Acid.*

THE sparry acid discovered by Mr Scheele has received



ceived that name, because it is extracted from a kind of neutral salt, which is called by the name of *sparry fluor*, or *vitreous spar*.

This acid when pure is in the form of gas. The sparry gas is heavier than air: it extinguishes candles, and kills animals: it possesses a penetrating smell, approaching to that of the marine gas. It is so caustic as to redden the skin, if exposed ever so short a time to its contact. It is not altered by light and heat.

Pure air renders it turbid, and changes it into a white vapour. Its union with water is rapid, and attended with heat; but it presents a particular phenomenon in this union, which is the precipitation of a very fine white earth, which M. Macquer esteemed a quartz earth.

It appears then that this acid is never pure, unless it be in the state in which it has now been described: Hence we are led to believe that it is not pure, but in proportion to its separation by water from the earth, which it raises in its volatilization.

The sparry acid spirit has the same smell, and almost the same causticity with the gas. It reddens the syrup of violets deeply. It has the singular property of corroding and dissolving the siliceous earth, according to M. Scheele and Bergman. Dr Priestley has discovered that the sparry gas also corrodes glass, and eats it through. M. Macquer thought this acid produced this effect in its state of gas only; and that when liquid, or dissolved in water, it did not affect the glass.

The sparry acid spirit may be decomposed like the spirit of salt, by heating it in a retort, the neck of which is received under a vessel full of mercury. The sparry acid is obtained, and the water remains almost pure.

The two French chemists, called *Boulanger*, who in the year 1773 published a set of experiments on the vitreous spar, or sparry fluor, think that the acid of spar is only the marine acid combined with the earthy matter, which the water only is able to separate. Mr Bergman looked upon it as a particular acid, and fully di-



distinguished by the different combinations which it forms. It would appear that this last opinion is the most universally received at present by the chemists.

The sparry gas, and sparry acid spirit, combine with clay, terra ponderosa, magnesia, quicklime, and the alkaline substances. In these combinations neutral salts are formed different from those which are formed by all the other acids: Its affinities also are in a different order from that of the other acids; it deserves then to be accurately distinguished.

The sparry acid has not yet been employed for any purpose.

## L E C T U R E XV.

### Species 4. *Nitrous Acid.*

**T**HAT which is called *nitrous acid* in laboratories, is the spirit of nitre, or the combination of that acid with water. It is either yellow or red: it emits a copious vapour of the same colour: it is so caustic that it burns and instantly disorganises the skin and the muscles.

It reddens the syrup of violets, and destroys the colour of it entirely. It is so volatile, that the heat of the atmosphere alone is able to expand it into vapour.

When exposed to the rays of the sun, it acquires colour and more volatility, which shows an action on the part of the light; when very much concentrated, it attracts humidity from the air.

It unites with violence to water; which gives it a green colour, and afterwards a blue. This combination occasions a good deal of heat: when very much diluted, it is colourless, and forms aquafortis.

The spirit of nitre has no action on the vitreous and quartz earths: it unites with clay, terra ponderosa, magnesia, quicklime, and with the alkalis, with which it forms argillaceous nitre, nitre with base of terra ponderosa, nitre of magnesia, calcareous nitre, pure



nitre, rhomboidal nitre, and nitrous ammoniac. All these salts shall be examined after the acids.

The nitrous acid mixes with the chalky acid, which it absorbs in part, and which it appears to contain in more or less quantity, as will be proved in the history of Nitre. It combines with the marine acid, and emits red vapours during this combination. Although the nitrous acid gas cannot be separated from water, in the same manner as the chalky and marine acids, it is probable that this acid is of the nature of a gas just as these last: But as we are not acquainted with any fluid upon which the nitrous acid has no action, and which it consequently cannot pass through without being altered, it has not as yet been possible to obtain it in its state of purity. We believe, however, that the nitrous acid gas exists in the superior part of the vessels which contain the rutilant spirit of nitre, and which are not filled with it entirely.

It is a long time since chemists observed that the nitrous acid acts in a very violent manner upon combustible bodies, especially upon the metals: it then discharges a great quantity of red vapours, and in that form is often dissipated entirely. The combustible body which is exposed to its action, is very soon found to be reduced to a scorched or calcined state. Frequently it inflames even the combustible bodies, as the oils, charcoal, and some metals, as M. Proust has discovered. Stahl ascribed this effect to the rapidity with which the acid combines with the phlogiston of the combustible body.

Mr Priestley, by receiving under a vessel full of water the vapour which is disengaged during the action of the nitrous acid on iron, found, that instead of a red vapoury fluid, a transparent gas, and without colour, like air, is obtained, which he designed by the name of *nitrous gas*.

This gas has all the external characters of air; but it differs from it in a great number of chemical properties.



erties. It cannot be employed either for combustion or respiration: It is strongly antiseptic; it has no sensible taste; it does not change the colour of the syrup of violets. The nitrous gas is not altered, at least not in a perceptible manner, by light. Heat dilates it; pure air readily combines with it, and converts it into the state of nitrous acid. This combination exhibits several phenomena of importance, and necessary to be known. As soon as the air comes into contact with the nitrous gas, these two fluids, neither of which has any colour, become red, and like the fuming spirit of nitre: A very brisk heat is raised; the water mounts in the receiver, and absorbs all the red vapours, which show the character of aquafortis. The purer the air is, the more evident are these phenomena, and ever so little of it may change a given quantity of nitrous gas into acid. M. Lavoisier found that it required 16 parts of atmospheric air to saturate  $7\frac{1}{2}$  of nitrous gas, whilst four parts of pure or dephlogisticated air are sufficient to saturate completely  $7\frac{1}{2}$  of the same gas. This beautiful phenomenon perfectly resembles combustion, as M. Macquer has imagined. In short, it is attended with heat, absorption of air, and production of saline matter.

As in this artificial decomposition of the nitrous acid, the air produces different effects according to its purity, Dr Priestley has thought that the nitrous gas may serve as a test for knowing the quantity of pure air which it contains, by taking for the two terms that of the most impure air, or of a gas not respirable; such as the chalky acid, which does not change the nitrous gas in any manner, and that of pure or dephlogisticated air, which alters it the most. The proof of this consists in employing known and proportionate quantities of these two gases, and observing those which are necessary to form their complete and reciprocal saturation. The less the quantity of air requisite to saturate this gas, the purer the air is; on the contrary, the more of it that is obliged to be employed, it is the less pure.

Several



Several physicians have found the means of conducting this experiment with the strictest precision. The Abbe Fontana has carried this point the farthest of any: He contrived an instrument called *Eudiometer*, of which we find an exact description in the inquiries of M. de Ingenhouz concerning vegetables. With this instrument we can estimate almost to infinity the degrees of purity or impurity of the air which we examine; but its use requires an exercise and attention which necessarily renders it difficult and susceptible of error, as Fontana himself has observed.

It may be also proper to remark, that these experiments, ingenious and useful in themselves, are not near so advantageous as was expected to the health of mankind, and to that part of medicine which contributes to the preservation of health: They only show the quantity of respirable air contained in that gas which we examine: they point out none of the offensive qualities of this fluid relative to the other functions, but respiration; such as its action on the stomach, on the skin, and in particular on the nerves; effects that cannot be known but by the observation of physicians, which however are perceptible in almost all the alterations of the air.

As yet chemists are divided on the cause of the production of the nitrous acid by the mixture of nitrous gas and pure air. Dr Priestley, who has the merit of this discovery, thought that this gas was only the nitrous acid overcharged with phlogiston; with which the pure air having more affinity than the nitrous acid has with it, seized the phlogiston, and left the acid free. It remained to be known, why the pure air, which in this operation was employed in the quantity of four measures to saturate seven and more of the nitrous gas, was afterwards found to be reduced to less than half a measure, although it was combined with a new body, the phlogiston. M. Lavoisier thought that this property of the nitrous gas was capable of explaining the composition  
of



of the nitrous acid. By combining two ounces of nitrous acid of a determined strength with mercury, which is a combustible body, he obtained 196 inches of nitrous gas, and 246 inches of dephlogisticated air. The mercury, after changing form during the separation of the first of the gas, was restored without any diminution, after the pure air came over. He concluded from this beautiful experiment, 1. That the spirit of nitre is a compound of pure air, of nitrous gas, and of water, with so much the more probability, as these three bodies united reproduce the acid. 2. That the nitrous gas is the nitrous acid without the air. However, there is a difficulty in this opinion: for M. Lavoisier was not able to reproduce all the acid employed; and he lost at least the half of it, and there was much more pure air than was necessary to saturate all the nitrous gas obtained. He confessed his ignorance of the cause of this circumstance. M. Macquer thought that that depended on the loss of phlogiston or light, which he looked on as one of the principles of the nitrous acid, and which, by dissipating through the pores of the vessels during its decomposition, left a part of its pure air, which could not be dissipated in the same manner. Although this last opinion seems very well adapted to remove the difficulties, it may be objected to M. Macquer, that it is not evident why part of the phlogiston should remain in the nitrous gas, whilst the rest was exhaled through the pores of the vessel. The kind of gas which remains after the mixture of nitrous gas with air has not a little embarrassed the chemists. This residuum very little resembles pure air, since, according to M. Lavoisier,  $7\frac{1}{4}$  parts of nitrous gas, with four parts of dephlogisticated air, produced only  $3\frac{1}{2}$  of their whole bulk. This gas resembles the aerial acid: it extinguishes candles, and precipitates the lime of lime-water; it is much more abundant after the decomposition of nitrous gas by atmospheric air. Some chemists have supposed, that this residuum is the air which



has been employed to decompose the nitrous gas, and which is combined with the phlogiston of this gas. But this opinion does not agree with the experiment, which demonstrates that the pure air employed is united with the nitrous gas, to form the nitrous acid from which it may be extracted. It is possible that this portion of the aerial acid belongs to the nitrous acid itself, since we know several facts, which prove that this last acid, when it is decomposed in close vessels, yields a certain quantity of the first. It appears also, that in certain circumstances the nitrous acid is decomposed, without giving nitrous gas, and is entirely changed into pure air and aerial acid, as is proved by the alkalisation of nitre by heat and in close vessels.

All these views, which perhaps are very far from the truth, but which at least are founded upon certain and confirmed facts, prove that nothing is less known than the nitrous gas, and that this singular substance merits a particular and very extensive examination. The nitrous gas does not combine with water. This fluid alters it after a long time, and assumes the character of an acid: but we have not well comprehended this kind of alteration, which perhaps is owing entirely to the air contained in the water. The earthy and alkaline substances, as well as the acids, have no remarkable action on this gas.

It is employed to determine the purity of the air; but it only shows the quantity of respirable air, which is contained in the kind of air exposed to its action, as we have already observed.

Species 5. *Aqua Regia.*

THE alchemists gave the name of *aqua regia* to an acid composed of two others, the nitrous and marine, which they employed to dissolve gold the king of metals. It must always appear singular, that two acids, which separately have no action on gold, become capable of dissolving it when they are united. The alchemists,



chemists, content with having found a solvent to this precious metal, were not solicitous to investigate the cause of this phenomenon. It was only some years ago that two Swedish chemists, M. Scheele and Bergman, endeavoured to ascertain the alterations which the nitrous and marine acids undergo by their union. The first of these chemists observed, that in distilling the marine acid from the calx of manganese, it expanded into a reddish vapour, with a smell similar to that of aqua regia, which destroys the blue colour of vegetables, has a very strong action on the metals, and particularly on gold, which it dissolves in the same manner that aqua regia does. He supposes that these new properties are owing to its being deprived of phlogiston by the manganese; and that in consequence of this change, it has a very strong tendency to recover that principle wherever it finds it, and that this change invests it with a strong action on combustible substances. From these properties he called it *dephlogisticated marine acid*. We will observe afterwards, that this theory is quite contrary to the theory of Stahl, which Mr Scheele seems to adopt and extend; since the marine acid, on losing its phlogiston, acquires new properties, which that great man attributed to the presence of that principle; such as volatility, a strong smell, and action on all inflammable matters. We suppose, however, that these phenomena may be explained with more probability by the new theory, which we shall immediately proceed to deliver.

Mr Bergman thinks that the nitrous acid seizes on the phlogiston of the marine, and is in part dissipated in vapour; and that the marine is in the same state as when distilled from the calx of manganese: For this reason aqua regia dissolves gold, in consequence only of the marine acid dephlogisticated which it contains. This is the opinion of the celebrated Upsalian chemist. The theory which seems to me to correspond with the facts is this: When the nitrous acid is poured on the marine, these two liquids grow warm, become coloured,



loured; some nitrous gas is produced, which is readily disengaged, and emits a mixed odour, that is less penetrating than the pure spirit of salt, but quite particular, and like to that of the marine acid distilled from the calx of manganese. According to the new doctrine, it is known that the nitrous acid never forms nitrous gas, except it lose a portion of its air. Now if this acid, united with the spirit of salt, gives nitrous gas, it is the marine acid that carries off a portion of the pure air which the nitrous contains. The marine acid in aqua regia, then, is only the marine acid charged with pure air; and which, in consequence of this superabundant principle to which it adheres but slightly, becomes capable of calcining the most perfect metals, such as gold and platina, and of acting with rapidity on combustible substances in general. For that reason, it is necessary to use a small quantity only of nitrous acid to give the marine the character of *aqua regia*. For the same reason the reguline salt of gold alone yields marine acid in distillation, as has been very lately observed in aqua regia itself. But it is proper to observe, that as we often use much more nitrous acid than is necessary to saturate with the air, or to dephlogisticate the marine acid, the aqua regia resulting from the union of them contains these two acids; each of which has its peculiar manner of acting, and forms particular salts with all the bodies exposed to their action. It might then be of importance to determine, how much nitrous acid is requisite to saturate a given quantity of marine with air, and to convert this acid into aqua regia; without which care it would contain a portion of aquafortis, which alters and renders its action uncertain. Hence chemists are sensible how necessary it is, in their researches, to ascertain the respective quantities of the acids of which the aqua regia, which we employ, is composed.

The specific gravity of aqua regia is less than that of the two acids which compose it. Its smell is particular;



cular; its colour is generally of the yellow hue, and often quite on the orange; its action on the different bodies in nature distinguishes it from all the other acids. From the light it suffers no sensible alteration. Heat separates the two acids which it contains. The air causes no change. It combines with water in all proportions, and causes heat during their mixture. It dissolves clay but gradually; it unites with the terra ponderosa, quicklime, and the other alkalis; combinations of mixed salts are formed, which sometimes crystallize together when they are equally soluble, or are crystallized separately, according to the order of their solubility. Great use is made of aqua regia in chemistry and in the art of assaying.

## L E C T U R E XVI.

Species 6. *Vitriolic Acid.*

**T**HE vitriolic acid is a saline substance exceedingly caustic; when concentrated, it burns and cauterises the skin, reddens the syrup of violets without destroying its colour, and only possesses a sour taste somewhat styptic when it is very much diluted. It is in the form of an oily fluid, very transparent, double the weight of water, and without smell. This fluid contains the acid united with the water; from which it cannot be entirely separated by any known means. For this reason, so long as this acid is pure, it is always in the form of a fluid, at least it cannot be rendered solid by cold. That which is called *glacial oil of vitriol*, is not pure vitriolic acid, as we shall notice in another place. It is without doubt the same with a kind of smoking oil of vitriol of Nordhaus, mentioned by M. Meyer, of which the first distilled portions become crystallized when they are cool.

Stahl looked upon the vitriolic acid as most universally dispersed in nature, and as the principle of all others. The first of these assertions founded upon this, that linen rags, impregnated with fixed alkali, and exposed to  
the



the air, contain at length vitriolated tartar, is false; because these rags do not contain an atom of this salt, but much chalky tartar, which the moderns improperly have called *aerial alkali*. As to the second, nothing is less demonstrated than the formation of all the acids by the vitriolic; the inquiries of the moderns having proved, that every acid has its particular principles different from those of other acids, except pure air, which seems to enter into the composition of every one of them.

The vitriolic acid exposed to the contact of the light in vessels that are transparent and accurately shut, by degrees acquires colour, and forms the sulphureous acid. Even it is affirmed, that after a long time some sulphur is produced in this experiment. But this fact is not yet certain: if it were, it would prove that the light really combines with the vitriolic acid to form sulphur.

The oil of vitriol when heated loses part of its water, becomes concentrated, and is volatilized by an extreme degree of heat only. If it be coloured, it loses its colour, and becomes transparent by the action of the fire. This operation is called the *concentration and rectification of the vitriolic acid*. While it is going on, a very strong smell, and penetrating gas, is disengaged, which we shall know very soon by the name of *sulphureous gas*.

The oil of vitriol exposed to the air, attracts humidity from it, loses part of its own elasticity, and acquires colour in consequence of the combustible particles that float in the atmosphere, upon which this acid has a strong action. It often attracts much more than its own weight of atmospheric water.

M. le Duc d' Ayen has proved, by fine experiments made in the extraordinary cold of January 1776, that oil of vitriol much concentrated, if exposed for some hours to a cold from the 13th to the 15th degree of Reaumur's thermometer, is susceptible of congelation; that



when diluted with two or four parts of water, it congeals no more; that when congealed, if it be left constantly exposed to the air, it becomes fluid, although the cold be more intense than the cold with which it congeals. This phenomenon is owing to the water that is attracted by it from the atmosphere, with which it unites by producing heat, which prevents its congelation.

The oil of vitriol unites with water with all the phenomena which announce a sudden penetration and an intimate combination. It produces a brisk heat, a kind of hissing, and discharges a disagreeable nauseous smell. This acid diluted with water loses much of its taste; its fluidity is increased, and then it is called the *spirit of vitriol*. The water may be volatilized by heat, which again converts it into oil of vitriol.

This acid has no action on the quartz earths; however, it in part dissolves those which have been fused with the fixed alkalis, and which seem to have assumed the character of *clay*. It combines with true clay, terra ponderosa, magnesia, quicklime, and the other alkalis. It is one of the acids which adhere most strongly to the different bases, as will appear in the history of the Neutral Salts.

The combinations which it may form with the other acids have not been investigated. It is only known that the nitrous acid, poured upon the vitriolic, blackened by some combustible body, takes away its colour, and renders it transparent.

The manner in which it acts upon combustible bodies, discovers its nature and principles. Whenever a combustible body, such as any animal or vegetable substance, is put into contact with the oil of vitriol, that body sooner or later acquires the appearance of a burnt or charry matter, and the acid is decomposed. But this alteration, instead of being altogether like that of the spirit of nitre, is of two kinds, according to the nature of the combustible substance; that is to say, during the combination of the vitriolic



acid with the combustible substance, two different gases are disengaged; either some inflammable gas, which we shall examine afterwards, or sulphureous gas; whilst the nitrous acid, with all combustible substances, constantly gives the same gas which we have called *nitrous gas*. This striking difference depends entirely on the inflammable substances which are combined with the acid; however, as the production of the sulphureous gas is more frequent, and as it throws more light than that of the inflammable on the principles of the vitriolic acid, it is chiefly the phenomena that accompany the separation of the first which it is necessary to observe with attention.

A cold combustible body turns black, if it be immersed for some minutes in oil of vitriol; afterwards the acid becomes of a brown colour, and very soon turns black. If an inflammable substance in combustion be plunged into it, as a burning coal, instantly it acquires the smell and volatility of sulphur; and emits a white, suffocating, and very copious fume. If, for the sake of conceiving more fully what happens in these combinations, this acid be put in contact with a combustible body that is more simple than the organic substances, and whose alterations are more easily followed and ascertained than the alterations of these substances, we can then arrive at the knowledge of the principles of the vitriolic acid, and we are able to analyze it. When for this purpose we heat a mixture of oil of vitriol and mercury in a glass retort, the neck of which is put under a vessel full of this metallic fluid, as soon as the acid boils, a permanent gas passes over, of a strong and suffocating smell, resembling sulphur when it burns. This aeriform fluid is called *sulphureous acid gas*. It extinguishes candles, kills animals, reddens and takes away the colour of syrup of violets: it unites with water with less rapidity than marine acid gas; it dissolves chalk, camphire, and iron: it is absorbed by charcoal and all bodies that are very porous.

It



It is a particular acid, a modification of the vitriolic, susceptible of forming, with the alkalis, neutral salts, which are different from those formed by the vitriolic.

Stahl, who very attentively observed all these important phenomena, supposed, that in this combination the phlogiston of the metal united with the acid gave it smell and volatility: But this celebrated chemist not having prosecuted the experiment farther, undoubtedly did not perceive that a very strong objection to this doctrine might be made from this very fact. M. Lavoisier, M. Bucquet, and myself, have each of us examined the issue of the reciprocal action of the mercury and vitriolic acid. When the mixture is white and dry, but very little sulphureous gas passes over. If then this mercurial vitriolic salt be heated very strongly, there is disengaged a little water and a gas of a nature quite different from the first. It is some air as pure and as respirable as that which Mr Priestley has named *dephlogisticated air*. As this passes over, the mercury is reduced, flowing, and quite like that which was employed, except some portions, which do not equal a fourth part of the quantity used in the experiment. Hence it appears, that the mercury not having been attracted, the two gases which we obtained belong to the vitriolic acid which has been decomposed.

The sulphureous gas, then, appears to be to the vitriolic acid, what the nitrous gas is to the nitrous acid. However, there is really much difference betwixt the compositions of these two acids, since it is impossible to recompose the vitriolic by the union of the two gases which it furnishes, whilst we can reproduce the nitrous acid at pleasure, by combining the pure acid and the nitrous gas which are separated during their analysis. It is probable that the vitriolic acid cannot be reproduced till after some length of time; since it is actually effected by exposing to the air the compounds of the sulphureous acid and different bases, which by degrees contain no more but the vitriolic



acid. In this manner the combination of the sulphureous acid and vegetable fixed alkali, called the *sulphureous salt of Stahl*, very soon becomes true vitriolated tartar. We must not forget to observe, that the sulphureous acid gas is a mean substance between the vitriolic acid and sulphur; and it is truly this last which is to the vitriolic acid what the nitrous gas is to the nitrous acid.

In the decomposition of the vitriolic acid, there is still a fact which I ought not to pass over in silence, viz. that the pure air furnished by this acid is mixed with a small portion of aerial acid. This fact is proved by lime-water.

The vitriolic acid is in use in several arts, and particularly among the hatters and dyers. It is employed in medicine as a violent external caustic; and internally, as a cooling, tempering, and antiseptic remedy. In the last case it is diluted with water, so that it possesses but a slight acidity.

The sulphureous acid is employed in dying and for taking away the colour of silken stuffs.

#### Species 7. *Acid of Borax, sedative Salt.*

THE works of a great number of chemists have proved, that borax is a perfect neutral salt, formed by the combination of a particular acid with the mineral alkali: however, since to obtain the first of these salts, called *sedative salt* by Homberg, who discovered it, we are obliged to employ other acids; and as, on the other hand, the characters of the sedative salt are not pointed out, chemists did not agree in the opinion of its being a particular acid. The greatest part of them thought that it was a kind of neutral salt, whose saturation was not complete, and which consequently was susceptible of being united with the alkalis. But since M. Hub. Fran. Hoefer, apothecary to the great duke of Tuscany, discovered that the water of several lakes of that country, those of Castelnovo and Monterotondo in particular, contain a good quantity of the sedative salt quite



quite pure in solution, which forms with the mineral alkali true borax, it cannot be doubted that this salt is a particular acid, whose properties it is necessary to examine apart. It is even probable that it will be found in several other mineral waters; and it seems to be formed in fat substances corrupted, as we shall observe more fully hereafter.

Sedative salt, native, or extracted from borax by the processes which we shall explain in the article on this neutral salt, is a concrete substance, crystallized in small spangles, very slender, and of a considerable lightness. Sometimes it has a kind of brilliancy. Its taste is weak, although sensibly acid; exposed to the fire, it is not volatilized, but it fuses into a transparent glass, which becomes opaque in the air without being efflorescent. This glass is the salt without alteration.

The acid of borax suffers no alteration from the contact of air. It dissolves with difficulty in water, since, according to the academicians of Dijon, a pound of this fluid boiling can take up 183 grains only. It crystallizes by cold, and partly by evaporation. This solution instantly reddens the tincture of turnsol, and alters, although slowly, the syrup of violets. If in a cucurbit furnished with a head, we heat some sedative salt moistened with water, part of the acid will sublime by means of watery vapours which carry it along; but as soon as it is dry, it is no longer volatile; which proves that this salt of itself is fixed.

The sedative salt is used to fuse the vitrescent earths; and by fusion forms with them a white glass. By the assistance of heat it dissolves the earth precipitated from the liquor silicum. It unites with the terra ponderosa, magnesia, quicklime, and the other alkalis; and combined with these substances, it forms particular salts, whose nature, that of borax excepted, is not yet perfectly known.

All these properties, and particularly its taste, the red colour which it gives to the blue tincture of vegetables,



and its combination with the alkalis, sufficiently point out its nature.

The action of the acids upon sedative salt is not well known. It seems to decompose the vitriolic acid, because it is converted into the sulphureous acid when it is distilled from this salt.

There have been many different opinions about this salt. Several chemists believed it to be an intimate combination of the vitriolic acid and vitrescent earth with a fatty matter. M. Bourdelin and Cadet supposed that it was formed of the marine acid. The latter imagined that it contained a small quantity of the earth of copper. M. Model regarded it as the combination of a particular alkali and the vitriolic acid which is employed to separate it; but since this salt is always the same, whatever acid we employ to separate it, this opinion cannot be admitted. M. Beaumé says, that he made sedative salt by leaving a mixture of clay and fat to macerate for eight months. He extracted, at the end of this period, by washing, a spangled salt, which possessed all the properties of sedative salt. Hence he thinks that this salt is a combination of the acid of the fat with a very fine earth, of which it is impossible to deprive it. He adds, that the vegetable oils give the same salt, although more slowly. This fact has been in part confirmed by the discovery of a kind of borax, formed in stagnating soap-water. The history of this discovery we will mention in the article upon this neutral salt.

The acid of borax, or that of sedative salt, has been employed in medicine since the time of Homberg, who ascribed to it a calming, and even narcotic property; but practice has taught us, that this salt has but a very inconsiderable efficacy, though employed in a much stronger dose than that which he prescribed, as in the quantity of a gros or more. What makes it to be laid aside with less regret, is, that medicine possesses a great



great number of remedies of this class, whose action is much more powerful and much more certain.

ORDER II. *Secondary, compound, or neutral Salts.*

WE comprehend under the name of *secondary salts* all the bodies which are composed of two saline substances combined. These salts have been called *neutral*, because they have not the qualities of the primitive salts; that is to say, they are neither acid nor alkaline. However, this is not the case with some of them, as borax, chalk, and the mild alkalis, which enjoy some of the properties of primitive salts, but in a degree much less perceptible. Those secondary salts have not so strong a taste as the greatest part of the primitive salts have, and their tendency to combination and solubility is less considerable. What particularly distinguishes them is their incapacity to communicate saline properties to other bodies as the primitive salts do. They are equally combustible with the primitive; and their constant crystalline form is a noted character, the study of which belongs to the naturalist, and which sometimes points out their nature, although it is often the source of error in that respect.

The most fixed substance which enters into the combination of the neutral salts, is generally termed the *base*. As this base, which is sometimes volatile, affixes some constant general properties to the several combinations with the different acids which we have examined, we choose the name of *base* to distinguish the genera which we will establish among the secondary salts. We will divide these salts then into as many genera as there are saline bases which are capable of being united with the acids.

The *first* genus will comprehend those which are formed by the union of the fixed alkalis with the acids; them we shall call *neutral* or *secondary perfect salts*, because their union is very intimate.

The *second* genus will include those which are com-  
N 4 posed



posed of the volatile alkalis combined with the acids: They will be distinguished by the name of *ammoniacal salts*; a name adopted from one of the salts, which for a long time has borne that name. They may also be termed *imperfect salts*, because they are much more easily decomposed than the former.

In the *third* genus we shall rank the neutral salts, whose base is quick-lime. In general they are less perfect than those of the second genus, although lime has more affinity with the acids than the volatile alkali has, as the examination of them will prove. These salts will have the title of *neutral calcareous salts*.

The combination of magnesia with the different acids, will constitute the *fourth* genus of neutral salts. These salts are more easily decomposed than the preceding, because lime and the alkalis have a greater affinity with the acids than magnesia has. They will retain the name of *neutral salts with base of magnesia*. The *fifth* genus will be left for those which have the pure argillaceous earth for their base. As alum is the principal ingredient of these combinations, we shall give them the general term of *aluminous salts*. The alkalis, lime, and magnesia, decompose the salts with base of clay.

In the *sixth* and *last* genus, we will place the neutral salts with base of terra ponderosa. These salts, as well as most part of those of the two preceding genera, are almost unknown. There are even some chemists who do not admit of this particular earth; the discovery of which is due to M. Bergman. I confess that I should have followed their example, if M. d'Arcet, whose great merit and accuracy are known, had not enumerated the terra ponderosa among the chemical substances, and if he had not made a particular meeting to explain the properties of it in his last course at the Royal College.

It may be thought that these different bases combined with the acids whose properties we have examined, ought to produce a great number of neutral salts; and that



that that number may even be much increased, if it be admitted, along with M. Bergman, that such are particular compounds as result from the union of these same bases with the acids which he calls *phlogisticated*, and which, according to the modern doctrine, are deprived of a part of their pure air. But these last substances are only modifications, which are less durable, alter by the contact of air, and are very readily converted into true neutral salts. We are of opinion that their number is already too considerable, and ought not to be multiplied; and we do not mean to point out differences which these salts present according to the state of their acids. We observe further, that the substances or bases which we are to enumerate, when combined with aqua regia, give nitrous and marine salts mixed, which may be obtained separately, and are perfectly similar to those that these two acids form separately. We will only mention the combination of these bases with the six simple acids.

With respect to the rank and disposition of the different species of neutral salts, we imagine that we ought to follow the order of the force of affinity of the acids. Thus, in all the genera, we will begin with the vitriolic salts, and go on to the nitrous; to the marine; to those into which the acid of borax enters; to those formed by the sparry acid; and will finish our detail with the salts which contain the chalky acid, because it seems to be the weakest of all.

GENUS I. *Perfect neutral Salts, or Salts with base of fixed Alkalis.*

Species I. *Vitriolated Tartar.*

VITRIOLATED tartar is a perfect neutral salt, resulting from the combination of the vitriolic acid with the alkali of tartar or the fixed vegetable alkali. This salt appears in the form of a transparent body, more or less white and regular. Its crystals vary according to the circumstances of its crystallization. When it is made  
in



in small and slowly, it forms white transparent crystals with six sides, sharpened a little before like the points of rose-cut diamonds, or, what happens more rarely, it forms prisms with six surfaces, terminated by one or more hexaëdral pyramids, somewhat resembling rock-crystal: But if the evaporation has been very quick, all the crystals agglomerate and blend themselves into the form of a solid crust, the surface of which is set with points in irregular pyramids. Of this sort is that which we find in commerce. In short, to obtain the crystals of this salt very regular, it is necessary to set the mother-water of its solution to evaporate slowly and spontaneously. By this means we obtain solids with twelve faces, formed by two hexaëdral pyramids united at their base. It is true, that these crystals are commonly impure, and never have the whiteness and transparency of those which are obtained by the first evaporation. But this is a difficulty that exists in all the neutral salts: Almost always they are white with the loss of form, or regular with the loss of transparency.

Vitriolated tartar has a very disagreeable bitter taste. It suffers but little alteration by the fire; it decrepitates when we put it on burning coals, and is burnt into small fragments. This phenomenon depends on the sudden expansion of the water of its crystals; but after it has decrepitated, it loses nothing of its properties. If we expose it in a crucible to the action of the fire, it loses its transparency, and becomes dry and friable by losing the water contained in its crystals. It grows red before it fuses; and in order to fuse it, an extreme violent heat is requisite, such as that which bakes porcelain, or which fuses hard glasses. With this degree of heat it melts, and exposed to the cold it forms into an opaque mass friable and soluble: but it suffers no other alteration in its principles; for we can restore its transparency and crystalline form by redissolving it in water. If it be kept in fusion for some time it is volatilized, but always without being decomposed.

Vitri-



Vitriolated tartar suffers no alteration from the air; it retains its crystalline state, without suffering any change in its form or in its transparency. It has little solubility in water; but, however, varies according to the temperature of the fluid. According to M. Spielman, it requires about eighty parts of cold water to dissolve one of vitriolated tartar; but when the water is boiling, it dissolves almost a fourth of its weight, four ounces of boiling water, according to M. Beaumé, being capable of dissolving seven gros and forty-eight grains of vitriolated tartar: It crystallizes in part by cold, and still more by evaporation; it contains but little water in its crystals; for which reason it suffers no alteration when exposed to the air.

Vitriolated tartar has no action upon the simple earths. It is an observation, that a quantity of it which by chance has been united with the salts that are used as fluxes, and employed in the manufacture of glass, is found in the scoriæ, and contributes nothing to the vitrification; a circumstance which undoubtedly depends upon its infusibility. According to M. Bergman, the terra ponderosa readily decomposes it, because it has a greater affinity with the vitriolic acid than the vegetable fixed alkali has. If a little of that earth be put into a solution of this salt, the spathum ponderosum is precipitated, and is quite insoluble. It shall be examined afterwards. The vegetable fixed alkali remains pure and caustic in the solution. Quick-lime and magnesia have no action upon vitriolated tartar; but several acids have a very remarkable one upon it. M. Rouelle has imagined that it was possible to combine a greater quantity of the vitriolic acid with it. This process consists in distilling some oil of vitriol upon vitriolated tartar, which remains impregnated with the acid, and derives some new properties from it; such as reddening the syrup of violets, being more soluble in water, having a sour taste, and raising an effervescence with the mild alkalis, even after being dissolved and crystallized.



lized. M. Beaumé proves that the acid is not really combined, and that it may be separated from the neutral salt, by simply making it drop through grey paper or through sand. M. Macquer remarks, that the vitriolic acid adheres with considerable force to the vitriolated tartar; and that this adherence is owing to a particular affinity betwixt these two substances, since the action of fire and water cannot destroy it.

M. Beaumé observes, that vitriolated tartar suffers an alteration much more remarkable from the nitrous acid. If some aquafortis is poured upon it, and made to boil, the nitrous acid attracts the vegetable fixed alkali, and disengages the vitriolic. By leaving this mixture to cool, some true nitre is formed.

It has been said, that this decomposition is not effected without the assistance of heat; I have found that fuming spirit of nitre poured upon vitriolated tartar in powder deposits some crystals of nitre in the space of a few hours. It has also been affirmed, that when the mixture becomes cold, the vitriolic acid re-attracts the alkali, and in its turn decomposes the nitre. However, I have kept for a year a mixture of vitriolated tartar and spirit of nitre, at the bottom of which were saline crystals, which detonated upon the coals, and which did not change their nature, although they were put into vitriolic acid separated by the nitrous acid. M. Bergman and Cornette have discovered that the concentrated marine acid also decomposes vitriolated tartar even in the cold.

From these two facts it follows, that the law of affinity, relative to the different acids, is not so constant as has been supposed; however, it is proper to observe with M. Bergman, that in this experiment a third only of vitriolated tartar is decomposed, whatever be the quantity of nitrous and marine acids employed, whilst the vitriolic acid, in a moderate dose, completely decomposes the nitrous and marine salts.

The most important decomposition of vitriolated tartar,



tar, is that which happens by the addition of almost all combustible matters, and particularly of charcoal. If we apply a strong heat to a mixture of this salt and charcoal in a crucible, the vitriolated tartar will no longer exist, and there will be found only some sulphur united with the fixed alkali. Stahl looked upon this experiment as well suited to demonstrate the presence of phlogiston. It will be known, in the article of Sulphur, what we ought to think of it: It is only necessary to observe, that the vitriolic acid has changed its nature, and has become sulphur.

Vitriolated tartar very rarely exists in nature; it is almost always a production of art. It may be made in three ways: The first is by directly combining vitriolic acid with the caustic vegetable fixed alkali. From this union some vitriolated tartar accordingly results, which may be dissolved in water, and made to crystallize, as has been already mentioned.

The second way is to decompose, by the aid of the vitriolic acid, the neutral salts which are formed by the union of the vegetable alkali with the other acids; such as nitre, febrifugal salt of Sylvius, and the tartar with chalky acid: there always results some vitriolated tartar from these decompositions.

The third way of forming this salt, is to decompose the vitriolic salts with earthy or metallic bases, by means of the vegetable alkali. The alkali precipitates the saline earthy and metallic substances, united with the vitriolic acid.

We shall return to the history of the two last ways of preparing vitriolated tartar, when we come to inquire into the neutral salts which are employed for this preparation.

Vitriolated tartar is used in medicine only. It is a very good purgative. It sometimes is administered alone, in the dose of half an ounce or an ounce. For the most part it is prescribed in the dose of one or two gros only, joined as an auxiliary to other purgatives.

It



It is also employed as a solvent in chronic diseases, and particularly in obstructions of the milk : Then it is given in a dose of a few gros in any convenient while.

## LECTURE XVII.

### Species 2. *Glauber's Salt.*

**T**HE salt of Glauber, a German chemist, who discovered it, is a perfect neutral salt, formed by the union of the vitriolic acid and the marine or mineral alkali. This salt has many properties in common with vitriolated tartar, and it has some particular ones. It is equally crystallizable ; it has a bitter taste ; it is very unfusible ; it dissolves easily in water ; it does not unite with the earths ; it may be decomposed like vitriolated tartar by the acids. However, several of these properties of it recede far from those of the vitriolated tartar, as we shall see in their description.

Glauber's salt is a body more or less white and transparent, and generally of a regular form. Its crystals are prisms with six striated surfaces, terminated by two-sided tops. Their form, however, is rarely so very regular : The number of their surfaces varies, as well as their extent, their position, and their striæ. The taste of Glauber's salt is at first cooling, afterwards extremely bitter. It does not alter the blue colour of vegetables.

Exposed to the action of the fire, it fuses very readily ; but it dries and soon becomes of a white hue. In this state it requires a considerable heat to fuse it, such as is used for the fusion of the hard glasses. To have a proper notion of what passes in the action of the fire upon it, it is necessary to distinguish two kinds of fusion in saline matters ; one of which is owing to the water that enters into the form of their crystals, and is called the *watery fusion*. This happens only in the case of salts which are more soluble in warm water than in cold ; and it is owing to this, that a portion of this fluid, which is one of the principles of saline crystals, is heated,



ed, and hence becomes capable of dissolving the saline matter. This aqueous fusion, then, is only a solution by means of hot water: But if the heating of the fused salt is continued, it dries and becomes white; then the fusion, which is effected by means of a great heat only, is truly owing to the fire, and is called *ignited fusion*. Glauber's salt then is as difficult of fusion as vitriolated tartar; like which it is also volatilized by the greatest degree of fire.

The great quantity of water that the crystals of Glauber's salt contain, is also the cause of that property which they possess, of being reduced into a very fine white powder when they are exposed to the air. This phenomenon is called *efflorescence*, because the crystals are really covered with a powdery down, resembling the whiteness and appearance of some flowers. The loss of the water in their composition is the only reason of their falling into powder; the efflorescence also is always most rapidly formed, and most remarkable, when the air is very dry, and consequently very attractive of moisture. This phenomenon then is very analogous to the exsiccation by means of heat, both depending on the evaporation alone of the water, which makes a constituent part of the crystals. However, as the water which enters into the crystals of Glauber's salt, and into those of the efflorescent salts in general, is accurately combined with the saline matter, it appears that the efflorescence is owing to a kind of affinity between the air and the water. This has always been my conception of it; and I do not see how it can be explained otherwise.

Glauber's salt loses about a third of its weight by this alteration: but its nature is not changed; it resumes its crystalline form upon restoring the water which it had lost.

It is of importance to know exactly the quantity of water which Glauber's salt loses in its efflorescence, in order that a proper dose of it, as a medicine, may be always prescribed in each of these two states. A third



less ought to be given when it is in an efflorescent state than when it is in fine transparent crystals.

Glauber's salt is very soluble in water. It requires only four parts of cold water to dissolve it. The quantity of water necessary for its solution diminishes in proportion to the heat of that fluid. A given quantity of boiling water dissolves an equal quantity of the salt. Upon this property its crystallization depends: As it is more soluble in warm water than in cold, it is sufficient to allow a very strong solution of it to cool; and it gives crystals so much the more beautiful and regular, as the solution is made in greater quantity, and as it cools more slowly.

Glauber's salt has no more action upon the earths than vitriolated tartar has; and from want of fusibility, it enters no more than the vitriolated tartar does into the formation of glass. The terra ponderosa decomposes it as it does vitriolated tartar; but from the other saline earthy substances, it seems to suffer no alteration.

The caustic vegetable fixed alkali, mixed with a solution of Glauber's salt, decomposes it, according to a discovery of M. Bergman, and vitriolated tartar is obtained by evaporation. There remains in the mother-water some caustic mineral alkali.

The nitrous and marine acids decompose it in the same circumstances as they do vitriolated tartar; and when it is strongly heated with charcoal, it forms some sulphur, just as the last mentioned salt does.

All the properties of Glauber's salt, which differ from those of vitriolated tartar, are manifest; since the two fixed alkalis, which are perfectly alike when considered in their state of purity, are, however, very different from one another, forming with the same acid very different salts.

Glauber's salt is more abundant in nature than vitriolated tartar. It is found in great quantity in sea-water, in saline fountains, and particularly in several mineral waters. Besides, art can produce it in



the three ways mentioned in the article of *Vitriolated Tartar*. It is not more employed in the arts than the former, but much more than it in medicine. It is given as a solvent, aperient, and purgative, from half a gros to an ounce and a half, according to the case in which it is administered. Its effects are even more remarkable and more speedy than those of vitriolated tartar, because it is much more soluble in our humours, and its taste stronger.

Species 3. *Nitre*.

NITRE, or Saltpetre, is a neutral salt, formed by the union of the nitrous acid with the alkali of tartar. It has a cooling taste, is perfectly neutral, and does not in the least change the colour of the syrup of violets. The crystals are prisms, with six surfaces, terminated by pyramids, diedres ou en biseau (*a*), and frequently perforated by a canal which passes through their whole length.

This salt exists in great abundance in nature. It is daily formed in places inhabited by animals, where we find it in great quantities upon the walls. In this state it is called *saltpetre* (*b*) *de houffage*. Three principal circumstances seem to favour its formation. The first is the presence of chalk, or of some calcareous salt. In this manner the nitre de houffage is formed, which is scraped off from walls that are covered with plaster; and this is the cause why the ruins of old buildings afford it in considerable quantities. It is also found quite pure in chalk beds: M. le Duc de la Rouchefoucauld procured an ounce in the pound of a chalk of Roche-Guyon.

The second circumstance which favours its formation, is the putrefaction or spontaneous decomposition

VOL. I.

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(*a*) *Diedres ou en biseau*, is a term of art, signifying two-sided, or in form of a house-top.

(*b*) This term is used to signify coarse or impure, in opposition to refined.



of vegetable and animal substances. It is a fact well known, that places moistened with animal fluids, or which contain animal substances in putrefaction, such as dunghills, stables, and privies, produce abundance of it. The constant observation of this has taught us to form artificial hillocks for its production. Ditches or earth-houfes are formed, which are covered a-top, but exposed to the air in the sides: These are filled with animal substances; such as dung, excrements of quadrupeds, fæces of birds, rubbish of vegetables. We moisten this composition from time to time, and stir it in order to allow the air free access through it. When the putrefaction has advanced, we take a small quantity of it, and wash it, that we may know the quantity of nitre which it contains. If the quantity it contains be considerable, the whole undergoes the same process.

The third circumstance which favours its production, is the contact of the air. This is the cause of the formation of the nitre de houffage. It is with the same intention they stir the mixture of the materials for the artificial production of it, to permit the air to touch it in all points; and to confirm this, the chalks, which naturally contain nitre, furnish it only to a certain depth under the surface, and never below that.

If these three circumstances be united, the formation of nitre will be very abundant.

These are the principles which are necessary in the construction of the nitrous hillocks.

This salt undergoes considerable changes from heat. If it be exposed in a crucible to the action of fire, it soon liquefies, and this liquefaction is a true fusion; for though it be kept for some time in this state, it does not grow dry, but may be made red hot without losing fluidity. If, while in this state, it be poured upon a cold body, it assumes the appearance of an opaque mass somewhat vitreous, called *mineral crystal*, which is as weighty, as fusible, and as soluble as the crystals. There is this difference between the salt bearing this name



name in pharmacy and pure nitre fused, that the former contains a small quantity of vitriolated tartar, which is produced by the burning of the sulphur that is added in the proportion of one gros to the pound of nitre; according to the pharmacopœia of Paris.

If we leave fused nitre to the action of fire, it decomposes itself, and becomes alkalized without addition. This process also succeeds when performed in a retort, and at the same time throws light on the decomposition of the acid. In place of obtaining it pure, a large quantity of an aerial fluid passes over, which cannot be collected above water, and is true dephlogisticated air. In general, the remaining alkali quickly fuses the retort, and prevents the process from being continued to the end. Here then, we see, that the nitrous acid is entirely changed into pure air, without any nitrous gas being perceived.

Nitre exhibits a different appearance, when we expose it to the action of fire along with combustible bodies. When laid on charcoal, it produces a white vivid flame, accompanied with a kind of decrepitation. This is what is called the *detonation* or *fusion of nitre*: Hence it is said that this salt detonates or fuses. Stahl believed that this phenomenon was owing to the rapid union of the nitrous acid with phlogiston. M. Beaumé, following out this theory, thought that, in this experiment, a nitrous sulphur was formed, which instantly takes fire. In 1780, I presented a memorial to the academy, in which I demonstrated, that nitre is not combustible, and that it does not form nitrous sulphur in its detonation; but that this phenomenon is solely owing to the combustible matter, which it is necessary to add to the nitre for its detonation, which burns more or less rapidly, with the assistance of the pure air that is disengaged in great abundance from the nitre strongly heated. This theory is completely proved; 1. Because nitre does not detonate alone: 2. Because, after the detonation of it with an inflammable substance, the latter is entirely



consumed: 3. Because the greater the proportion of the nitre is to the inflammable substance, the more completely the body is consumed: 4. Because the detonation of nitre takes place in close vessels, as well as in the open air, which could not happen without the aid of the pure air that is furnished by the salt.

This assertion is fully demonstrated by what happens in the process for making clivus of nitre, which are no other but detonations of this salt with inflammable substances in close vessels. We shall only mention here its effects with charcoal. Two or three globes are adapted to a retort of earth or iron; in the upper part of which an opening has been formed that we may shut up with a lid. The retort is made hot; and when its bottom is red, the mixture of nitre and charcoal is projected by degrees through the aperture. During the detonation the globes are filled with vapours, part of which condense into an insipid liquor, noways acid, and often alkaline; the residuum is entirely mild fixed alkali. The nitrous acid is then entirely destroyed: a considerable quantity of gas is produced; which may be collected by adapting to the upper part tubulated globes, or a bladder or tubes, which are immersed into vessels full of water. The gas is in a great measure aerial acid, mixed with a little inflammable gas.

In all the cases in which nitre is decomposed by the action of the fire, the residuum of fixed alkali makes a brisk effervescence with acids, and is united with a certain quantity of aerial acid; nevertheless it contains not a particle of it when united with the acid of nitre. The aerial acid, then, can only arise by the decomposition of the nitrous acid in close vessels, and perhaps is one of its principles. The remaining alkali is generally called by the improper name of *nitre fixed by charcoal*. It is one of the purest alkalis which we know.

From the facility with which heat decomposes nitre, we understand that it must not be kept too long on the fire when designed to form mineral crystal. Without this precaution the medicine would contain the fixed  
alkali



alkali in all its acrimony; the effect of which would be much more violent.

Nitre well purified is not sensibly changed by the air. It is very soluble. Three or four parts of cold water dissolve one of nitre; and boiling water dissolves double its weight. The solution crystallizes by being exposed to cold. Upon these two principles is founded the art of extracting nitre from rubbish in which it is contained. The saltpetre-makers pound the rubbish, and put it into a vessel, whose bottom having a hole bored in the middle, is covered with ashes. They make water pass through it, so that it may carry off the salt in considerable quantity; taking care to put pure water on the rubbish already washed, with the view of draining it quite, and putting the water, which has been thus impregnated, on new rubbish, with the view of saturating it completely (c). Afterwards they evaporate the mother-water of the nitre in copper vessels. They scum off the first pellicles, which are nothing else but a marine salt that was contained in the rubbish, that

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they

(c) The mother-water of nitre is employed to lixivate fresh cargoes of materials, upon the supposition that it will promote the formation of more nitre. It is not, however, evident in what way it can produce this effect, as the mother-water consists of nitrous acid already formed, which requires nothing but the addition of some fixed vegetable alkali to yield perfect crystals of nitre. Along with the nitrous acid there is a portion of the marine, which it is necessary to separate by some proper management. The process which has been last recommended for this purpose, displays considerable ingenuity. We are desired to take a given measure of the mother-water, and to ascertain, by experiment the exact quantity of alkaline salt requisite for the complete saturation of all the acid which it contains. We are next gradually to drop some solution of lead in spirit of nitre, into the same measure of mother-water. The infiltration of every drop occasions a cloudiness, because the marine acid in the liquor decomposes the metallic salt, and seizes upon the lead, forming an insoluble compound, which falls to the bottom of the water in the form of a white powder. We continue to add the solution of lead so long as any decomposition takes place; and when all the marine acid is saturated, we pour off the liquor, dry the precipitate, and weigh it. The weight of the precipitate enables us to appre-



they term the *grain*. When the water is sufficiently evaporated, they put it into large vessels, which are set in a cool place, where the nitre crystallizes. This nitre is very impure, and very dirty; it is called *nitre of the first boiling*. Some chemists have thought that the ashes employed by the saltpetre-makers serve only to purify the nitre; and their opinion appears to have been founded upon this, that these matters contain almost no fixed alkali; and in particular, that the saltpetre-makers of Languedoc use ashes of tamarisk only, which contain nothing but Glauber's salt. But this salt, as well as vitriolated tartar, is quite fit, by the help of affinity, for decomposing the calcareous nitre, which is found in great quantity in the rubbish; as M. Lavoisier has observed with regard to the lixivial ashes used by the saltpetre-makers at Paris. We shall touch on that fact at greater length in the article of *Calcareous Nitre*.

Nitre of the first boiling is, as we have already said, often very impure. It contains, beside nitre, five other kinds of salts, viz. the marine, nitre with base of magnesia, calcareous nitre, marine salt with base of magnesia, and the marine salt with base of calcareous earth; all which they endeavour to separate, in order to obtain the nitre in a pure state. They set about the purification by dissolving it in as little water as possible, and by clarifying this boiling liquor with ox-blood; the coagulum of which, formed by the heat, entangles all the impurities, as they rise from the bottom of the liquor to the surface. This is next set to evaporate; and thereby they obtain a nitre, which is a much purer salt, and is called

appretiate the original quantity of marine acid which the mother-water contained. By knowing this, we learn the quantity of alkaline salt consumed by the marine acid; and in all our subsequent additions, we subtract this quantity of alkaline salt, leaving no more than what is barely sufficient to saturate the nitrous acid. In this way the nitre is formed, free from the admixture of any febrifuge salt of Silvius. The process seems sufficiently accurate for business, and is not difficult to execute.



called *nitre of the second boiling*. Still it is mixed with a certain quantity of mother-water; on that account they purify it a third time by the same process, whereby it becomes a much purer and a much whiter salt. This is called *nitre of the third boiling*.

When it is made to crystallize very speedily, it forms into thick very irregular masses: however, in the middle of the vessel there are some regular crystals, called *nitre in sticks*. This last is rejected in the arsenals, because it is less fit for making gun-powder than the nitre in thick irregular masses, in consequence of the water which it retains in crystallization, and which would impede the kindling of the powder.

The chemists and apothecaries purify the nitre of the third boiling again, by fresh solutions and crystallizations. In this way they are sure of procuring nitre very pure, containing no heterogeneous substance.

Nitre undergoes some alterations by means of vitreifiable earths. We can draw off the acid by distillation with sand. This acid passes off without colour, and discovers some vapours. The residuum is more or less vitreous according to the quantity of sand, and according to the degree of heat employed. The sand seems to decompose the nitre by the tendency which it has to combine with the fixed alkali: for if we distil the nitre without intermixture, we do not get the acid of nitre; we have nothing but pure air. I suppose that this, in the distillation without intermixture, happens in consequence of the reaction of the alkali upon the acid which is decomposed, and takes from it one of its principles, which gives it the power of effervescing. As soon as we heat the nitre mixed with sand, the latter, striving to unite with the alkali in order to form a glass, prevents the alkali from acting on the acid, which then passes off unaltered.

The argillaceous earths also decompose it: but it is as yet uncertain if this is the property of pure clays; for experiments have not been made with earths of this



nature : Clays more or less coloured have always been used. M. Beaumé supposes that the decomposition is owing to the vitriolic acid contained in the clay.

The distillers of aquafortis employ a similar earth : They mix two pounds of nitre of the second boiling with six pounds of coloured clay of Gentilly in earthen retorts of a particular shape, which they call *des Cuines* ; several of which are placed one at the end of another, their neck being received into a bottle of the same form, which serves for a receiver. By this means they draw off a transparent liquor, a little acid, called the *phlegm of aquafortis* ; afterwards the acid, more and more concentrated. The residuum is an earthy substance, red, and very hard, which serves to make a kind of mortar.

This experiment is the farthest from a proof that clay can decompose nitre. 1. The distillers only employ an impure nitre, which contains a great quantity of nitre with earthy base : 2. They employ a very compounded clay, which often contains a great deal of pyrites, the vitriolic acid of which is able to decompose the nitre. In order to ascertain this decomposition, we should use a white clay, or, what is still better, earth of alum. This earth not having so much tendency to unite with the alkali as the sand, nor forming a glass with it, does not appear to possess equal powers of decomposing nitre as sand does. Nevertheless, M. Beaumé says he decomposed it with porcelain and clay, formed into a hard brown stone, which did not seem to contain the vitriolic acid. Terra ponderosa decomposes nitre, and separates the alkali from the nitrous acid, according to M. Bergman. He asserts, that it has a greater affinity with the nitrous acid than the fixed alkali has.

Magnesia, lime, and the alkalis, show no action on nitre. The acids have a very remarkable action upon it, especially the vitriolic, which has a greater affinity to the alkalis than the nitrous has. If oil of vitriol is poured on nitre well dried, a considerable effervescence ensues, and we see red vapours disengaged, which are  
just



just the spirit of nitre. In performing the process in a retort, to which a receiver is fitted, the nitrous acid is collected in the globe. This process is known in laboratories by the name of the distillation of the nitrous acid after Glauber's method. We are obliged to leave a small hole open in the globe, to give vent to the vapours of the nitrous acid.

It was remarked, that these vapours were very difficult to be condensed; and that they might occasion two accidents. The first was the loss of a very considerable quantity of the strongest spirit of nitre, which is dissipated through the small hole of the globe: the second was the danger to which the operator is exposed from these vapours, which are very strong and corrosive. But Mr Woulfe, a famous English chemist, has found means to remedy both these inconveniences. In place of employing a globe, pierced with a small hole, he uses a globe with two points. In the end of this vessel he places a tube opposite to the retort; one end of which makes a right angle with the other, which is plunged into a bottle: this bottle has two openings in its sides; and every one of these openings receives a syphon, which passes into another bottle, placed at every side of the first. The two side-bottles are joined with two similar vessels, whose lateral openings remain unshut. All the bottles contain such a quantity of water, as that the inferior extremity of the tube, which communicates with the first bottle, is immersed in the water, and that there remains above the water a void, in which the superabundant nitrous acid gas is received, and from whence it is carried into the water of the adjoining bottles by the superior extremity of another tube, which opens into this void. By this means nothing is lost, and the operator under no inconvenience. The nitrous acid passes in vapour into the globe; and from thence goes into the first bottle, where it is absorbed in the water. What cannot be absorbed there passes into the collateral bottles, and



and unites with the water which they contain. Some pure dephlogisticated air is disengaged from the last bottles.

This apparatus is very commodious; but still it has an inconvenience sufficiently great. At the end of the operation, when the retort is left to cool, a vacuum is formed in the vessels, and the external air, pressing on the water in the last open bottles, forces it to mount through the syphons into the first bottle, and from these into the middle one and into the globe. In this manner the product is spoiled, and the nitrous acid weakened by the water. To remedy this inconvenience, M. Bucquet has been in the custom of putting no water into the first bottle, and to have it large enough, in case of absorption, to contain all the water of the four lateral bottles without being filled; so that the fluid not finding the tube in the bottom of this bottle, never passes into the globe. Thus he was sure of obtaining his acid very strong.

In order to perform this process, we put four pounds of nitre into a tubulated earthen retort, and pouring at once two pounds and a half of oil of vitriol upon it, we shut the retort. The heat is raised by degrees until no more come over. The process may be regulated after the disengagement and passage of the gas into the bottles: If it distil too rapidly, the fire is too violent, and must be diminished; if it be not strong enough, the fire must be increased. This apparatus has yet the advantage of informing the artist about the progress of the process.

The residuum of this decomposition is vitriolated tartar, formed by the union of the vitriolic acid with the fixed vegetable alkali of the nitre. It is known in pharmacy by the name of *Sal de duobus*, or *Arcanum duplicatum*.

The nitrous acid obtained by this process, is very red and very smoking. This method of preparing nitrous acid has been practised since the time of Glauber, from whom it is generally called in laboratories by the name



name of *Glauber's smoking spirit of nitre*. The process was far from acquiring in his hands that certainty and perfection at which it arrived under M. Woulfe and Bucquet, whose ingenious apparatus, over and above, has the great advantage of being applicable to several other important processes. Sedative salt decomposes nitre by heat, and expels from it a strong enough nitrous acid. The fixedness of the sedative salt seems to be the cause of this decomposition, as the academicians of Dijon think; nevertheless it must be attributed in part to the affinity that subsists between the sedative salt and the fixed vegetable alkali, the basis of the nitre.

Nitre is of very extensive use in the arts. The glass-makers employ it. It is the principal and most useful of the ingredients in gun-powder, of which we spoke in the article *Sulphur*. Burnt with different proportions of tartar, it forms fusing matters, called *fluxes*; which are employed in the art of assaying, in order to fuse and reduce metallic substances.

It is often used in medicine, as a sedative, cooling, antiseptic, antiphlogistic remedy. It is prescribed in a draught, from the quantity of six or ten grains to that of a gros or more. Physicians observe excellent effects from it every day. It is one of the three remedies which compose the famous *pulvis temperans* of Stahl.

## L E C T U R E XVIII.

### Species 4. *Rhomboidal Nitre*.

**W**E call the perfect neutral salt *cubic* or *rhomboidal nitre*, resulting from the combination of the nitrous acid with the mineral alkali.

Generally this salt is in very thick and very regular rhomboidal crystals: it deserves the name of *rhomboidal* rather than that of *cubic nitre*.

Its taste is cooling and bitter like that of nitre.

The fire decomposes it as it does ordinary nitre.

It



It is a little more alterable by the air than the latter is, and attracts a little humidity from it.

It dissolves very well in cold water, and much more copiously than ordinary nitre. Two parts of cold water dissolve one of it. Boiling water does not dissolve more. In like manner, to have it crystallize regularly, the evaporation must be slow.

With regard to its other properties, it has all the other characters of nitre. It detonates in the fire when exposed to it along with other combustible substances; the combustion of which is accelerated by means of the dephlogisticated air which the nitre furnishes, which becomes alkalized. It may be decomposed by the terra ponderosa and vitriolic acid. It even appears to differ from nitre in nothing but in its rhomboidal form, its slight deliquescence, its greater solubility, its property of crystallizing by evaporation; and particularly in its decomposition by the caustic vegetable alkali, whose affinity with the nitrous acid is greater than that of the mineral.

Rhomboidal nitre is never found in nature; it is always a production of art, by which it is formed in five different ways. 1. By directly uniting the nitrous acid with the caustic mineral alkali. 2. By decomposing, by means of the same alkali, the nitrous salts with earthy bases, the ammoniacal nitre, and the nitres with metallic bases. 3. By decomposing marine salt by the intervention of nitrous acid. 4. By decomposing Glauber's salt by smoking spirit of nitre. 5. And lastly, by decomposing the metallic solutions in nitrous acid, which are susceptible of decomposition by the marine salt. In this last case, according as the marine acid unites with the metal which it separates from the nitrous acid, the nitrous acid combines with the marine alkali, which quits the first acid. All these decompositions will be particularly described in the article relating to each of the salts which are susceptible of them.

Quadrangular or rhomboidal nitre may be employed  
for



for the same purposes as ordinary nitre; but as it does not produce all the effects of it, on account of its greater affinity with water, undoubtedly it is not used in the arts; besides, as nature never produces it, but it is always the production of art, it has not been brought into particular use. We have not even made all the inquiries into it which are necessary for the complete knowledge of its properties.

Species 5. *Febrifugal Salt of Sylvius.*

THE febrifugal salt of Sylvius is formed by the union of the marine acid with the vegetable fixed alkali. It has been improperly named *regenerated sea-salt*, since it differs from it in the nature of its base. Its crystals are very regular cubes, which touch one another obliquely, and by their angles only. They have a confused appearance, and a form seemingly irregular. Its taste is salt, pungent, bitter, and disagreeable: When put into the fire, it decrepitates; that is to say, its crystals burst and split into little pieces; which is owing to the sudden rarefaction of the water that enters into their decomposition. If it be left in the fire after it is decrepitated, and if the fire be very strong, it fuses, and is volatilized, but without being decomposed.

It may be made use of as a flux to the earths and metallic substances.

In that case, its principal utility is its covering the materials. It fixes the action of the other fluxes, and prevents them from being volatilized, and also the alterations which the access of the air might occasion.

The air occasions but little alteration on febrifugal salt; which only attracts a very slight degree of humidity from it. It requires about three parts of cold water for its solution; hot water does not dissolve more of it: for which reason it is necessary to have recourse to a slow evaporation, that it may be obtained crystallized.

Clay seems to decompose it in part. According to  
M. Ber-



M. Bergman, the terra ponderosa attract its acid, and separates the fixed alkali from it. The vitriolic and nitrous acids disengage the marine from it with effervescence (*d*). This phenomenon is more remarkable according to the dryness of the febrifugal salt. Decrepitated febrifugal salt occasions a very considerable effervescence, and the mixture becomes very hot. If these decompositions be made in retorts, and the vitriolic acid made use of, we obtain spirit of salt in the recipient, and the retort will contain vitriolated tartar: On the contrary, if we employ nitrous acid, the recipient will contain some aqua regia, and the retort some nitre. The acid of borax, or sedative salt, decomposes febrifugal salt by means of distillation.

This salt is frequently found in nature, but in very small quantities. It is found in sea-water, and sometimes in fountains: it exists, though very rarely, in places where nitre is contained; it is even found in the ashes of vegetables, and in several animal humours. Art also may produce it; 1. By directly combining the marine acid with the vegetable alkali: 2. By decomposing the marine salts with earthy bases, or the ammonical metallic salts by means of the same alkali: 3. By decomposing vitriolated tartar or nitre by means of the marine acid, as has been shown by M. Cornette.

At times this salt is employed as an excellent febrifuge;

(*d*) We have already observed, in speaking of the decomposition of nitre by oil of vitriol, that the nitrous acid was driven off with a brisk effervescence. Here we find the same phenomenon in the marine acid: it is also much more remarkable in the febrifugal salt; because its acid has a great tendency to put itself into the state of a gas. This is the general cause of effervescence; the nature and differences of which have been but very lately known. It was formerly believed that they were always owing to the disengagement of air: at present it is proved, that it is not air; but that all the bodies which can be put into the aeriform aggregation produce it. As this truth requires a repetition, that it may be well known and understood through all the world, we will frequently make remarks on this subject, in treating of the different neutral salts which are susceptible of decomposition by the acids.



fuge; but it possesses this quality, which Sylvius has attributed to it, only in consequence of its bitterness. At present, vitriolated tartar and Glauber's salts are preferred to it.

The febrifugal salt is not in use in the arts. Its disagreeable taste prevents it from being used as a seasoning like the marine salt: otherwise it has all the chemical properties of the marine; from which it differs in its bitter taste, its inferior solubility, its unchangeableness by the contact of the air, and its less regular crystallization. On account of these differences, we shall insist on its history no farther.

#### Species 6. *Marine Salt.*

MARINE salt is perfectly neutral, formed by the combination of the marine acid with the mineral alkali.

This salt is found in considerable quantity in nature; it is the most abundant of all the salts. It is found in immense masses in the heart of the earth, in Calabria, Hungary, Muscovy, and particularly in Wieliczka, in Poland, in the neighbourhood of the mountain Crapacks.

The mines of this last place are of great extent; and the marine salt is found there in considerable quantity. When contained in the earth, it is generally of an irregular form, and seldom crystallized: it is more or less white: some of it is found coloured. In this state it is called *sal gem*; because it generally possesses the transparency of the crystals called by that name. The seawater is likewise loaded with it, as well as some lakes and fountains. From these solutions it is extracted by four general processes.

The first is the spontaneous evaporation by means of the heat of the sun. This method is practised in some of the southern provinces, in Languedoc, at Peyrac, Pécays, and other places. At the side of the sea a kind of ditches is dug, the bottoms of which are done over with well beat clay; within them they are at pains to construct



construct little walls, which include several apartments, and communicate with one another. When the tide flows, a quantity of sea-water is left in those ditches, and is retained there by the partition-walls: a very small depth of water only is allowed to be formed, that the heat of the sun may easily evaporate it. When a saline pellicle is formed, they break it, and it falls to the bottom; and they repeat the breaking of it until there be no more water; then they collect the salt into heaps with rakes, that it may dry. This salt is mixed with all those which are dissolved in sea-water; such as Glauber's salt, Epsom salt, and marine salt with earthy base. It is also rendered impure by a portion of the clay, the foundation of the saline ditches. This is the salt of the Gabelle. In the northern provinces of France, in Normandy and Bretagne, they use the artificial evaporation by means of fire. In Avranchin, they take the moving sands, upon which the sea deposits its crystals: they wash them with the least possible quantity of sea-water, just as much as is requisite for the solution of the salt. This impregnated solution is put into kettles of lead, in which it is evaporated to dryness. This salt is very white, and purer than that of the saline marshes. M. Guettard has accurately described this procedure in the *Memoirs of the Academy* *anno* 1758.

Many saline fountains are found in Lorrain and Franche Comté. The water of these fountains is charged with different quantities of marine salt. At Montmoret, in the last of these provinces, in order to obtain this salt, they join the spontaneous evaporation to the assistance of the fire.

For that purpose, the water of the saline fountains is conveyed by pumps into a large basin. This basin is placed at the head of an apartment made for the purpose. Planks, on which little faggots of thorns are placed, are suspended under the apartment through the floors: The water falls upon these faggots through cocks; it is divided into fine rain; and by present-  
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ing a large surface, it is evaporated almost two-thirds; it leaves the selenite upon the faggots; and when it abounds with so much as will add 13 or 14 degrees to the weight of the liquor, it is carried into large vessels of iron, supported by hooks of the same metal. These vessels, called *pans*, are very large, but not deep: They contain 100 hogshheads of salt-water: they are heated quickly; and when the water comes to boil violently, it is at first troubled, and on its surface it deposits an ochry earth in form of scum. A salt of little solubility, which is only some selenite, and called by the workmen *pan-scratch*, is then separated from it. It is mixed with a little marine salt, some Glauber's salt, and marine salt with earthy base. It is received into small iron troughs placed at the sides of the pans, into which it is carried by the streams of the boiling liquor. They are carried away from time to time and replaced, until a great quantity of small cubic crystals, which the workmen call *flies feet*, is formed at the bottom of the liquor. These troughs are then carried away for the last time; the fire is diminished, and the marine salt skimmed off as soon as it is crystallized in sufficient quantity. They continue thus to skim it off, and to evaporate the water, till it refuses to give any more. The salt which is obtained, is in more or less confused crystals, according to the rapidity or slowness of the evaporation; the remaining water is called *bittern*: it contains marine salts with earthy bases.

Wallerius relates a fourth process for extracting the marine salt from sea-water, employed in the countries of the north. The sea-water is exposed in ditches dug at the sea-side. As it is but very shallow, the cold penetrates it, and it congeals: But as the superabundant portion of the water is only susceptible of congelation, that which remains fluid retains all the salt that was retained in the first quantity; and it is so concentrated, that the marine salt is ready to crystallize with the least



degree of heat (a). It is conveyed into leaden vessels to evaporate (b).

The crystals of marine salt are very regular cubes; but if the evaporation has been too slow, they are more con-

(a) A neutral salt is prepared at Montmorat, under the name of *Epsom salt of Lorraine*; but it is only Glauber's salt, the crystallization of which has been interrupted. It is distinguished from true Epsom salt by its efflorescence when exposed to the air, while the latter attracts its humidity.

(b) A large proportion of the common salt consumed in Britain is prepared from sea-water by evaporation. The heat of the summer is too small, and its duration too short, to be of much use in forwarding the process; more especially as the refuse of the coal, called *panwood*, which answers the purpose excellently well while it is good for little else, is sold at a low price. However, the sun is employed to concentrate the sea-water in the salt-pans at Lerington with considerable advantage; so that although the brine be afterwards boiled down with Newcastle-coal, the salt can be afforded at a cheaper rate than what is made at the mouth of the coal-pit. Dr Brownrigg proposes to extend this practice to different parts of Britain; and in recommendation of it, he endeavours to prove, that 30 inches of water exhale, during the four months, May, June, July, and August, while only 10 inches of rain fall. The experiment was actually tried near St Andrews, in Scotland, by the ingenious Dr Martin, without the smallest appearance of success; so that Dr Brownrigg seems to entertain hopes more sanguine than the trials will justify.

The strength of sea-water varies in different climates, from the greater or less degree of heat affecting the evaporation of the aqueous parts. A pound of sea-water in the Baltic scarcely yields two drams of salt; in the British Channel, it yields one ounce; and still farther south, in the Mediterranean, it yields two ounces. The purest salt is prepared by a slow evaporation: On this account the salt made by the heat of the sun is the purest. All other kinds of salt prepared from sea-water, especially by strong boiling, are contaminated with heterogeneous matters. Those matters are some calcareous earth united with marine acid, forming calx salita; some magnesia, united with the same acid, forming magnesia salita; and some magnesia united with the vitriolic acid, forming Epsom salt. Every one of those salts impairs the qualities of the marine salt, both by making it deliquescent, and rendering it less useful in the preservation of meat. From these considerations, it becomes an object of great importance in commerce, to free the marine salt from these admixtures: and there is one property of the marine salt which



confused : They adhere together with their sides, as if they formed kinds of stair-cases, or hollowed mill-hoppers.

Its taste is saline and agreeable.

When it is exposed to a brisk fire, it sparkles and jumps, making a crackling noise. This phenomenon is called *decrepitation* ; and is owing, as we have already observed when treating of vitriolated tartar and febrifugal salt, to the water which composes the crystals : it is suddenly rarefied, and bursts all the little laminæ of which they are composed. When all the water is thus evaporated, the decrepitation ceases, and the salt is reduced to powder. If afterwards it be strongly heated, it fuses when it turns red : if we pour it upon a metal plate, it fixes into a kind of mineral crystal, but is altered in no other way ; for it may be reduced to its former state by solution in water : Fire then does not decompose it. By keeping it in fusion for some time, it is at last volatilized without alteration ; but this requires a fire of extreme violence.

Marine salt, when very pure, suffers no sensible alteration from the air : It dries rather than grows moist, and attracts humidity only when it is mixed with some calcareous marine salt.

It is very soluble in water, requiring only three parts

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enables us to make it very pure. Marine salt dissolves in as great quantity in cold as in hot water ; and upon this principle the purification is conducted. Some salt is put into an inverted conical vessel, perforated with holes in the bottom, to favour the passage of a fluid. Part of the salt is taken out, and made into a saturated solution in boiling water. This solution is then poured upon the top of the salt ; and as it runs down to the bottom, it dissolves the salts with earthy bases ; but takes up no more of the marine salt. By repeating this operation once or twice, all the heterogeneous matters are entirely carried off, with little loss of marine salt, which is thus made perfectly pure. The salt obtained after this process is purer than the pit or bay-salt ; and although the proposed method of purification has not as yet been introduced into general practice, it will probably be soon employed all over the island, as it will certainly prove a very great improvement in the manufacture.



to dissolve it. Three ounces of water very completely dissolve one of marine salt; nor is it more soluble in boiling than in cold water: It is obtained in crystals by a very slow evaporation. It forms on the surface of the liquor flies feet, which join and produce a pellicle more or less thick. Sometimes, instead of cubes, we observe kinds of square and hollowed pyramids, resembling mill-hoppers. M. Rouelle, who has observed with great care all the phenomena of this crystallization, takes notice, that those mill-hoppers are formed in the following manner: When a cube is formed, this little solid being specifically heavier than the water, it hollows it a little; a second is afterwards produced, which is attracted by the first, and attaches itself to it by one of its sides; and so on with regard to the rest. It is easy to conceive, that this successive increase will produce hollowed pyramids, whose points will be undermost and base uppermost. When their number becomes too great, they fall to the bottom of the liquor. The water in which this salt was dissolved, and which was evaporated till it would furnish no more salt, contains no other saline matter, if the salt employed was very pure. That of the sea, and of saline fountains, always contains some salts with earthy base. The earth may be precipitated from them by the addition of the fixed alkali, as shall be mentioned in the article upon the earthy neutral Salts.

Marine salt seems to facilitate the fusion of the glasses. It always occupies the superior part of the pots in which these matters are fused, and constitutes the glass gall. It is used for glazing the surface of certain earthen ware, and likewise for giving them a kind of covering, by vitrefying their external part. This is easily done, by throwing a certain quantity of the salt into the ovens in which we bake the ware. There it is volatilized, and spreads itself upon the surface of the ware, of which it helps the fusion by the extreme heat. The English earthen ware is done over in this manner.

Pure



Pure clay has less action upon the marine salt than upon nitre: By distillation with this salt, it only gives a weak acid and a little phlegm. The distillers of aqua-fortis, it is true, extract the spirit of salt in this manner: but they employ the salt of the Gabelle, which contains much marine salt with earthy base; and they use also a clay very much coloured and impure.

The terra ponderosa decomposes marine salt, as all the other alkaline salts, according to the experiments of M. Bergman.

Quicklime and magnesia occasion no change upon it. The caustic vegetable fixed alkali decomposes it; because it has more affinity with its acid than the mineral alkali has. A solution of marine salt mixed with the caustic alkali of tartar, by evaporation gives sal febrifugus, and the mother-water contains the mineral alkali pure and uncombined. The acids exert a very remarkable action upon marine salt. If we pour oil of vitriol upon it, a very considerable motion and a brisk heat arise; a violent effervescence (c) is observed; and we see the marine acid disengaged in vapour, which is known by its white colour and pungent odour. If the operation is performed with the pneumato-chemical apparatus with mercury, we obtain a good quantity of marine acid gas. Glauber used this way of decomposing the marine salt by the acid of vitriol, in order to obtain its acid; for which reason it gets the name of *Glauber's spirit of marine salt*. He discovered his *sal admirabile*, by examining what remains after this operation. In distilling spirit of salt, almost all authors direct us to put some decrepitated marine salt into a

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(c) An effervescence is as manifest in this operation, as in the union of the same acid with quicklime, and the alkalis saturated with the chalky acid. It always takes place, when a body separated from combination is volatilized in the form of gas. It may be then occasioned by the chalky acid, the marine acid, the nitrous acid, the sulphureous acid, the sparry acid, the volatile alkali, &c. It ought not to be ascribed to the disengagement of air



tubulated stone retort, and to pour through the tube half its weight of oil of vitriol. This acid instantly disengages the spirit of salt in copious vapours, which pass through the neck of the retort, and are collected into two globular vessels adapted to that purpose. The last of these vessels is pierced with a small hole, to allow the vapours to pass, and prevent the rupture of the apparatus. In this operation, as in the distillation of spirit of nitre, a great quantity of the most pure acid is lost, being dissipated in the form of marine gas through the hole of the globe; and persons are much troubled by the very corrosive vapours of it that fill the laboratory in which it is made. M. Beaumé, in order to shun a part of these inconveniences, puts some water into the retort. The water, when volatilized into the globe, absorbs a part of the marine gas; but as this is much more volatile than the water, a considerable quantity of it is always lost.

M. Bucquet has corrected all these defects, and has found means to procure the spirit of salt in a state the strongest and most concentrated that is possible, by employing the inverse of the process of M Beaumé. Instead of volatilizing the water, in order to absorb the marine acid vapours, he places this fluid so as to meet with the gas; and for that purpose uses Woulfe's apparatus, which we have described in the article of Nitre. He puts eight ounces of distilled water into the collateral bottles to a mixture of two pounds of marine salt, and a pound of oil of vitriol in the retort. The acid gas, conducted by the tubes into the water in the bottles, is absorbed: the water becomes hot by its combination with the marine gas; it is even ready to boil, and it absorbs an equal weight of it. When it contains this quantity, it takes up no more, and becomes cold; but the gas passing into the second collateral bottles unites anew with the water they contain, and makes it boil.

This process, very ingenious and well adapted to the properties of the marine acid gas, has several advantages.



tages. 1. It prevents the inconveniences arising from the marine acid gas being diffused through the air. 2. It prevents the loss of the very great quantity, which happens even in M. Beaumé's process. 3. It affords the strongest, the most concentrated, and most fuming spirit of salt, which it is possible to obtain. 4. This acid spirit is at the same time very pure, since it is solely formed of marine gas dissolved in water. It is likewise very white, whilst that which they had formerly in the laboratories was always of a citron colour: a circumstance which has even led the chemists into an error, they having given this colour as a character of the acid. The portion of spirit of salt, which, in the process of M. Bucquet, is condensed in the tubes, is yellow and contaminated, owing to a fat matter that is contained in the mixture, just as happens in the ancient process. 5. The new method warns the artist of the necessary degree of fire, and of the manner of conducting his operation, by the more or less rapid passage of the marine acid gas through the water in the bottles. Lastly, it is the more precious; it furnishes the means of determining exactly the quantity of acid contained in the marine salt, since there is no portion of it left.

The nitrous acid likewise decomposes the marine salt; but as it is volatile, part of it rises and unites with the marine acid: from that union, the mixt acid, known by the name of *aqua regia*, results. M. Baron has discovered, that sedative salt, by the assistance of heat, disengages the acid of the marine salt.

The use of marine salt is very extensive. It is employed, 1. In the manufacture of earthen ware, to promote the fusion of their surface, and give them a kind of covering. 2. In glass-making, for whitening and purifying the glass. 3. In the docimasia or assaying of minerals, to serve as a flux to the bodies which form the scoria, in order to facilitate the precipitation of the



metals, and to prevent their alteration from the contact of the air.

It is used as a seasoning to our victuals, of which it corrects the insipidity; and it promotes digestion, by occasioning the commencement of putrefaction in the alimentary substances. Although it is fully proved by the experiments of Drs Pringle and Macbride, that, like the most part of saline matters, it retards putrefaction, and is a powerful antiseptic when mixed with animal substances in great quantity; yet it acts in a very different manner when mixed in small quantity with the same substances, since it reduces them sooner to the state of putrefaction; which is proved by the experiments of the author of the Essay on the History of Putrefaction, and by those of M. Gardane.

The marine salt is not of less utility in medicine; it is used as a very active stimulant in acrid glysters. It is strongly recommended by Ruffel in the tabes glandularis, and in the lymphatic obstructions which depend upon a scrophulous taint. M. Lorry has assured me, that he has experienced very good effects from it in several diseases of this nature. It purges when administered in the dose of a few gros. However, as it is the grey marine salt which we generally use, may it not be the calcareous marine salt which is mixed with it, on which this property depends?

## LECTURE XIX.

### Species 7. *Borax* (d).

**B**ORAX is a neutral salt, formed of the acid improperly called *sedative salt*, and of the mineral fixed alkali.

The history of this salt, which comes to us from the East

(d) In examining the neutral salts, we have hitherto begun with those that are formed by the combination of each acid with the vegetable fixed alkali: but with regard to those which contain the sedative salt, we must begin with that which has the mineral alkali for its base, because it is the only one properly known,



East Indies, is very uncertain; we are not even positively certain whether it is the production of nature or of art. Indeed, if the discovery of the acid of this salt, which is found dissolved in the waters of several lakes in Tuscany, as we have mentioned in the history of that acid, can enable us to presume that borax is a natural production, several facts, which we are to explain more fully afterwards, seem to demonstrate, that it is possible to form this salt from all grounds, by means of certain processes; and perhaps, some day, we may have artificial mines of borax, as now we have artificial nitrous hillocks in different parts of Europe.

Three kinds of borax are met with in commerce. The first is the impure borax, tincal, or cryfocolle, which comes from Persia. It is in greenish masses, greasy to the touch, or in form of opaque crystals, of a pear green, which are prisms with six surfaces, terminated by irregular pyramids. This salt is very impure, and mixed with many different substances.

The second kind of borax is called *Chinese borax*, and is a little more pure than the preceding. It is in form of small plates or masses irregularly crystalized, of a pale-white colour: we observe in it the rudiments of prisms and pyramids, but confounded together without any symmetrical arrangement. We observe also an argillaceous powder, which covers the surface of the crystals.

The third kind is the borax of Holland, or refined borax. Its form is that of portions of crystals very pure and transparent: we find in them pyramids with several sides, but their crystallization has been interrupted. This shows, in a certain degree, that the method employed by the Dutch in the refining of this salt is solution and crystallization. There is at Paris, in Lombard-street, a druggist who possesses the secret of purifying and refining impure borax, and who prepares it in as great purity as that which is purified by the Dutch.

Besides these four kinds of borax, an apothecary of Paris



Paris has discovered, that it is daily formed in soapy waters, mixed with those of the kitchen, which a private person allows to remain in a kind of ditch. In a certain time some pure borax in fine crystals is obtained. Although this be a fact, we are not yet more fully informed of its formation. It only appears that it is the production of stagnant waters, which contain fatty matters. Some authors assure us, that in China it is made artificially by mixing in a ditch grease, clay, and dung, in alternate beds, by moistening this mixture with water, and leaving it to remain in this situation for some years. When this time is expired, the materials are washed, their ley is evaporated, and we extract impure borax. Others have imagined, that it is extracted from water which has been filtrated through mines of copper. M. Beaumé positively says, that the first of these processes has succeeded very well with him; *Chem. Exper. tom. 2. p. 132.* Purified borax possesses a very regular form. Its crystals are prisms with six sides, two of which are generally larger, terminated by three-sided pyramids. There are besides many varieties in its crystals. Its taste is styptic, and very strongly contracts the fibres of the tongue. It turns the syrup of violets green as the alkalis do. When we expose it to the action of the fire, it is very quickly fused by means of the water in its crystals: it gradually loses this water, and acquires a considerable bulk; then it becomes a white mass, porous and very friable. This shows us, that the air alone is not always the cement of bodies, as had been concluded from the experiments of Hales; but that water is sometimes the cause of their solidity, particularly in the neutral salts (*e*). The considerable bulk, the lamellated and porous form, which borax assumes

(*e*) It is certain, that in the organized substances, when the air is dissipated, by means of a very advanced decomposition, they lose their hardness, and even all their consistence. It is even certain, that some simple salts acquire solidity, by combining with substances which have the form of air, as we have seen in the case of the union of



assumes in its calcination, are owing to the water being disengaged in the state of vapour, which supports the saline substances in pellicles, and to the bubbles which it forms bursting at the surface of the salt. These pellicles grow dry, and place themselves above one another, so as to leave intervals between them. Borax in this state is called *calcined borax*. It is nowise altered; it only loses the water necessary to its crystallization, which amounts to above six ounces in the pound. We may restore it to its former shape by solution in water, and setting it to crystallize; but if we expose it to the action of the fire, it fuses as soon as it begins to turn red, and forms a very fusible transparent glass, a little green, which the air tarnishes, and which is soluble in water. The borax undergoes no change in its nature by this fusion: all its particular properties may be reproduced by means of solution and crystallization.

The air does not alter this salt; it only forms a small efflorescence by separating a portion of its water.

Borax is very soluble in water. It requires twelve parts of cold water for its solution; but six parts of boiling water are sufficient. Its crystals are obtained by cooling its solution; but the most beautiful and regular crystals are formed in the mother-water, when allowed to evaporate very slowly, and by the temperature of the atmosphere.

Borax is used as a flux to the vitrescent earths, with which it forms a very good glass. It is also employed in the preparation of the artificial precious stones. In like manner, it vitrifies clay, magnesia, and lime. This last substance, heated with a solution of borax, decomposes it. The lime attracts its acid, and forms with it a salt, which has little solubility, leaving the caustic mineral

of the chalky acid with the alkalis and lime, as well as with regard to oil of vitriol combined with nitrous gas: but there is a great number of bodies which owe their solidity to water; and in particular, all the crystals of the neutral salts, such as borax, owe their solidity to this circumstance,



neral alkali to swim above. This experiment belongs to M. Bergman: It proves, that lime has more affinity with the sedative salt than the mineral alkali has.

We have not yet examined whether the pure vegetable fixed alkali decomposes it, as happens to the other neutral salts with base of mineral alkali.

The acids have a very remarkable action on this salt.

If, into a boiling solution of borax, we pour with caution oil of vitriol, until there be a slight excess of acid in the liquor, we obtain, after the mixture is filtrated and cooled, a very copious precipitate, disposed in small brilliant scales. This salt, fused with combustible matters, such as charcoal, acquires a reddish colour; but we cannot explain the alteration which they produce.

Borax is of great use in several arts. It is used in the manufacture of glass as an excellent flux, and likewise in the art of assaying. It is used with great advantage in soldering, because it fuses the alloy destined for that purpose; besides, it gives the surface of the metals we want to unite a softness which is very requisite in this operation; and by covering them, it prevents their being acted upon by the air.

#### Species 8. *Vegetable Borax.*

WE give the name of *vegetable borax* to the combination of the acid sedative salt with the vegetable fixed alkali. We know these two substances are very susceptible of union; and from this union the neutral salt we are speaking about results. This salt is obtained from the residuum of nitre decomposed by the sedative salt. M. Beaumé says, that this residuum was in a white mass half fused; and when dissolved in water produced a salt in small crystals. We see, then, that vegetable borax is fusible, soluble, and crystallizable. It is probable that the pure acids would decompose it, as well as ordinary borax. We know nothing more about this salt requiring farther examination.

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Species 9. *Sparry Tartar.*

THIS name may be given to the combination of the sparry acid with the alkali of tartar, like that of vitriolated tartar. This species of neutral salt has been but slightly examined by Mr Scheele and Boullanger. It is always in a gelatinous state, and never crystallizes, according to these two chemists. When dried and fused, it is acrid, caustic, and deliquescent, according to Mr Scheele. This chemist accordingly compares it to the liquor silicum. It seems that the fire disengages from it the sparry acid; and that the siliceous earth, with which Mr Scheele supposes the acid to be always charged, fuses into a soluble glass by means of the fixed alkali.

The sparry tartar is very soluble in water; it always retains so great a quantity of it, that it cannot be made to assume a crystalline form. When it is properly saturated, the solution of it does not change the syrup of violets.

We are not acquainted with the action of quartz, clay, terra ponderosa, nor magnesia, upon this salt. According to Mr Scheele and Bergman, lime has a greater affinity with the sparry acid than the vegetable fixed alkali has. Sparry tartar put into lime-water is instantly decomposed: The lime unites with the acid, and forms an insoluble salt which disturbs the liquor, and which we shall explain more fully afterwards under the name of the *sparry* or *vitreous fluor*.

The sparry acid, then, is not the only acid which has more affinity with this saline earthy substance than the alkalis have. Oil of vitriol decomposes the sparry tartar, and drives off the acid, which, according to Mr Boullanger, comes over with the odour, and in the white vapour peculiar to the marine acid. In performing this experiment with a distilling apparatus, we collect the sparry acid in the same manner as we do that of nitre and marine salt decomposed by the oil of vitriol.

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The action of the nitrous and marine acids upon this salt has not been examined, nor that of the neutral salts, as far as we know. This salt being very little known, is besides of no use.

Species 10. *Sparry Soda.*

By this name we call the neutral salt formed by the combination of the sparry acid with the mineral alkali, or salt of soda. This salt, like the preceding, has been very little examined. It is only to M. Scheele and Boullanger that we owe any knowledge of it; and as yet they are not agreed about the form which it assumes.

M. Scheele says, that the marine alkali, united with the sparry acid, forms a jelly like the former. Boullanger assures us, that this combination affords very small crystals, which are hard and brittle, and formed into oblong squares of a bitter and somewhat styptic taste.

This salt laid on coals decrepitates like sea-salt: It dissolves with difficulty in water.

Lime-water decomposes it like the sparry tartar.

Oil of vitriol disengages the acid with effervescence in a white vapour, and with a pungent odour like that of sea-salt.

After this brief explanation, this salt is evidently as little known as the preceding.

Species 11. *Aerial Tartar.*

THE two last neutral salts which remain to be examined, are the combinations of the aerial acid with the fixed alkalis. Those substances have never been ranked among the neutral salts, although they be really such. Along with M. Bucquet we give the name of *aerial tartar* to the combination of the aerial acid with the vegetable fixed alkali. This saline substance, which always has been taken for pure alkali, was not acknowledged to be a neutral salt till after the experiments of Dr Black. It got the name of the *fixed salt of tartar*, because it was extracted from the ashes of the



tartar of wine. It was looked upon as an alkali, because it possesses some of the properties of the alkaline salts. No doubt it tinges the syrup of violets green, but borax and the vitriols have the same property: Its taste is alkaline, but so is that of borax. It was distinguished from the alkali of soda, only by the property which was ascribed to it, of readily attracting humidity from the air, and of being incapable of crystallization(*f*). But these two properties depend on this alone, that the fixed salt of tartar is not a perfect neutral salt, as it contains a certain quantity of pure caustic vegetable alkali also: it is from this excess of the alkali that it is deliquescent. At present, we have discovered the means of having an aerial tartar very crystallizable, which does not at all attract the humidity of the air, and which rather effloresces. M. le Duc de Chaulne, who has been much employed about this subject, prepares this salt by exposing the caustic fixed alkali, or this alkali charged with a little aerial acid, in a place filled with this gaseous acid, as in the upper part of a vessel in fermentation. The alkali seizes upon all the aerial acid which it can absorb, and very regularly crystallizes. Its crystals are prisms with four sides, terminated by pyramids with four very short sides.

The taste of aerial tartar is urinous, but much weaker than that of the caustic vegetable alkali. According to the calculation of M. Bergman, the aerial tartar, saturated with acid, and properly crystallized, which he calls *aerial vegetable alkali*, contains in the cwt. 20 parts of aerial acid, 48 of pure alkali, and 32 of water: But it must be observed, that the aerial salts in general are  
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(*f*) Bohnius relates, that having evaporated, by a slow and gentle heat, some oil of tartar, he obtained, under a saline pellicle, beautiful crystals, which were preserved more than six years without alteration, although exposed to different temperatures, (*Dissert. Physico Chem.* 1666). Mr Montet, a celebrated chemist of Montpellier, who undoubtedly had no knowledge of Bohnius's discovery, found out a process by which the fixed salt of tartar may be made to crystallize. *Acad. des Scien. an. 1764. p. 576.*



more susceptible than the other salts of very different doses of acid. Notwithstanding this property, this salt never furnishes regular crystals but when it is perfectly saturated; and we may look upon M. Bergman's calculation as exact and constant.

Aerial tartar, when it is properly crystallized, suffers no alteration from the air; its crystals remain transparent, without liquefying or efflorescing.

This salt dissolves very well in four parts of cold water, and in a little less of hot water: It produces some cold in its union with this fluid; it crystallizes by means of evaporation and cold; it can be used as a flux to the earths, like the pure vegetable fixed alkali, because it is alkalized by the action of the fire. Clay has no action upon it; and it reduces the clay by fusion into a glassy frit, with a little more difficulty than the pure vegetable fixed alkali does.

The terra ponderosa deprives this salt of its aerial acid. Lime also decomposes it, because it has more affinity with the aerial acid than the vegetable fixed alkali has.

If some lime-water is poured into a solution of aerial tartar, a salt, formed by the union of the lime and the aerial acid, is precipitated, and the pure alkali remains in solution in the water. This decomposition is used in pharmacy for the preparation of the *lixivium causticum*, which is only the fixed vegetable alkali rendered caustic by the lime.

Modern experience teaches us, that the process of Lemery followed by several pharmacopœias is very defective. It consists in mixing two pounds of ashes of tartar of wine (*g*) with a pound of quicklime, in moistening this mixture with 16 pounds of water, in filtering and evaporating the ley in a copper vessel, and infusing in a crucible and pouring upon a plate the residuum

(*g*) The ashes of tartar are those furnished by the combustion of grape-husks and the dregs of wine. These ashes contain much alkali or aerial tartar and a little vitriolated tartar.



duum of this evaporation. By this process we obtain only an impure alkali, little caustic, charged with copper. M. Bucquet, who perceived all these inconveniences, has given a process, very tedious and very troublesome, I confess; but, upon the whole, much surer and more useful for the preparation of vegetable alkali, very pure, if necessary, in chemical experiments. The process is as follows: To two pounds of good quicklime, slaked with a little water, we add a pound of fixed salt, and pour as much water as will form a paste; when the mixture is cold, we add water to the quantity of 16 pints, and put the whole on a piece of paper supported by a linen rag. About two pounds of a clear liquor pass through; and we wash the residuum with four pints of boiling water to dissolve all the alkali. This liquor makes no effervescence with the acids; but the best test of its perfect causticity is, that when mixed with lime-water it causes no hardness; which shows that it contains no more aerial acid. However, as after this operation it may still cause a little precipitation, if we desire to have a very pure alkali for delicate experiments, we must treat this ley with two pounds more of quicklime; then it passes very clear, and so caustic, that the transparency of the lime-water is not affected. When we evaporate the alkali on an open fire, it attracts the aerial acid from the atmosphere. To have it very caustic and in a dry form, we ought to evaporate the liquor in a retort. This very tedious operation is not necessary for the lapis causticus.

The vitriolic, nitrous, marine, and sparry acids, as also sedative salt, decompose aerial tartar, uniting with the fixed alkali, and volatilizing the aerial acid, which is disengaged with effervescence. It may be collected above water or mercury. It is distinguished by the three following characters; its extinguishing candles, reddening the tincture of turnsol, and precipitating lime-water.

The neutral salts, which we have been examining, are  
VOL. I. Q no



not altered by the aerial tartar, nor does it suffer any alteration from them. The aerial tartar is very abundant in nature. It is found ready formed in vegetables, and is extracted by the incineration of these organic bodies, as will be mentioned in the Vegetable Kingdom; particularly it is obtained from burnt tartar. It is also made by the detonation of nitre. Aerial tartar is of very extensive use in the arts. It is used in medicine as a very active discutient in obstructions of the mesentery and urinary passages. It is only administered in small doses, and given along with some other substance to moderate its action.

Species 12. *Aerial Soda or Natrum.*

THIS salt, like the foregoing, was formerly looked upon as an alkali: it is, however, a combination of the aerial acid with the fixed mineral alkali. The name of *natrum* has been retained, which was given to it by the ancients. This salt has an alkaline taste, and renders the syrup of violets green. It is naturally purer than the aerial tartar, for it is long since its property of crystallizing was known; a property which, taken in general, distinguishes the neutral from the simple salts. This property is owing to its containing a greater quantity of aerial acid, and to the more intimate union of the aerial acid with the mineral than with the fixed vegetable alkali. The aerial soda or natrum rapidly crystallized, forms rhomboidal laminæ, obliquely adhering to one another, so that they seem to be covered in the same manner as tiles. If it is slowly crystallized, it assumes an octaëdral form whose pyramids are truncated, or like ten-sided solids.

This salt in general fuses more rapidly than the aerial tartar. In the manufacture of glass it is employed preferably to aerial tartar. It loses the greatest part of its acid by heat, but always retains a little of it. M. Bergman has found by an exact analysis, that 100 parts of aerial soda, which he calls *aerial mineral alkali*, contain



tain 16 parts of aerial acid, 20 parts of pure alkali, and 64 parts of water; so that the mineral alkali requires more aerial acid than the vegetable does for saturation, and the natrum in its crystals retains double the quantity of water the aerial tartar retains.

Aerial soda is more soluble than aerial tartar. It dissolves in two parts of cold and in an equal quantity of boiling water. It is crystallized by means of cold; but a slow evaporation furnishes the most regular crystals.

The aerial soda, when exposed to the air, falls into powder, because it loses the water of its crystallization; but it is not altered, and it may be reduced to its former state by solution and crystallization.

This salt greatly facilitates the fusion of the vitrescent earths, and forms a glass less susceptible of alteration than the glass formed by means of aerial tartar; for which reason, it is preferred in the manufactory of glass. It is observed, that sand, by uniting with this salt, disengages the aerial acid with remarkable effervescence.

The terra ponderosa, and likewise lime and its solution, decompose the aerial soda as they do the aerial tartar, and disengage the mineral alkali in its caustic state. If we wish to have this salt in a state for delicate chemical experiments, we must use the process described for the preparation of the *lixivium causticum*.

Natrum is decomposed, like aerial tartar, by the vitriolic, nitrous, and marine acids, &c. Its aerial acid may be obtained above water or mercury. This salt is ready formed at the surface of the earth in Egypt. It is found in the ashes of marine plants also, but not saturated with all the acid with which it may be united. To render it more perfectly neutral, we may combine it directly with aerial acid, whether by agitation over a vessel in fermentation, or by receiving into its solution some aerial acid disengaged from chalk by spirit of vitriol. It is also made by impregnating the sides of a vessel containing a solution of soda, and introducing into the vessel some aerial acid;



acid; we cover it with a moistened bladder, and in a few hours the combination is complete; the bladder is hollowed on account of the vacuum formed in the vessel, and the neutral salt is laid in regular crystals upon the sides.

Natrum may be employed for the same purposes as aerial tartar.

## LECTURE XX.

GENUS II. *Imperfect neutral Salts with base of volatile alkali; or Ammoniacal Salts.*

THE ammoniacal salts are more easily decomposed than the perfect neutral salts: They are all formed of an acid united to the volatile alkali; their taste in general is urinous; they are all more or less volatile. We are acquainted with six kinds; vitriolic ammoniac, nitrous ammoniac, marine ammoniac, or sal ammoniac properly so called, sedative ammoniac, sparry ammoniac, and aerial ammoniac.

### Species I. *Vitriolic Ammoniac.*

THIS salt results from the combination of the vitriolic acid with the volatile alkali. It was called the *secret ammoniacal salt of Glauber*, because that chemist discovered it. It is in the form of needles, which, carefully examined, seem to be prisms with six surfaces; two of which are large, terminated by pyramids with six sides, and of the same form as the prisms: Some variety occurs in these crystals; they sometimes resemble rock-crystal, or vitriolated tartar.

The taste of this salt is bitter and urinous; it is very light and friable.

As it retains much water in its crystallization, it liquefies even with a very gentle fire; but it gradually becomes dry from the dissipation of the water of its crystals. In this state it begins to redden, and fuses very quickly without being volatilized, according to M.



M. Bucquet, although Mr Beaumé declares that it is semi-volatile. By a repetition of this experiment, I found, indeed, that part of the salt sublimes, but that a fixed portion remains in the vessel. It is undoubtedly this salt which M. Bucquet meant. This fact requires confirmation.

Vitriolic ammoniac suffers almost no alteration from the air: it does not fall into an efflorescence, like Glauber's salt; on the contrary, it slightly attracts the air's humidity.

It is very soluble in water, two parts of cold water dissolving one, and boiling water its own weight. It crystallizes by cold; but the most beautiful crystals are obtained by insensible and spontaneous evaporation: It unites also with ice, which it melts, and with which it produces a considerable cold. It has no action upon the earths, nor on magnesia; although this last substance seems to decompose it through length of time, according to the observation of M. Bergman.

Lime, terra ponderosa, and the pure fixed alkali, disengage its volatile alkali, as will be taken notice of in the article *Sal Ammoniac*. If we distill some aerial tartar, or natrum, with vitriolic ammoniac, a double decomposition and double combination takes place: the vitriolic acid seizes the fixed alkali, to form vitriolated tartar or Glauber's salt; the aerial acid is dissipated along with the alkaline gas: these two bodies unite, and form a particular sal ammoniac, which crystallizes in the recipient. We shall explain more fully this subject in the article on *Sal Ammoniac*.

The nitrous and marine acids disengage the vitriolic from it as from vitriolated tartar.

It has not hitherto been found among the productions of nature: however, we read in the Essay on Crystallography, of M. Romé de Lisle, 1772, page 57. that, according to the M. Sage, the native salt of volcanos is of the same kind. It is artificially produced by a direct combination of the vitriolic acid with the volatile



alkali ; by decomposing the earthy or metallic vitriolic salts by means of the volatile alkali ; or lastly, by decomposing the nitrous, marine, and aerial ammoniacs, by means of the vitriolic acid.

This salt is of no use, though Glauber strongly recommended it in the operations of metallurgy.

Species 2. *Nitrous Ammoniac.*

THIS salt, like the preceding, is the production of art. It is prepared directly by combining the nitrous acid with the volatile alkali : it is crystallized in prisms, whose number and disposition of sides has not been well examined. M. Romé de Lisle says, that it is capable of crystallizing into beautiful needles, very like those of vitriolated tartar. When it is exposed to the action of fire, it liquefies, exhales in aqueous vapours, dries, and, after being red hot for a long time, it detonates alone without the contact of any combustible substance, and even in close vessels. This singular property undoubtedly depends on the volatile alkali, since, as we have already observed, the alkaline gas seems to have something combustible ; and it augments the flame of candles previous to their being extinguished.

We do not know whether this salt be fusible ; for the first liquefaction is entirely owing to the water of its crystals, and it takes fire before it undergoes the second.

Neither of its volatility can we form a judgment, since, before it be sublimed, it is destroyed by combustion.

It attracts a little humidity from the air ; so that its crystals adhere, and form kinds of knots.

It is very soluble in water ; it unites with ice, and fuses it, and then produces a considerable degree of cold. It is more soluble in warm water than in cold ; it only requires the half of its own weight of hot water to dissolve it, and it crystallizes by cold : But this crystallization is irregular ; and to obtain well-formed crystals,



stals, it is necessary to have recourse to spontaneous or insensible evaporation. Nitrous ammoniac is decomposed by the terra ponderosa, lime, and the alkalis, like the secret ammoniac of Glauber. The alkaline gas, separated by these caustic substances being very volatile and very expansible, the decomposition of nitrous ammoniac, like that of all the salts of this kind, is perceptible in the cold, and is effected by the trituration of this salt with lime; but we cannot, without danger, employ fire for its decomposition, even in close vessels, on account of its inflammability.

The vitriolic acid disengages the spirit of nitre of this salt with effervescence, and with its base forms some ammoniacal salt of Glauber. Aerial tartar and aerial soda decomposes it, and are themselves mutually decomposed.

Nitrous ammoniac is of no use.

### Species 3. *Sal Ammoniac.*

SAL ammoniac is the combination of the marine acid with the volatile alkali. The ancients gave it this name, because they brought it from Ammonia, a country of Africa, where the temple of Jupiter Ammon was situated. This salt is found about volcanos; but that employed in the arts is an artificial preparation.

The true origin of this factitious salt was not known till the commencement of this century, although it has been used in a great number of arts from time immemorial. By a letter written in 1770 by Mr Lemery, then consul at Cairo, we are told, that sal ammoniac is extracted by sublimation from a foot that issues from hillocks of animal dung, which is burnt in that country instead of wood. This foot is put into large round bottles, a foot and a half in diameter, terminated by a neck two inches high: these bottles are filled with it within four inches of the neck. Every bottle contains about forty pounds of foot, and furnishes rather more than six pounds of salt. These vessels are placed in a



furnace in form of an oven, so that the neck only may project. The fire is kindled with the dung of animals, and continued for three successive days and nights. The salt only begins to sublime on the second and third day. The bottles are then broken, and the cakes of salt taken out: These cakes, which are brought to us in the same shape in which they are taken out of the bottles in Egypt, are convex and unequal on one side, in the middle of which there is a tubercle that marks the neck of the vessel in which they were sublimed; the inferior side is concave and impure, and likewise the superior, by a kind of soot. Pomet showed a sal ammoniac which came by the way of Holland, and was in the form of truncated cakes, like those of sugar. Geoffry, the first person in France who found out the materials of this salt, and formed a conjecture of the process employed at Cairo for its preparation, discovered that this second kind of sal ammoniac is made in the Indies; that it is prepared in much greater quantity than in Egypt; and that it differs from this last only in its form, being also sublimed. Indeed these cakes, weighing from four to five pounds, are hollowed at their base, and formed of different layers. The cone is truncated, because the point is broken off, which is nothing but an impure matter.

M. Beaumé has established in the neighbourhood of Paris a manufacture of sal ammoniac, where they prepare this salt to a considerable extent; in which it differs from that prepared by the Egyptians, who extract it only in smaller quantities: the salt of M. Beaumé has also the advantage over that of the Egyptians, of being much purer.

The taste of sal ammoniac is pungent, acrid, and urinous. The form of its crystals is that of an hexaëdral elongated pyramid, that in form of plumage being only the reunion of all those pyramids which approach to one another at an angle more or less acute. M. Romé  
de



de Lisle thinks, that the crystals of sal ammoniac are octaëdral figures united. We find, though rarely, cubic crystals of this salt. This salt has a very singular physical property, a kind of ductility or elasticity, which makes it yield to the hammer, and flexible by the fingers. Sal ammoniac is altogether volatile, but it requires a very strong fire for its sublimation. This process is used to obtain it very pure and as free of water as possible. It is pounded and put into matraffes in a sand bath, surrounded to the middle of their bulb with the sand. The heat is gradually increased for several hours; by this process a mass is obtained composed of channelled needles adhering lengthwise. When the operation has been managed with address, we often find in the middle of these leaves very regular cubic crystals; but if a very strong heat has been applied, there only appears a very dense shapeless mass, semi-transparent, and seeming as if it had been fused.

M. Beaumé observed, that in subliming this salt several times, a little volatile alkali and marine acid was every time disengaged; so that it would perhaps be possible, as this chemist thinks, to decompose it by repeated sublimation. But this requires confirmation.

Sal ammoniac is unalterable by the air. It is very soluble in water. Six parts of cold water are sufficient for its solution. During this solution, a considerable cold is produced. This cold is still more intense when mixed with ice. Boiling water dissolves its own weight. It crystallizes in cooling; but the most regular crystals are obtained, like those of other salts, by spontaneous or insensible evaporation. Frequently a very copious solution of this salt, contained in a flask, deposits in a few days crystals like plumage, formed by a small filament, to which a great number of other filaments are joined perpendicularly, and those support other less ones, so that it seems perfectly to imitate vegetation. I have several times observed this phenomenon



non in my laboratory (a). Neither clay nor magnesia decomposes sal ammoniac, at least not sensibly.

Lime, and likewise the terra ponderosa, disengages its volatile alkali even in the cold. The trituration of sal ammoniac with quicklime is sufficient instantly to volatilize the alkaline gas, the odour of which strongly affects the nerves. If the experiment be performed in close vessels, we may collect the volatile alkali; but as this operation is not sufficiently well explained by authors, although modern knowledge might have rendered both its explanation more accurate and its execution more certain, it is our opinion that something more should be said about it. If we employ a very strong quicklime, and very dry sal ammoniac, and heat this mixture in a retort having its neck sunk below a vessel full of mercury, we may procure a great quantity of alkaline gas: when we distill a similar mixture in vessels without a pneumatic chemical apparatus, we understand why we obtain almost no produce, and why we are exposed to the danger of the vessels bursting; the state of rarefaction, and the quantity of alkaline gas disengaged in this experiment, are the real cause. M. Beaumé has directed to put some water into the retort. This fluid indeed absorbs and carries off a part of the alkaline gas along with it; but as the gas is much more volatile than the water, we always lose the greatest part of it. M. Bucquer, with great success, employed M. Woulfe's apparatus, founded upon the strong affinity of this gas with water, and upon its singular volatility.

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(a) No chemist but has experienced how interesting it is from time to time to visit the products preserved in a laboratory, particularly the solutions of the salts. When chance presents any curious observations, we ought instantly to note them, that facts may not be lost, which may become very important. I have thus observed crystals formed which I never could obtain by evaporation. It also happens in stopping or unstopping vessels, that some time after crystals are deposited, the formation of which is singularly promoted by the agitation and contact of the air. This note, useless to those who labour much, is inserted for the sake of such persons only as intend to free themselves of chemical researches.



This ingenious process consists in adapting to a balloon with two points an empty bottle, to which are joined two or four other collateral ones which communicate by the aid of syphons. Into a stone retort, which is to be luted to the balloon, we put the quicklime and dry sal ammoniac in powder; we raise the heat slowly and with much precaution, to such a degree as to redden and even vitrify the bottom of the retort; the alkaline gas, disengaged by the lime, passes over into the balloon and into the bottles, and unites with the water, causing a heat, saturates it, and forms in the first bottles the strongest and most caustic alkaline spirit possible. By this means no portion of the volatile alkali is lost; and besides, with all advantages we conduct the operation, we have a very pure and transparent product, we are nowise affected by the vapour; and lastly, in short, we have nothing to fear from the rupture of the vessels. M. Bucquet also has ascertained, by a great number of experiments, that only  $1\frac{1}{2}$  parts of quicklime are sufficient, instead of three, which were generally employed for the decomposition of one of sal ammoniac.

Lime slacked by the air decomposes this salt as well as quicklime; the residuum is some calcareous marine salt, which we will examine afterwards. This operation proves, that lime has more affinity with the marine acid than the volatile alkali has.

The two fixed alkalis decompose this salt just as lime does.

The vitriolic and nitrous acids separate the marine acid from the salt, and unite with its volatile alkali, with which they have a greater affinity. The neutral salts have no action upon it: those only which are formed by the aerial acid, that is to say, the aerial tartar and soda, decompose it. In mixing these, a double decomposition and double combination takes place: accordingly, whilst the marine acid unites with the fixed alkalines, the aerial acid, which is separated from them, unites with the disengaged volatile alkali, and forms  
with



with it a neutral ammoniacal salt, which sublimes in crystals, and with which the inner side of the balloon is encrusted. To perform this operation, we mix one part of very dry aerial tartar with one part of sublimed sal ammoniac in powder; we put this mixture into a stone retort, to which a large balloon is adapted, or rather a cucurbit of glass; a gradual fire being applied till the bottom of the retort be reddened, a well crystallized white salt is sublimed into the cucurbit. It is aerial ammoniacal salt; a little moisture also passes over: the residuum is febrifugal salt. By this means a very considerable quantity of this salt is obtained, which almost equals 2-3ds of the sal ammoniac employed. This phenomenon led Du Hamel to think that a little fixed alkali passed over along with the volatile. But, now that modern experiments have elucidated this theory, we easily conceive, that the aerial acid of the fixed alkali, which is reunited to the volatile, is the cause of the considerable quantity of the sublimed salt which is obtained. However, even down to these times, we have always regarded the concrete volatile alkali as the purest, and attributed to it the property of crystallizing and effervescing with acids; whilst that which is obtained by means of lime, and which is the true pure volatile alkali, was reckoned an altered and in part a decomposed salt. Hence we may estimate how much light the discoveries of Dr Black have thrown upon the saline substances; and we cannot but say that they have introduced a chemistry entirely new.

The uses of sal ammoniac are very extensive. In medicine, it is employed internally in the dose of a few grains, as a deobstruent, in obstructions, intermittent fevers, &c. Externally, it acts as a powerful antiseptic in gangrene and other complaints.

It is used in a great number of arts, particularly in that of dyeing, and in the operations of metallurgy, which relate to the reuniting, or soldering of different metals.



metals. The braziers employ it to cover the surface of copper which they want to tin.

Species 4. *Sedative Sal Ammoniac.*

SEDATIVE sal ammoniac, or ammoniacal borax, is the combination of sedative salt with the volatile alkali. Nobody has as yet examined this neutral salt. I made the following observations upon some of its properties.

I dissolved very pure sedative salt in the caustic volatile alkali, till the saturation seemed complete. I diluted this solution with a little water, and evaporated about half the liquor in a sand bath; by cooling, I got a bed of crystals united, the surface of which presented polyedral pyramids. This salt has a pungent and urinous taste: it renders the syrup of violets green, and it is not sensibly altered by the air: it seems soluble enough in water: lime disengages the volatile alkali. These are the principal properties which I remarked at first sight; but I have not examined it with sufficient accuracy to comprehend all its varieties. It is of no use.

Species 5. *Sparry Ammoniacal Salt.*

THE properties of this salt, like the former, have not as yet been investigated. M. Boullanger agrees with M. Scheele in saying that the sparry acid combined with the volatile alkali does not crystallize, but forms a gelly, and emits vapours analogous to those of marine acid, by the addition of the vitriolic. These two chemists have not examined the other properties of this kind of salt; but they have seen enough to distinguish the sparry acid from the marine.

Species 6. *Aerial Ammoniacal Salt.*

M. BUCQUET has given the name of *aerial ammoniacal salt*, to what was formerly called *concrete volatile alkali*; but which is truly a neutral saline combination of the aerial acid with the pure volatile alkali. It is not found pure and uncombined in nature. It is extracted from almost



almost all animal substances. It may be formed by the direct union of aerial acid with the caustic volatile alkali, either by agitating the alkali over a vessel in fermentation, or by making the aerial acid pass into the spirit, or by introducing this acid into a vessel whose sides have been moistened with some volatile caustic alkali. In all these cases we very soon observe the formation of ammoniacal crystals. It is also obtained by decomposing sal ammoniac by the aerial neutral salts.

It is susceptible of a regular form. Its crystals seem to be prisms with several sides. M. Bergman says they are octaëdral, having four of their angles truncated. M. Romé de Lisle has seen quantities of this salt in the form of small three-sided prisms squeezed together, and terminated at their upper extremity by a three-sided top.

Its taste is urinous, but much weaker than that of the caustic volatile alkali; its smell, though similar to the last, is also much less pungent; it turns the syrup of violets green.

It is very volatile, and sublimes entirely with a small degree of heat. If it is well crystallized when we heat it, it begins to liquefy by means of the water of its crystals; but almost at the same time it is volatilized.

It is very soluble in water, and its solution raises some cold, like all the crystallizing salts. Two parts of cold water dissolve more than one of aerial sal ammoniac; warm water more than its own weight; but as it is dissipated by the heat of boiling water, it is impossible, without the danger of losing much of it, to employ this means for its crystallization.

It slightly attracts the humidity of the air.

The earths have no more action upon it than upon the other ammoniacal salts. Magnesia does not decompose it. Lime decomposes it, like the true sal ammoniac, by seizing on its acid, with which it has a greater affinity. If we pour some limewater into a solution of aerial ammoniacal salt, a precipitation instantly ensues, and we feel a pungent odour from the volatile alkali.

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The lime seizes on its aerial acid, with which it forms chalk, which is precipitated, and the volatile alkali is separated. Quicklime triturated with this salt, instantly disengages the alkaline gas. By putting this mixture into a retort, we may, by means of water placed in the bottles of M. Woulfe's apparatus, obtain the caustic or fluid volatile alkali, as we obtain it from the sal ammoniac distilled with the same intermedium: This decomposition proves, that lime has more affinity with the aerial acid than the volatile alkali has; a fact which the other acids equally show.

The caustic fixed alkali decomposes aerial sal ammoniac as the lime does, by separating the volatile alkali, and uniting with its acid.

Lastly, the vitriolic, nitrous, marine, and sparry acids, and even the acid of borax, have more affinity with the volatile alkali than the aerial acid has. When we pour one of these acids upon the aerial ammoniacal salt, a brisk effervescence ensues, owing to the dissipation of the aerial acid. If this decomposition be tried in a long narrow vessel, we may be sensible of the presence of the aerial acid, by plunging a candle into it, which will be extinguished; by its turning the tincture of turnsol red; and by its precipitating lime-water.

These decompositions of the aerial ammoniacal salt by means of lime and the fixed alkali, which seize upon its acid, disengaging the volatile alkali, and likewise by means of the acids which disengage the aerial acid, those uniting with the volatile alkali, clearly demonstrate the composition of aerial ammoniac.

M. Bergman has found, by accurate experiments, that a hundred measures of this salt crystallized contain forty-five of aerial acid, forty-three of alkaline gas, and a dozen of water. As there is more acid in this salt than in the aerial tartar or in the aerial soda, hence this learned chemist concludes, that the weaker the alkaline base is, the more acid it requires for its saturation.

The aerial ammoniac has no action on the perfect neutral



neutral salts. We shall more fully mention afterwards, that it decomposes the calcareous neutral salts by means of a double affinity; a change which the pure caustic volatile alkali cannot produce.

Aerial ammoniac is employed in medicine as a sudorific and antihysterical, &c. We mix it with any aromatic substance. It is reckoned a specific against the bite of the viper. It is given in the dose of a few grains in the drinks recommended. Several persons have proposed this salt as a very useful antivenereal remedy. Lastly, it is used as a very good medicine in diseases of the skin. These two last properties require further confirmation from experience.

### GENUS III. *Neutral calcareous Salts.*

#### Species 1. *Vitriol of Lime, Selenite, Gypsum.*

THE combination of the vitriolic acid with lime gets the name of *calcareous vitriol* or *selenite*. This salt exists in great abundance in nature. As it assumes different forms, the naturalists have distinguished a great variety of them; of which we shall only mention the most essential to be known.

1. *Selenite in rhomboidal laminæ.*—It has an icy transparency; the pieces which are found in cabinets are irregular, but always split into rhomboidal laminæ.

2. *Cuneiform selenite, or selenite in form of a spear-top.* It is formed of two saline triangles, reunited in the middle, each of which is composed of triangular laminæ, as M. de la Hire observed. We call this *selenite, lapis specularis, sharp glass, or talc of Montmartre*.

3. *Rhomboidal selenite with ten sides.*—This is what is found in the quarries of Passy.

4. *Prismatic selenite with ten sides.*—It is formed of six-sided prisms, terminated by two-sided pyramids, or by a returning angle. It is found in Switzerland.

5. *Selenite of Montmartre, in the form of yellow rattles.* These are piles of little lenticular crystals, obliquely placed at the side of one another.



6. *Silken or striated selenite, silken gypsum of China.*—It is found in Franche Compté, in Angumois, &c. It is formed of very neat prisms, united into bundles, for the most part shining and resembling satin.

7. *Common gypsum, or stone-plaster.*—This substance is white, more or less grey, strewed with little brilliant crystals easily taken out with a knife. It is found disposed in layers, and composes most of the mountains about Paris. It will be mentioned afterwards, that this is not pure selenite.

8. *Gypseous alabaster.*—This is a kind of a stone for plaster, more hard and more ancient than the preceding, from which it differs only in its transparency, a grey yellow colour, and a disposition into little beds, which are more or less varied.

Selenite is also found dissolved in waters, as in the wells of Paris; but it is never pure, and is always found combined with some other earthy salt with base of magnesia.

Selenite was long taken for a stony substance by the naturalists. As they found it had no taste nor solubility, they did not imagine it a true salt. However, it has a particular taste, which it communicates to water, and of which the stomach is very sensible; for a solution of it occasions a considerable sensation of cold and weight in that viscus. With respect to the solubility, the form, the purity, the transparency, the quantity, and besides the disposition in beds, of the selenite crystallized in many places, as well as in all the environs of Paris, sufficiently show, that it has been at first dissolved, and afterwards deposited, by the water. Selenite, exposed to the action of the fire, loses the water of its crystals, decrepitates when quickly heated, and becomes of an unpolished whiteness, and considerable friability. It forms what is called *fine plaster*. As with water it is susceptible of a certain tenacity, we can by moulding the paste so formed, make very white and beautiful statues; but this plaster easily drying, and retaining but



very little water, it is subject to be broken with the least stroke. If we urge it with the fire, when in white powder, it fuses at length into a kind of glass: but for this purpose a heat of the most extreme violence is requisite, such as that of porcelain furnaces, or of the focus of a glass lens. M. d'Arcet and Macquer have fused selenite. Macquer observed, that by exposing the polished sides of cuneiform selenite to a burning mirror, it is only whitened; but if we present it on its edge, it boils, and instantly fuses.

Selenite, put upon a hot iron, turns phosphorescent.

It is unalterable by the air; it is soluble in water. According to the chemists of Dijon, about 500 parts of water are required to dissolve one of selenite. Hot water dissolves no more. By evaporating this solution, we do not obtain crystals like those which nature presents, but resembling leaves or laminæ, which precipitate in proportion to the evaporation of the boiling liquor. According to M. Bergman, terra ponderosa has more affinity with the vitriolic acid than lime has, and even decomposes the selenite. The fixed alkali also decomposes this neutral salt. We get a precipitate of lime, by pouring some caustic fixed alkali into a solution of selenite. If we evaporate the supernatant liquor, we get vitriolated tartar or Glauber's salt, according to the alkali we employ.

The volatile alkali, which has less affinity with all the acids than lime has, does not decompose selenite, if the selenite be very pure, and the volatile alkali employed very caustic: for if the water in which selenite is dissolved contain any salt, with base of magnesia or clay, the volatile alkali occasions a precipitate from these substances. To insure success in this experiment, it is requisite to dissolve some calcareous spar in the vitriolic acid, and to dissolve it in a sufficient quantity of distilled water; the caustic volatile alkali poured into this solution, or farther the alkaline gas being made to pass through it, causes no precipitation.

Selenite



Selenite has no action upon the perfect vitriolic neutral salts; but it decomposes the nitrous and marine salts with base of either of the fixed alkalis. Their mixture forms vitriolated tartar, or Glauber's salt, and calcareous nitre, or calcareous marine salt. These decompositions are perceptible only when we evaporate the liquors into which they are converted, because the new salts which result remain dissolved.

The aerial tartar is decomposed by selenite. In this mixture a double decomposition and combination happens. The vitriolic acid leaves the lime, in order to unite with the fixed alkali, and to form vitriolated tartar. The aerial acid, disengaged from the alkali, unites with the lime, and forms the salt called *chalk*.

Aerial soda likewise decomposes selenite, and is decomposed by it. In this mixture some Glauber's salt and chalk is formed.

The aerial ammoniacal salt decomposes it by means of a double affinity; for whilst the vitriolic acid attracts the volatile alkali, the lime is separated from the vitriolic by the aerial acid, with which it has a very great affinity, forming chalk, which is precipitated. As it was formerly believed that the concrete volatile alkali, or aerial ammoniacal salt, was the pure volatile alkali, hence Geoffroy affirmed, that this salt really precipitates selenite, and believed that this alkali had more affinity with the vitriolic acid than lime has.

Selenite is decomposed by combustible matters, and forms sulphur by the combination of the phlogiston of these substances with the vitriolic acid, according to Stahl; or by the decomposition of this acid and the subtraction of its air, according to the doctrine of the moderns.

Pure selenite is almost of no use. With the gypseous alabaster we make different moveables, which are pretty enough.

The stone for plaster is one of the most useful materials which nature produces. This stone is a mixture



of selenite and chalk. When we expose it to the action of the fire in order to bake the plaster, the selenite loses the water of its crystals, and the chalk its acid. The plaster baked is then a mixture of lime and selenite deprived of its water. When we pour water upon this substance, it is very rapidly absorbed by the lime, and a heat ensues. The odour of liver of sulphur, which the extinction of the plaster discovers, arises from a little sulphur, formed by the vitriolic acid of the selenite, united to the charry animal or vegetable matters which are always found in the stone-plaster. This sulphur, dissolved by lime, forms a kind of liver of sulphur, which emits the odour we are speaking of. When the lime has absorbed enough of water to render it a paste, it envelops the selenite, which, meeting with a portion of this fluid, crystallizes in the middle of the paste. The lime drying by degrees, becomes, by means of the crystals of selenite, a substance, in the form of a kind of mortar, which is called *plaster*.

From this theory, we understand why the plaster ought to be roasted to a particular degree. If it be not well enough, it does not fasten with the water, because the lime is not quick enough. If it be too much, the lime forms with the selenite a kind of bad vitreous frit, which cannot be united with water: this is the burnt plaster. We also know, that if the plaster lose its quality when left exposed to the air, the lime is gradually flacked; and we may restore its power by calcining it afresh. Lastly, it is easy to conceive why the plaster is preserved in places that are dry and warm, and why it is destroyed and raised into scales or laminæ in moist places. In the last case, the selenite, which is soluble in water, gradually loses its crystalline form and consistence: It is by this solubility that the plaster differs from the true mortars in which the sand or cement that constitutes their base suffers no change from water. We likewise do not employ the plaster in places where there is water, as basons, reservoirs, &c.

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## L E C T U R E XXI.

Species 2. *Calcareous Nitre.*

**C**ALCAREOUS nitre, or the salt resulting from the combination of the nitrous acid with lime, is more rarely found than calcareous vitriol. It is found in those places only where alkaline nitre is found. It is formed upon the sides of walls, in places inhabited by animals; it exists in the mother-waters of nitre.

When it is crystallized, according to the process to be mentioned hereafter, it is in the form of a prismatic solid with six surfaces, greatly resembling nitre, and terminated by two-sided pyramids. However, it is very rarely obtained in so regular a form; for the most part it is in small needles, the form of which cannot be determined.

This salt has a bitter and disagreeable taste, in which it differs widely from selenite. Its taste has something cooling in it, resembling that of nitre; it is easily liquefied by fire, and becomes solid on cooling. If we carry it into the dark after it has been heated, it appears luminous; and in this state constitutes the phosphorus of Baudouin, Balduinus. Put it upon a red hot iron, it exhibits the same phenomenon; thrown upon a burning coal, it fuses and detonates slowly: If it be heated for some considerable time, it loses its acid which is decomposed. When this is done in a retort, with its neck plunged under a vessel full of water, we obtain a considerable quantity of very pure dephlogisticated air, and toward the end some aerial acid. This decomposition of the nitrous acid into pure air and aerial acid, is absolutely similar to what happens in the distillation of alkaline nitre by itself, as was taken notice of in the history of this neutral salt.

Calcareous nitre very quickly attracts the humidity of the air; it is therefore necessary to keep it in close vessels to preserve its crystals.

This salt is very soluble in water: it requires only

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two



two parts of cold water, for solution, to dissolve one of it; boiling water dissolves more than its weight. To obtain it in a crystallized state, we must evaporate a solution of it; and when it has acquired a consistence somewhat less thick than that of syrup, it must be set in a place that is cool. Prismatic crystals, considerably long, are afterwards formed, which generally are in bundles, whose needles diverge from a common centre. A solution of calcareous nitre, not so much evaporated as the preceding, exposed to a dry and warm temperature, at length forms regular prisms, similar to those described at the beginning of this article.

Sand and clay decompose it, and separate its acid.

The action of magnesia on this salt has not been examined. According to M. Bergman, the terra ponderosa decomposes it as it does selenite. M. de Morveau has observed (*Journal de Physique, tome xvii. p. 224. to p. 227*), that lime-water, poured into a solution of calcareous nitre, causes a precipitation. He ascribes this effect to the phlogiston of the quicklime; and thinks that this last has more affinity with the nitrous acid than the lime previously united with it has, which the acid has already robbed of its phlogiston. Unhappily this chemist has not examined the nature of this precipitate; an examination would probably have furnished some light upon this singular experiment. M. Beaumé has already observed, that a solution of calcareous spar in the nitrous acid, is precipitated by lime-water; but he ascribed this phenomenon to a small quantity of argillaceous earth. (*Chimie Experim. et Rais. tome I. p. 286.*)

The fixed alkalis also attract its acid, and precipitate the lime; very pure caustic volatile alkali does not decompose it more than it does selenite.

The vitriolic acid disengages the nitrous from it with effervescence. The nitrous acid thus disengaged, may be obtained in the same manner as from ordinary pure nitre. Spirit of vitriol poured into a solution of calcareous



reous nitre, instantly occasions a precipitate of selenite. We are not acquainted with the action of the other acids upon this salt.

Calcareous nitre decomposes the vitriolic neutral salts; hence some selenite, and some ordinary nitre, or rhomboidal nitre, is formed. The same thing happens to vitriolic ammoniac; which, when mixed with a solution of calcareous nitre, forms some nitrous ammoniac and selenite. This last substance, which is only very little soluble, instantly precipitating from the mixture, leaves no doubt of these double decompositions. Aerial tartar likewise decomposes calcareous nitre, which at the same time separates its principles; and there results from the mixture some nitre and chalk. Aerial soda, whose action upon calcareous nitre is the same, produces cubic nitre and chalk. Aerial sal ammoniac likewise decomposes this salt by means of the double affinity: from this mixture we get some nitrous ammoniac and chalk (*a*). Selenite does not change calcareous nitre; but when these two salts are dissolved in the same water, as the first is but little soluble, and the second very soluble, we may separate them by crystallization. The selenite is soon after precipitated, and the calcareous nitre crystallizes when the liquor, after being much evaporated, cools.

Calcareous nitre is of no use.

### Species 3. *Calcareous marine Salt.*

CALCAREOUS marine salt, formed by the combination of the marine acid with lime, is very abundant in all those places where true marine salt is found, and particularly in the waters of the sea, to which it gives the acrid and bitter taste, which was on that account formerly supposed to be owing to a bitumen in these waters: But

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(*a*) It cannot be too often repeated, that these double decompositions are owing to the great affinity which subsists between lime and the aerial acid; and that this affinity more and more authorises the denomination of *chalky acid*, given to fixed air by M. Bucquet.



it is never pure in these fluids; it is always mixed with some marine salt with base of magnesia. If we want then to have very pure calcareous marine salt, we must directly combine the marine acid with lime. It has been improperly called *fixed sal ammoniac*, because it remains after the decomposition of sal ammoniac by means of lime.

This salt, when in a dry and solid state, is in the form of prisms, with four striated surfaces, terminated by very acute pyramids. It has a salt and very disagreeable bitter taste. Exposed to a gentle fire, it liquefies by means of the water of its crystals, and fixes by cooling. With a strong fire it suffers almost no alteration. M. Beaumé observed that it did not lose its acid. Put upon a red hot shovel, it becomes luminous; which is the reason of its name of *Homborg's phosphorus*. Calcareous marine salt, which remains in the retort after the decomposition of sal ammoniac by lime, is fused into a kind of frit, of a lightish grey slaty appearance, and without the acid being driven off, although we should make the heat capable of fusing the surface of the retort. This frit strikes fire with steel; and rubbed in the dark with steel, it exhibits phosphoric sparks (b).

Calcareous marine salt exposed, to the action of the air, readily attracts humidity, and entirely falls into deliquium. It is necessary to keep it in a close vessel, if we want to preserve it in its crystalline form.

It is very soluble in water, requiring only about  $1\frac{1}{2}$  parts of this fluid cold to dissolve one of the salt. Hot water dissolves more than its own weight. When a  
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(b) It is necessary to observe, that calcareous marine salt, which remains after the decomposition of sal ammoniac by means of lime, generally contains a portion of this last substance not saturated; because more lime is employed than what is necessary to decompose the salt. This superabundant quantity of lime undoubtedly occasions the property in the residuum of giving a glassy frit, which besides is altered and moistened through time when exposed to the air. Calcareous marine salt, without excess of lime, never assumes so much hardness by the action of the fire as this residuum has.



solution of it is evaporated almost to the consistence of a syrup, and afterwards left to cool slowly, we obtain crystals in three-sided prisms several inches long, as if in the form of so many rays coming from a common centre; a form which all the calcareous salts constantly seem to assume. If the liquor be very much evaporated, and very hastily cooled, it turns into a shapeless mass, having the appearance of needles at its surface. A solution of this salt, evaporated to about 45 degrees of Beaumé's areometer, and exposed to the cold, deposits very regular and very thick prisms. Terra ponderosa decomposes this salt, because, according to the experiments of M. Bergman, it has more affinity with the marine acid than lime has. Lime and magnesia do not alter it. The fixed alkalis precipitate the lime from it. If the two liquors are concentrated, the lime, absorbing the little water they contain, almost instantly forms a gelly, which very soon becomes solid. We may call this experiment a *chemical miracle*, because it exhibits two fluids, which suddenly pass in the state of a solid.

Very pure volatile alkali does not decompose it.

The vitriolic and nitrous acids disengage its acid with effervescence; and with a distilling apparatus we might obtain it as we do from ordinary marine salt. The distillation of this earthy salt with the nitrous acid, gives aqua regia, in consequence of the volatility of these two acids.

This salt decomposes vitriolated tartar and Glauber's salt. We may easily ascertain this fact, by mixing the solutions of these different salts; for a precipitate instantly happens, which we know to be selenite. The supernatant liquor contains some febrifugal salt, or marine salt, which we may obtain by evaporation.

Aerial tartar and soda likewise decompose this salt. With respect to the aerial ammoniac, it only decomposes it by means of the double affinity, as has been explained in the articles of Selenite and Calcareous Nitre. In these three decompositions, we get always some  
chalk



chalk, and febrifuge, common, or marine ammoniacal salts, according to the neutral salt employed for precipitation. This salt, dissolved in water with calcareous nitre, is difficult of separation; because the law of their crystallization is the same: but we know very well, that if it were dissolved along with selenite, it might be easily obtained separately; because this last salt, only crystallizing by evaporation, would leave the calcareous marine salt, pure, which crystallizes by cooling. It is of importance to make this remark, because these two salts are frequently found dissolved in the same mineral water.

Calcareous marine salt is of no use.

As it exists in very great quantity in the salt of the Gabelle, which is recommended as a purgative and obstruent in schrophulous cases, we may suspect that the latter owes a part of its properties to the calcareous marine salt.

#### Species 4. *Calcareous Borax.*

WE may give this name to the combination of the sedative salt with lime. This salt has not been at all examined, although it be certain that sedative salt is capable of uniting with lime, since, as we have already mentioned, this last decomposes borax. The chemists of the academy of Dijon have observed, that the sedative salt, mixed with slacked lime, and exposed to the fire, gave a matter weakly agglutinated, and not adhering to the crucible. This matter, thrown into water, does not exhibit the phenomena of lime, which proves that there is a true combination. M. Beaumé says, that he saturated lime-water with sedative salt. This liquor, evaporated by means of the air, did not afford crystals, but yellow pellicles, which had a weak taste of sedative salt. The academicians of Dijon likewise digested a saturated solution of sedative salt, upon lime slacked by the air in a sand-bath.



This solution, filtrated, gave a white and copious precipitate by means of the fixed alkali.

These different experiments show only the solubility of lime by the acid of borax, and discover nothing about the properties of the neutral salt resulting from this combination.

Species 5. *Sparry Flour, Vitreous Spar.*

THIS kind of salt is a combination of the sparry acid with lime. There is great abundance of it in nature. We find it particularly in the environs of mines, of which it is an indication. To the present time it has been regarded as a stony matter. Before M. Scheele's discovery, the vitreous spar, though well distinguished by miners from all the other mineral substances, on account of its fusibility, had been confounded by naturalists either with the gypsums, calcareous spars, or with the heavy spars, which we have also called *fusible*. The celebrated Margraaf had, however, distinguished this salt from the heavy spar, by adopting, for the first, the name of *vitreous fusible spar*, and for the second, that of *phosphoric fusible spar*; and we ought to pay this chemist the honour of the first discoveries made about the properties of vitreous spar.

This salt is generally in the form of cubic crystals, of different colours, very regular, of an icy and vitreous transparency.

It is broken by the stroke of steel. It is always found in mines, and commonly serves for their matrix. Sometimes it is opaque and in irregular masses. It possesses a more considerable weight than any of the saline matters which we have hitherto examined. We distinguish nine varieties of this substance presented to us by nature.

Varieties.

1. Cubic vitreous spar, white and transparent.
2. ————— white and opaque.
3. ————— yellow; false topaz.



## Varieties.

4. Cubic vitreous spar, reddish; false ruby.
5. ————— pale green; a false marine precious stone.
6. ————— green; false emerald.
7. ————— violet; false amethyste.
8. Vitreous octaëdral spar, with truncated pyramids.  
I am in possession of a crystal of this kind, which is semitransparent and a little blackish.
9. Vitreous spar, in a lump. It is for the most part of a clear green, or violet colour. It forms the matrix of several mines.

These different varieties of vitreous spar, for the most part, are but one and the same saline substance; that is, a combination of the sparry acid with lime: however, as they are formed by nature, we generally find amongst them, after a complete analysis, several foreign matters; as some quartz, clay, and iron. In general this is the character of the natural production.

The vitreous spar, exposed to a gentle fire, acquires a very remarkable phosphoric property; but if it be heated to a red heat, it loses it entirely. The colour of the green vitreous spar is also dissipated; it becomes white and friable: if we heat it briskly it decrepitates, but less than marine salt. A strong heat fuses it into a transparent glass.

It is not alterable by the air, nor soluble in water.

It serves as a flux to the earthy and the saline earthy substances.

According to M. Bergman, the pure fixed alkalis cannot decompose it, on account of the lime's greater affinity with its acid than that of the alkalis. Oil of vitriol disengages the sparry acid; and this is the process usually employed to obtain it. Into a glass retort, we put one part of vitreous spar in powder with three parts of oil of vitriol; the mixture grows gradually warm, an effervescence is produced, and sparry acid vapours are disengaged. This distillation is carried on without the aid of external heat; and a white substance like



like flowers, deposited by the sparry gas, is sublimed into the recipient. If we apply fire, we obtain the sparry acid concentrated, which is covered with an earthy pellicle, thick, and similar to the white efflorescence just now mentioned. We may obtain this acid in the form of gas, by plunging the neck of the retort into a vessel full of mercury. This aeriform acid is transparent, and does not precipitate the earth which is united with it, but when it comes into contact with water.

From this we know why the liquid sparry acid deposits stony crusts in the receiver, since it cannot hold them dissolved, whenever it combines with water. This acid may be received into a vessel full of water: it is completely separated from all its earth, and forms a much thicker crust. When the distillation is over, we observe the residuum to be hard, white or reddish, in plates, and the retort is very perceptibly hollowed or corroded. This observation has not escaped M. Margraaf and M. Scheele and Boulanger. Most of the chemists also who have repeated their experiments, have had occasion to observe this phenomenon. If we examine the nature of the residuum, we find it to consist of selenite mixed with a little quartz, often with clay and a little magnesia. These two last substances, as well as iron, appear to be accidental only. The crust deposited by the sparry acid is of a quartz nature; for it is neither soluble in the acids nor fusible, and the fixed alkalis form with it a white and durable glass.

The nitrous acid too decomposes the sparry fluor, but exhibits very different phenomena. According to M. Boulanger, we do not observe the crust in this operation, as in that with the oil of vitriol.

According to M. Scheele, the marine acid likewise separates the sparry acid. We do not yet know the action of the greatest part of the neutral salts upon the vitreous spar; we only know that the aerial tartar and soda decompose it by means of double affinity, whilst  
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the caustic fixed alkalis do not decompose it (c). If we fuse one part of this spar with four of aerial tartar, and put this mixture in fusion into water, we get a precipitate of chalk, formed by the union of the aerial acid with the lime of the spar, and the fluid contains some sparry tartar, which may be got in the consistence of a jelly by evaporation. This process, repeated with aerial soda, furnishes chalk and sparry soda, which may be obtained crystallized by evaporation.

The vitreous spar is of no use, except in some countries abounding in mines, where it is used as an excellent flux.

Species 6. *Calcareous Spar; calcareous matters in general.*

CALCAREOUS spar is a neutral salt, formed by the com-

(c) It were much to be wished, that the analysis of the fluor spar had been so complete, as to ascertain with accuracy the nature of those properties which have of late so much engaged the public notice. We know that it is a compound substance, and that the acid which it contains is capable of dissolving siliceous earth; though it still remains a matter of doubt, and must be determined by experiment, whether or not the vapour of the sparry acid be actually converted into solid flint upon meeting the vapour of water. In the distillation of the acid in a glass retort, there is some flint constantly found in the water of the receiver; an appearance which many chemists are inclined to ascribe to the corrosion of the glass. It is indeed certain, that the sparry acid does in some measure dissolve the flint which enters into the composition of the glass, which it afterwards deposits in consequence of its superior attraction for the water. There are, however, some circumstances which tend to favour the opposite opinion: If, for example, the receiver be filled with spirit of wine instead of water, there is no formation of siliceous earth. Besides, the acid may be distilled, and siliceous earth generated, with a heat too gentle to corrode the glass: And even in those cases where the glass is corroded in the distillation, the quantity of flint produced does not correspond to the loss of weight which the glass has sustained by the erosion. The siliceous earth collected in the receiver weighs much more than it should have done according to this supposition. It has also been asserted by some chemists, that the siliceous earth is produced when the distillation has been conducted in such metallic vessels as the vitriolic acid does not attack. Such is the present state of our knowledge with regard to this very curious substance.



combination of the aerial acid with lime. This substance has been placed amongst the number of the stones by the naturalists, because they had not perceived in it any saline property. However, we will find that it has a taste, solubility, and fusibility; that it can be decomposed; and that in its analysis it furnishes a great quantity of aerial acid, and the saline earthy substance, lime, already understood. As the calcareous spar is the last modification of a substance very varied in its form, which passes through many different states before being crystallized regularly, it is necessary to consider the calcareous substances in general.

No part of natural history presents a wider field for speculation, or a more complete collection of positive evidences, than that of the calcareous substances. Long observation, which has never belied itself, and particularly the opportunity of following the operations of nature step by step in the formation of these substances, have taught us, that the bosom of the sea is the laboratory where they are perpetually forming. Amongst the great number of animals which those immense collections of water nourish, there are several classes, the individuals of which, multiplied almost to infinity, seem destined to add to the mass of our globe: These are, the shell-fishes, the madrepores, the lithophites; the solid parts of which, examined chemically some time after they have ceased to live, show all the characters of calcareous substances. It is the base of that kind of marine skeletons which produces, by their successive heaps, mountains entirely formed of these substances. Although there be a wide difference between the natural state of these animated substances, and the crystallization of calcareous spar; although it be difficult at first sight to perceive the astonishing difference that subsists between the soft and pulpy substance of those animals when alive, and the hardness of these stony matters which they form with time, and which are designed to impart solidity to lasting buildings; it is, however, possible



possible to form an idea of the varieties of alteration through which they pass, so as to be confounded with mineral bodies. From the following demonstration, we may trace those gradations from the time of the acting animal organization, to the regular deposition, which gradually forms the transparent spar.

The waters of the sea, in poizing themselves according to the laws of a motion, with which we are as yet unacquainted, are imperceptibly displaced, and change their bed. This fact is demonstrated in the learned theory of the earth, by M. le Comte de Buffon. As the waters quit a part of their bed, they expose to view the grounds on which their varied motions, so well explained by the celebrated man we have just now mentioned, have formed beds by the successive deposition of solid particles, or the skeletons of sea-animals. These beds are almost entirely filled with shells; the putrefaction of which very soon destroys the animal-gluten, and afterwards having lost their colours, the polish of their internal surface, and particularly their consistence, they become friable, earthy, and pass into the state of fossils. Hence the production of the shell-earths, and stones of the same nature.

These stones, being wasted by the rains, gradually lose the organic form, become friable, and very soon form a substance, in grains very little adhering, called *chalk*. When a shell-stone has acquired enough of hardness to be susceptible of polish, and when the shells which compose it have put on different colours, preserving their organization, it then constitutes the *luma-chelles*. If the organization is destroyed, if the stone is hard and susceptible of polish, we give it the name of *marble*. The water which is charged with chalk, deposits it on all the bodies over which it runs, and forms incrustations. When it is filtrated through the vaults of subterranean cavities, it lets fall white and opaque depositions, formed of concentric layers, resembling pendulous conical masses. These are the *stalactites*.

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If these last, reunited into a great mass, and filling caverns, remain for a long time in the earth, they acquire a considerable hardness, and give rise to alabaster. Lastly, when the water, which holds a very fine and attenuated chalk in solution, slowly penetrates the stony cavities, it will deposite this substance, molecules on molecules; and these small bodies, approaching one another with the surfaces which will suit best, will assume a symmetrical and regular arrangement, and form hard transparent crystals, resembling those of the saline substances. We call these *calcareous spars*. This, then, is the last degree of attenuation of the chalk, the state in which it is the most distant from animal origin, and in which it most resembles a true salt.

These transmutations of the calcareous substances, so various and so numerous, the consideration of which furnishes to the naturalist such extensive views upon the antiquity of the globe, its alterations, and the œconomy of the animal kingdom, which constitutes a great part of its mass, exhibit to the chemist's eyes one single substance only, always like itself, a single individual and neutral salt, formed of lime and the aerial acid. We go on to consider it under this double point of view.

§ 1. *Natural history of the CALCAREOUS Substances.*

BEFORE we enter into a detail of the calcareous substances, it is proper to take a general view of their disposition in the globe. These substances form beds more or less extensive, horizontal or inclined, which evidently retain an impression from the action of the waters. Those beds compose entire mountains and valleys, forming a great part of the outside of the globe: They show that the waters of the sea have covered our globe, and deposited on it an immense quantity of the spoils of its inhabitants. The rains, in filtrating through these calcareous masses, and carrying off portions of them, seem to distribute them more deeply in the cavi-



ties, under the different forms we are going to examine. Their general characters given by the naturalists, and which are very proper to distinguish them, are these, that they do not strike fire with steel, and that they effervesce with the acids. After what we have said, as the form of these calcareous substances is very various, it is indispensable to divide them into several genera. Of these we admit six (*a*).

GENUS I. *Shelly Earths and Stones.*

THESE substances have been arranged among the stones, because they have neither a perceptible taste nor apparent solubility; but their analysis demonstrates that they are truly saline, as well as all the other subsequent genera (*b*). We know them by the organic form. Frequently the shells are even quite entire, and the stone is only a heap of these organized bodies; sometimes they have preserved even a part of their colours. It also happens that animals are found, to which there are none alive analogous, in the heart of the seas, such as several kinds of cornua Ammonis. On the contrary, there are shells in Europe and in France, of which we know the analogous individuals in America. Some naturalists have made very extensive divisions of the fossil shells; but as they are similar to those of these living animals, we will treat of them elsewhere.

Several other animal substances are also found among the calcareous earths. When they evidently appear to have

(*a*) It will perhaps be astonishing to find new divisions of genera in the history of one species of salt; but we must observe, that those genera are only relative to natural history, and that in reality they must all be referred to the species of neutral salt, of which we are going to examine the chemical properties.

(*b*) Although these substances are really saline, the name of *earths* and of *stones* ought to be scrupulously observed; because, as M. Daubenton has said, the names are a public foundation which are not allowed to be altered. If all the philosophers had the same caution with this learned naturalist, they would not terrify the students, as they often do, with the frightful apparatus of a nomenclature.



have pertained to the known animals, we then give them a name relative to their origin, and generally formed from that of the class of animals to which they appertain, by adding a word which designates their stony state; such is that of the *madrepores*.

Sometimes we are ignorant of the origin of these substances; then we give them particular names, taken from their form: Such are the Jewish stones, which some persons have supposed to be spines of the sea-urchin; the numismal stones, or farthings of St Pierre, resembling pieces of money, and seeming to be only small cornua Ammonis adhering to one another; the fossil bezoar, a kind of round mass, formed of concentric layers; the ludus Helmontii, the holes of which seem to have been formed by the extraction and exsiccation of an earthy soft matter, and to have been filled up with calcareous earth; the trochites, entroques or asteriæ, which come from a zoophyte called *sea-palm*; the pisolites, oolites or meconites, which are supposed to be petrified eggs of fishes or of insects; but the true origin of which is unknown. It has been usual to refer also to this kind of truly calcareous stones, all the petrified substances from some animals to which they may have belonged; and hence have arisen the names of *gammarolites*, *cancrites*, *entomolites*, *ichthyolites*, *amphibiolites*, *ornitholites*, *zoolites*, *antropolites*. But since the new discoveries upon the bones, it appears that these substances are not wholly composed of chalk. We will speak of them in the mineral kingdom. It is the same with respect to the glossopetræ, or petrified sharks teeth; the ivory, or fossil unicorn, which is formed from the teeth of elephants; the turquoises, or the green and blue coloured bones; the toad-stones, grey or yellow and hollowed stones, which, according to M. Jussieu, are tops of the dentes molares of the fish of Brazil, called *grondeur*; and of the eyes of serpents, which belong, according to this naturalist, to the dentes incisivi of the same fish. After these details, this kind may be



reduced to two species, under which might be comprehended all the possible varieties.

1. *Entire or fossil shells.* Here we distinguish different degrees of alteration in their colours, polish, hardness, &c.

2. *Shell marle.* Shells bruised and in the form of earth. The soil of a part of Tourrain, and of several other provinces of France, is entirely of this nature. These earths are employed as excellent manure.

#### GENUS II. *Calcareous Earths and Stones.*

THESE are formed by the substances of the first genus, wasted and deposited by the waters. They are found disposed in beds or banks in the earth. We follow M. Daubenton in the distinction of the different species.

Species.

1. Calcareous earth, compacted; chalk. It varies in colour and fineness of grain; it is employed for many domestic purposes.
2. Spongy calcareous earth; stone marrow.
3. Calcareous earth in powder; fossil farina.
4. ——— in thick milk; lac lunæ.
5. ——— soft; hassock. It becomes hard and white by drying.
6. Calcareous stone in coarse grains. We have an example of this in that of Arcueil; we find in it shells half bruised.
7. Calcareous stone in fine grains. The stone of Tonerre is of this species.

Without entering into useless details, we know that the colour, the hardness, and the different uses for which we employ these earths and stones, furnish a great number of varieties, known by different names. In general, they serve to make lime for the construction of buildings.

#### GENUS III. *Marbles.*

THE marbles differ from the calcareous stones, properly so called, in a little more considerable hardness.

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Like them, they do not strike fire with steel; they raise an effervescence with the acids; and the fracture is granulated; but their grain is much finer and closer, their colours are more brilliant, and they take a more beautiful polish. All the world knows the uses of marble in sculpture, architecture, &c. It is also employed in some countries to make lime.

1. *Lumachelle*. This name has been given by the Italians to a kind of marble formed by agglutinated shells.

2. *Breche*. This is a marble composed of small round masses united by a cement of the same nature.

3. *Marble*, properly so called. We find in it neither the shells of the lumachelles, nor the composition of the breches in round masses. Its spots are irregular, and it is often full of veins.

According to M. Daubenton, it is never of a single colour. This naturalist divided the marbles, by the number and the combination of their colours,

1. Into marble of six colours, viz. white, grey, green, yellow, red and black; marble of Wirtemberg.

2. Into marble of two colours, viz. white and grey; marble of Carara.

3. Into marble of three colours, viz. grey, yellow, and black; lumachelle.

4. Into marble of four colours, viz. white, grey, yellow, red; brocatelle of Spain.

5. Into marble of five colours, viz. white, grey, yellow, black, red; breche of Old Castile.

4. *Figured marble*. It represents ruins like the marble of Florence, or herbs like that of Hesse.

#### GENUS IV. *Concretions*.

THE concretions are formed irregularly by a quicker or slower deposition of the calcareous matter, conveyed by the waters upon the surface of any body. They are



not disposed in great beds, but by fragments in heaps, at first detached, which gradually approach each other, and are united by the increase of their size.

Species.

1. *Incrustations*. The waters containing much chalk deposite it upon the surface of all the bodies over which they flow: the incrustations then may be in all possible forms, according to the substances which have served for their formation. Such are those of the waters of Arcueil, and such is the Osteocolle, &c.

2. *Stalactites*. They are slowly formed, and deposited by the waters in concentric beds on the arches of caverns. They differ in their size, transparency, or opacity, grain, colour, form. In general, they are pyramidal and hollow. The flos ferri is the purest of all. When they are pasted along the walls of subterranean cavities, they are called *congelations*; when deposited upon the ground, *stalagmites*.

3. *Alabaster*. The alabaster seems to be formed of the purest stalactites, for a long time buried under ground. It is not so hard as marble; when it is polished, its surface appears greasy and oily; it is manifestly composed of beds, which take different directions. It has always a greater or less transparence, which distinguishes it from the marbles; but it never equals that of some spars. Alabaster, besides, has all the properties of calcareous stones. It is used for making vases and statues. It may be distinguished into many varieties.

1. Oriental alabaster. This is the most transparent and hardest.
2. Occidental alabaster. It is less beautiful, and not so pure as the former.
3. Alabaster, spotted with different colours.
4. Waved alabaster. It is also called *agate-like alabaster*.
5. Flowered alabaster. It presents species of herborisations.

GENUS



GENUS V. *Calcareous Spar.*

CALCAREOUS spar differs from the four preceding genera in its form, which is most commonly regular and particularly in its fracture. It is formed of laminæ laid one upon another, and very apparent on breaking it. It is scratched by steel.

Species.

1. Opaque calcareous spar. It is white or coloured in different ways; generally formed of rhomboidal laminæ.

2. Transparent rhomboidal calcareous spar; Iceland crystal. It doubles objects.

3. Prismatic calcareous spar without pyramids. These are hexaëdral truncated prisms, whose surfaces are equal or unequal, and whose angles are sometimes cut off, so as to form prisms with twelve surfaces. This gives three varieties.

4. Calcareous spar in prisms, terminated by two pyramids. There is a great number of varieties in this spar: Some are hexaëdral prisms, terminated by pyramids also hexaëdral, either entire or truncated. Others present, at the extremity of the same hexaëdral prisms, three-sided pyramids, entire or truncated, or two-sided tops. Lastly, there are some with quadrangular prisms, terminated by two-sided tops. All these varieties may present one or two pyramids, according to their position.

5. Pyramidal calcareous spar. This is formed of one or two pyramids, united into an intermediate prism. The hexaëdral, or triangular form of these pyramids, the inequality of their surfaces, their angles often truncated, establish a great number of varieties (c).

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(c) If we wish to have an idea of the varieties of form distinguishable in the spars, and of the great number of species which might be made of them; and if we have regard to these varieties of form, we may consult the English work of Mr Hill, intitled, *The History of Fossils, containing the history of Metals and Gems, &c.* London

1748,



6. Twelve-sided calcareous spar. This spar, which resembles a kind of garnate or marcasite, appears to be formed of two pyramidal pentagons, truncated and united at their base.

7. Calcareous spar in striae. This is a collection of long prisms into bundles, presenting no regular form capable of being determined. The lapis suillus of the Swedes belongs to this species.

8. Lenticular calcareous spar. These are flat crystals, obliquely disposed at the side of one another.—M. Romé de Lisle supposes it a variety of the hexaëdral prismatic spar, terminated by two triangular pyramids, obtuse, and placed in opposite sides; *Cryсталlography*, p. 123.

§ 2. *Chemical properties of Spar, and of Calcareous Matters in general.*

As the spar, which we have just now described, is the most pure calcareous substance, it shall serve for the consideration of the chemical properties; understanding, however, that all those calcareous matters described in the five preceding genera, exhibit exactly the same phenomena.

In the analysis of calcareous spar, its aggregation must be destroyed by reduction into powder. In this form it is white and opaque; it has no remarkable taste; however, it contracts a little the fibres of the palate and tongue.

This salt, when exposed to the action of the fire, loses its acid and the water of its crystals. If we heat it briskly, it decrepitates, and loses its transparency: By distilling it, we extract some water and much aerial acid; but it requires a considerable heat to disengage this

1748, in fol. cum tab. æneis. M. Romé de Lisle has given an extract of it in his *Cryсталlography*, p. 131. and the next, p. 191. and the next, relating to the Calcareous Spar and Rock-crystal. He demonstrates, that Mr Hill's method is defective and embarrassing.



this last. After this operation, the calcareous spar is reduced to the state of quicklime; but we can restore its form, by combining the lime with the acid obtained in its decomposition. The distillation of chalk, which differs from calcareous spar in its small degree of coherence and opacity only, has been performed by M. Jacquin. M. le Duc de Rouchefoucauld, who has very carefully repeated it, observed that the stone-retorts allow a part of the aërial acid to escape. We may use an iron-retort, or a gun-barrel; but we always obtain a little inflammable gas, owing to the reciprocal action of the aërial acid and metal.

Calcareous spar, exposed to a great fire, is capable of being fused into glass. M. d'Arcet has fused several sorts of it into a transparent glass, marked with some stains. According to M. Macquer, it was not fused by the focus of M. de Trudaine's lens; undoubtedly because it reflected the luminous rays by means of its whiteness.

Calcareous spar is unchangeable by pure air; but the contact of the humid atmosphere, joined to the rays of the sun, makes it lose its transparency and the cohesion of its laminæ: its surface assumes the colours of the rainbow; it darkens, and gradually becomes obscure.

It does not appear to be soluble in water: Chalk, which art cannot effect to dissolve in this fluid when pure more than calcareous spar, is, however, held in solution by the waters which flow over these substances. Some even contain a considerable quantity of it. Such are the waters of Arcueil in the environs of Paris: they hold in solution enough of calcareous earth to incrust, in some months, bodies put into the channels through which they run. The waters of St Philip's baths in Italy, contain so much of this substance, as to deposit it in beds more than half an inch thick in the space of some days. They take advantage of this property to form pictures and figures in hollow moulds, which are plunged



plunged into them, and on the inner surface of which the waters deposite the chalk that they contain.

Calcareous earth assists the vitrification of some earthy and stony substances. Chalk, mixed by nature with an argillaceous earth, forms an earthy mixture, which the naturalists and farmers call *marle*. This substance presents a great number of varieties, which differ in colour, tenacity, &c. It is very successfully employed to fertilize the fields.

Terra ponderosa, magnesia, and lime, have no action on calcareous spar. The fixed alkalis and the volatile alkali do not alter it, because the aërial acid has more affinity with lime than with these substances.

The vitriolic, nitrous, marine, and sparry acids, decompose it, by seizing on its base, and dissipating the aërial acid. If we put spirit of vitriol upon calcareous spar, an ebullition is excited, owing to the aërial acid being disengaged in form of gas. The naturalists make use of this chemical character to distinguish all the calcareous substances. By means of the acids, calcareous spar may be completely analyzed. For this purpose we pour some spirit of vitriol upon the calcareous matter reduced into powder. The violent effervescence produced in the instant of mixture, indicates the separation of the aërial acid, which may be collected and measured, by receiving it by means of a siphon into vessels full of water. The effervescence is accompanied with a cold, on account of the volatilization of the aërial acid. When it is over, if we examine the new combination, we find it to be selenite, formed by the vitriolic acid united with the lime, which constituted the base of the spar. Some new experiments have shown, that some of these spars contain a little magnesia, and afford Epsom salt when dissolved by the vitriolic acid. The aërial acid has the property of giving solubility to the spar and other calcareous matters. We have already seen, in the article on this acid, that it forms chalk from lime-water, and redissolves it, if more  
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is added than is necessary for its precipitation. The chalky acid spirit, when allowed to remain on calcareous spar in powder, takes up by little and little a certain quantity of this neutral salt. Several waters also contain chalk by means of the ærial acid: but all these solutions are of short duration. When we expose them to the air, they gradually turn turbid, and precipitate the chalk in proportion to the dissipation of the ærial acid. The same effect is much more rapidly produced by means of heat; and this method is successfully employed for correcting the waters abounding in chalk, which always are hard and raw.

Calcareous spar has no action upon the neutral salts with base of fixed alkali. Like chalk, it decomposes the ammoniacal salts. On one part we obtain a calcareous salt, formed by the acid of the ammoniacal salts and the lime of the spar; and on the other part, some ærial sal ammoniac, resulting from the combination of the acid of the spar with the volatile alkali of the decomposed sal ammoniac. We perform this operation by distilling in a stone-retort a mixture of one pound of sal ammoniac and two pounds of chalk, or rather of calcareous spar, in powder. Care is taken to have these substances in a very dry state. We adapt to the retort a balloon, with the addition of a long tube, or, what is still better, a cucurbit of glass or stone. We gradually apply fire until the bottom of the retort be reddened: white vapours pass over, which condense in very white and pure crystals upon the sides of the receiver. This is ærial sal ammoniac. The residuum is calcareous marine salt, which is generally fused, if we raise a violent fire about the end of the operation.

The uses of the spar and of calcareous matters in general are very extensive, as we have already observed in treating of their natural history; but one of the most important is the preparation of lime from them. The art of lime-making consists in decomposing the calcareous matter by the action of the fire, and dissipating its acid.

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Of these substances, the stones charged with shells, and the greatest part of calcareous spar, produce the best lime. However, we most commonly use a kind of hard calcareous stone called *limestone*. These stones are arranged in a kind of oven or tower, so as that they form an arch: under this arch we kindle a fire of faggots, which is continued till a vivid flame be raised without smoke about ten feet above the oven, and until the stones become very white. To render the lime good, it ought to be hard, sonorous, to produce a brisk and strong heat with water, and to give a thick smoke in its extinction. If it has not been sufficiently calcined, it is not sonorous, and raises but a small and slow heat with water: If it has been too much, it is semivitrified, and has no more tendency to unite with this fluid. The lime-makers then call it *burnt lime*. We will not say any thing of the uses of lime, because we have treated of them in the history of this substance in its pure state.

## LECTURE XXII.

GENUS IV. *Neutral Salts with base of Magnesia.*

Species 1. *Vitriol of Magnesia, Epsom Salt.*

THE neutral salt, formed by the union of the vitriolic acid with magnesia, has been called *Epsom salt*, from the place where it is procured in greatest quantity. That place is a fountain in England. It is also found in the waters of Egra, Sedlitz, and Seydschutz.

This salt has a very bitter taste: for that reason it has been called *sal catharticus amarus*. It is in the form of very small prisms with four sides, terminated by pyramids likewise with four sides. These crystals differ from those of Glauber's salt only in being of much smaller size, and in not having their surfaces ridged with channels running along, as is observed in this last salt. Epsom salt retains enough of water of crystallization, to undergo, like Glauber's salt and borax, the aqueous liquefaction. It fuses with a less heat, and assumes



assumes the form of a shapeless mass by cooling. If, when it is fused, we continue the heat, it dries into a white friable mass, which is only the salt deprived of its water of crystallization, without any change of its nature. It requires an extreme heat to bring the Epsom salt, dried, into an ignited fusion. This salt contains more than the half of its weight of water of crystallization.

M. Macquer and several chemists have said that it receives a slight humidity from the air; a property that may serve to distinguish it from Glauber's salt, which effloresces. M. Bergman declares, on the contrary, that the Epsom salt, exposed to a dry air, soon loses its transparency, and is at last reduced to a white powder: and he asserts, that that which is sold in small needles, is deliquescent, on account of the marine magnesia which it contains. M. Buchni, a citizen of Geneva, says, that he has found some Glauber's salt in it.

Epsom salt is so soluble in water, that it does not require  $1\frac{1}{2}$  parts of this fluid, when cold, to hold it dissolved, and warm water can dissolve two parts. It crystallizes by cooling; but to have it very regular, we must allow a solution of it, made in the cold, to evaporate spontaneously.

This salt is not altered by the earths. Lime decomposes it; because lime has more affinity with the vitriolic acid than magnesia has. If we put a little Epsom salt into lime-water, or pour this last into a solution of the salt, a precipitate of magnesia and selenite falls down. This is, as was seen, a sure character to distinguish it from Glauber's salt.

The pure fixed alkalis likewise decompose Epsom salt. The caustic volatile alkali has the same property, whilst it does not decompose selenite; which demonstrates, that this salt has more affinity with the vitriolic acid than magnesia has, but less than lime. It may therefore serve to discover the presence of Epsom salt in waters. In this way, also, we obtain the pure magnesia



nesia by means of the caustic volatile alkali; the history of which we have given at the beginning of the saline matters.

As yet we do not well know the action of Epsom salt upon the neutral salts with base of fixed and volatile alkali. It is probable that the nitrous and marine salts would be decomposed by a double affinity: although M. Quatremere Dijonval, in his letter to M. de Morveau, *Journal de Physic*, May 1780, vol. 17. page 391. certifies, that when we unite a solution of Epsom salt with a solution of vitriolic ammoniac, a total precipitation of the Epsom salt without decomposition takes place. It falls to the bottom in the form of very thick crystals, which we may be certain of by their taste. He ascribes the effect to this, that the vitriolic ammoniac is capable of seizing the water of the Epsom salt, which he reckons to be very crystallizable. We shall recur to the explanation of this fact in the history of Nitrous Magnesia.

With respect to the aërial salts, it is certain that Epsom salt decomposes them, and is itself decomposed. When we pour a solution of aërial tartar or aërial soda into one of Epsom salt, there is a double decomposition and double combination. The vitriolic acid of the Epsom salt unites with the fixed alkalis; the aërial acid joins with the magnesia, and forms a neutral salt, called *mild* or *effervescent magnesia*. By this process we prepare the mild magnesia, made use of in medicine as a very good purgative.

According to M. Dijonval, a solution of selenite mixed with a solution of Epsom salt occasions a precipitation of the latter; although this phenomenon be very imperceptible, on account of the small quantity of selenite dissolved. Calcareous nitre and calcareous marine salt likewise decompose Epsom salt, and are at the same time decomposed; but we cannot conclude from this, along with M. Dijonval, that the nitrous and marine acids have more affinity with magnesia than the



vitriolic acid has; since, in these experiments, we must take into account the double affinities.

M. Bergman says, that 100 parts of crystallized Epsom salt contain 19 of pure magnesia, 33 of vitriolic acid, and 48 of water.

Epsom salt is employed in medicine with great success; it is a powerful mild purgative, having also the property of being deobstruent. It is even preferred to other salts for its great solubility. It is given either alone, from one to two ounces dissolved in water; or as an assistant, in the dose of one or two gros. It mineralizes the most part of the natural purgative waters.

Species 2. *Nitrous Magnesia.*

THE combination of the nitrous acid with magnesia has been examined by M. Bergman. This celebrated chemist says, that the solution of this salt made by art, after a proper evaporation, gives prismatic crystals, quadrangular, sparry, and without pyramids.

This salt has an acrid and very bitter taste: it is decomposed by heat, and attracts humidity from the air. It is very soluble in water. Its crystals are obtained by slow evaporation only. Terra ponderosa, lime, and the alkalis, decompose it. As this salt is found dissolved in the mother-waters of nitre, M. de Morveau proposed extracting the magnesia in great from it, by precipitating them by lime-water. This process would be very advantageous, by the facility of its execution, and the little expence it requires. The vitriolic and sparry acids disengage the acid of nitrous magnesia; and sedative salt also disengages it by means of heat, and on account of its fixity. These are the properties of this salt mentioned by M. Bergman.

M. Quatremere Dijonval, who has made inquiries concerning several combinations of magnesia, has found in nitrous magnesia some very different properties from those announced by the Upsal chemist. We are not as yet acquainted with his work communicated to the academy;



academy; only with what he says of it in his letter to M. de Morveau, cited in the article of Epsom salt. He says he obtained crystals of nitrous magnesia not deliquescent; and he adds, that the salts with base of magnesia are as crystallizable and disposed to effloresce, as the calcareous salts are deliquescent.

Nitrous magnesia appears to be capable of decomposing, by means of the double affinities, the vitriolic salts; such as vitriolated tartar, Glauber's salt, and vitriolic ammoniac. M. Dijonval, who has mixed the solutions of these different salts with solutions of nitrous magnesia, says, that he perceived no sign of decomposition, nor any kind of precipitation. On this head, it is necessary to observe, that as the salts formed by these double decompositions are all equally soluble, these operations are not sensible to the eye; and in order to perceive them, it is necessary to evaporate the mixture, or add spirit of wine to it, which attracts the water and precipitates the salt.

The same observer has announced a fact worthy of all the attention of the chemists; it is the precipitation of nitrous magnesia occasioned by calcareous nitre. When we mix transparent and very pure solutions of these two salts, the nitrous magnesia instantly falls in a crystalline form, and without being decomposed in any manner, and the liquor retains the dissolved calcareous nitre. It is indeed very singular, that two salts, when separated, should have enough of water to keep them in perfect solution, and that the mixing of them should occasion the sudden precipitation and crystallization of the one of them. M. Quatremere thinks, as we have observed more fully above, that this phenomenon depends on the great tendency of the calcareous nitre to unite with water. According to him, this salt being able to absorb a greater quantity of water than is necessary to hold it in solution, when we mix with it a solution of nitrous magnesia, which has a strong tendency to crystallize, it immediately seizes on the water of crystal-



crystallization of the other; and then the nitrous magnesia, being more weighty than the quantity of water which supported it, precipitates in a crystalline form. This theory, however, does not seem to explain several difficulties which it is possible to raise against it. How, in reality, can a salt, however soluble it may be, and whatever tendency it may have to combine with water, seize on the water of crystallization of another salt, when it is itself united with as much water as holds it dissolved? If we answer that it is not saturated with water, there is then a point of saturation at which the calcareous nitre would cease thus to precipitate the nitrous magnesia; and this should have been demonstrated. This supposition even admitted, how should the calcareous nitre seize on the water of crystallization of the nitrous magnesia, whilst it can absorb the water, which holds this same salt in solution, previous to its depriving it of the portion of this fluid, which makes a constituent part of its crystals? Lastly, how can we conceive, in this explanation, that nitrous magnesia deprived of the water of crystallization by calcareous nitre, would be capable of being instantly precipitated in a crystalline form, whilst it has lost one of the elements of its crystals? If I may be allowed these reflections on the explanation of M. Quatremere; whose abilities otherwise I know, it is only to engage him to persevere in so interesting a pursuit, and to seek out the cause of a phenomenon, that is owing perhaps to some circumstance, which as yet he has not been able to discover.

### SPECIES III. *Marine Magnesia.*

THIS salt is the saturated combination of the marine acid with magnesia. M. Bergman says that it has a very bitter taste: according to him, we cannot obtain it in crystals, but by suddenly exposing its solution to a great cold, strongly concentrated by evaporation. It is then in the form of small needles, very deliquescent. For the most part, this solution presents a transparent gelly. M.



Quatremere obtained this salt in a regular and permanent form. He even seems to announce, that it is efflorescent rather than deliquescent. Marine magnesia is decomposed and loses its acid by the action of the fire. It is very soluble in water. To get it well crystallized, we must allow its solution to evaporate by means of the open air into a great mass. It is decomposed by lime and the three pure alkalis. For this reason, the mother water of saline salt, contained in saline fountains, which are impregnated with a certain quantity of it, mixed with some calcareous marine salt, is precipitated by the caustic volatile alkali and by lime-water. The vitriolic and nitrous acids separate the marine acid from it, and the sedative salt does the same. To perform this last decomposition, we must distil in a glass retort a mixture of one part of sedative salt and two parts of marine magnesia. The acid of this last is volatilized, and the fixity of the sedative salt favours its combination with magnesia.

Marine magnesia decomposes the vitriolic and nitrous salts with base of fixed and volatile alkali, in consequence of double affinity; but to be certain of these decompositions, we must have recourse to evaporation, or mixing their solutions with spirit of wine, and pouring them into one of marine magnesia, because the new saline combinations remain dissolved in the liquor.

M. Quatremere has discovered, that marine magnesia in solution, put into a solution of sal febrifugus, is precipitated in crystals, owing to its great disposition to crystallize, as he allows, comparatively to the sal febrifugus, which retains the water that dissolved it. In the opinion of this chemist, it is still very difficult to conceive how a salt, so little soluble and deliquescent as the sal febrifugus, in comparison of the marine magnesia, can seize on the water which dissolved this last. One would be more inclined to think, that, on the contrary, it is the febrifugal salt which is precipitated, if we could not trust the accuracy of M. Quatremere's experiment. If we mix a solution of magnesia with one  
of



of calcareous marine salt, the first salt is precipitated in crystals, as the same chemist asserts.

SPECIES IV. *Borax with Base of Magnesia.*

WE may give this name to the combination of sedative salt with magnesia. This salt is almost unknown. M. Bergman has observed, that when we put some magnesia into a solution of sedative salt, it is dissolved in it but slowly. The evaporated liquor gives crystals in grains, without a regular form. This salt fuses by fire without decomposition. The acids decompose it, by seizing on the magnesia and separating the sedative salt. Spirit of wine also attracts its acid, and leaves the magnesia alone. We are unacquainted, as has been seen, with almost all the properties of this salt, upon which the chemists as yet have made no experiments.

SPECIES V. *Sparry Magnesia.*

IT is the same case with regard to the combination of magnesia with the sparry acid. It is not at all known. M. Bergman is the only chemist who has said any thing about it. According to him, the sparry acid rapidly dissolves magnesia. A great part of this salt is deposited on account of the approaching saturation. The solution, by spontaneous evaporation, furnishes a kind of moss, which creeps along the sides of the vessel, and presents some long and very fine filaments. We also get at the bottom of the vessel sparry crystals in hexagonal prisms, terminated by a pyramid, somewhat elevated, composed of three rhomboids. This salt, which M. Bergman calls *Fluor of Magnesia*, suffers no alteration from the most violent fire. No acid can decompose it in the humid way.

SPECIES VI. *Aërial Magnesia.*

THIS salt, named *mild* or *effervescent magnesia* by Dr Black, who first made it known, is formed by the intimate union of the aërial acid with magnesia. It is generally prepared by precipitating a solution of Epsom salt,



by means of the salts, united with the chalky acid as we will mention at the end of this article. For the most part, it has an earthy appearance; it is in a very white powder; however, M. Bergman and M. Butini have obtained it crystallized, in the manner to be afterwards more fully described. Like the chalky acid salts in general, it is capable of containing a greater or less quantity of acid, and its properties vary according to the quantity it contains. It has a crude taste, somewhat earthy. It has a more remarkable action on the intestines being purgative.

When it is exposed to the fire in a crucible, it loses its water and acid. M. Tingry, apothecary of Geneva, has observed, that when we calcine it in great, it bubbles and seems to betray a motion of fluidity. This phenomenon depends on the disengagement of its acid and gas. A lightish fog is raised from the crucible, which deposits upon the surrounding bodies a white powder that is nothing but magnesia which has been carried off by the current of the chalky acid. According to the same observer, if we immerse a hot body into it, it adheres to it; a cold body carries off still more of it. About the end of the operation, it glitters with a bluish and very sensible phosphoric light.

If we calcine in close vessels mild magnesia, by a pneumato-chemical apparatus, we obtain the water and acid which it contains. M. Butini, who has performed this operation with great accuracy, asserts, according to the calculations from the products which he obtained, that 32 grains of common magnesia, viz. that prepared for the uses of pharmacy, and which is not saturated with acid, contain about 13 of pure earth, 12 of acid, and 7 of water. M. Bergman estimates, that mild magnesia contains in 100 parts, 25 or 30 parts of acid, according to its condition, 30 of water, and 45 of pure magnesia. If we heat it very strongly, after it has lost its acid, it agglutinates and assumes a hardness like pure or caustic magnesia.

This salt is not changed by the air. Water dissolves  
but



but an infinitely small quantity of it; and the solution varies, according as it contains more or less chalky acid. If we mix it with a little water it forms a kind of paste, which has but a small adhesion, and which dries, without either acquiring consistence or suffering a contraction. Common magnesia, mixed with a considerable quantity of water, dissolves in the proportion of about a grain or a grain and a half to the ounce of this fluid; of which we may assure ourselves by evaporation. But there are ways of dissolving magnesia in much greater quantity, as we shall mention immediately.

Mild magnesia is not decomposed by the pure earths; lime attracts from it its acid, with which it has more affinity. Lime-water, poured into a solution of mild magnesia, occasions an evident enough precipitation, however small be the quantity of this neutral salt dissolved in the water. The precipitate is a little chalk and caustic magnesia; which we know is almost insoluble. The fixed and volatile caustic alkalis likewise decompose it; because like the lime they have more affinity with the chalky acid than magnesia has. Some tartar, soda, or volatile alkali, united the acid of chalk, results from these mixtures; the magnesia falls in a pure and caustic state.

The vitriolic, nitrous, and marine acids, decompose it in an inverse manner, and make the analysis of this salt complete. They unite to the magnesia, with which they have more affinity than the aerial acid has, and disengage it in the form of gas, which is the cause of the effervescence. We may be sure that it is the chalky acid by its characters. M. Butini, in his inquiries, has taken notice that the acids disengage less fixed air than fire does, and that every one of these salts separate different quantities of chalky gas. Thus, for example, the marine separates more than the nitrous, and this more than the vitriolic. Hence he concludes, that the neutral salts formed by magnesia, united with the acids, retain a portion of fixed air.

The chalky acid has the property of rendering the ef-



ferveſcing magnesia of Dr Black much more ſoluble than it is naturally. Upon the phenomena of this ſolution, the experiments of M. Butini are chiefly founded.

He has diſcovered, that when we put ſome ordinary magnesia, not ſaturated with aërial acid, into water impregnated with it, the magnesia is ſoon ſaturated with this acid, by depriving the water of it, and only diſſolves when it is in great abundance. Water impregnated with this gas may diſſolve even 30 grains of aërial magnesia in the pint. That ſolution turns the ſyrup of violets green. Exposed to the cold, it loſes its ſuperabundant air, but without having the magnesia ſeparated from it; which remains in the water, even when frozen, in perfect combination. If we heat a ſolution of magnesia with a ſuperabundance of acid, it turns turbid; and when left to cool again, becomes ſomewhat transparent. This ſingular phenomenon preſents to us, as M. Butini has very well ſaid, a new genus in the ſalts, whoſe character is to diſſolve in greater quantity in cold than in boiling water.

The more magnesia that is contained in water impregnated with aërial acid, the more quickly it turns turbid by heat. In order to obſerve well the paſſage of this ſolution from opacity to transparency by means of cooling, according to the above-mentioned chemiſt, we muſt take a ſolution which contains two grains to the ounce, and heat it to 60 degrees of Reaumur's thermometer. It becomes milky; and all the magnesia which is precipitated by means of the heat is rediſſolved by means of cold.

M. Bergman has announced, that the ſolution of magnesia charged with aërial acid, when evaporated ſlowly, gave cryſtals; ſome in transparent grains, and others reſembling two bundles of rays, which diverge from the ſame point. M. Butini, with the greateſt attention, has obſerved all the phenomena of this cryſtallization. By the very gentle heat of a lamp, he evaporated a ſolution charged with 9 grains of this ſalt in the



the ounce of water. It soon formed a pellicle at its surface; the under part of which, and likewise the sides of the vessel, were incrustated with several tufts of crystals. The residuum offered brilliant needles, conjoined at their bases, and composed of small hemispherical masses with diverging filaments. Those needles, which had no line, presented, by means of the microscope, long prisms with six faces, cut off by a hexagon, and resembling those of certain spars.

M. Butini has also discovered another manner of crystallizing aerial magnesia. It consists in exposing to the air an acid solution of this salt precipitated by heat. In a few days crystals are formed, similar to those obtained by evaporation. Magnesia precipitated from Epsom salt by aerial tartar, and dried, forms no crystals; when it is mixed in water, we always obtain it in the form of irregular masses in bundles. But a solution of Epsom salt, newly precipitated by the fixed alkali, in the space of a few days gives needles like crystals. The same solution, separated from its precipitate by filtration, also affords needles of magnesia.

The perfect neutral salts suffer no alteration from magnesia, and they have no effect upon it. According to M. Butini, they only increase its solubility in water. However, we must except mild tartar, which takes this property from it.

The calcareous neutral salts are decomposed by effervescing magnesia. It is by means of the double affinities that this decomposition is effected. We have observed that lime has more affinity with the acids than magnesia has; and that it decomposes the neutral salts which have this substance for their base. It is by means of the aerial acid only that these decompositions take place; and the great affinity which subsists between lime and this acid, is the cause of its leaving the other substances to unite with it, provided they find a substance with which they may combine.

When, therefore, we pour a solution of aerial magnesia into a solution of selenite, of nitre, or marine salt,



with bases of calcareous earth, the vitriolic, nitrous, or marine acids leave the lime to join the magnesia: they unite with it, and form Epsom salt, nitrous or marine magnesia; whilst the lime combines with the chalky acid separated from the magnesia, and precipitates in the state of chalk (a).

Mild magnesia is used in medicine. It was formerly made with the mother-water of nitre evaporated to dryness or precipitated by the fixed alkali. It has been since known by the name of *white powder of the count of Palma*, and *powder of Sentinelle*; it has been also called *Polychrest laxative powder* by Valentini, *white magnesia of nitre*, and *magnesia of common salt*, because it was also extracted from the mother-water of these salts. But this medicine, prepared in this manner, always contains some calcareous earth and several other foreign substances. That which we use at present is generally precipitated from Epsom salt by the fixed alkali. M. Butini has given a very good process to obtain it very fine, and in the greatest possible quantity. We mix any quantity of potash in double its weight of cold water; we leave this mixture exposed to the air for some months, if the time will permit, in order to absorb the ærial acid of the atmosphere; we filtrate it; we dissolve a quantity of Epsom salt equal to that of the potash, in four or five times its weight of water; we filtre the solution, and add to it some new water, a little more than five times its weight; we heat this liquor, and when it is boiling we add the alkali to it. The precipitate of magnesia is formed; the mixture is shaken well, and filtrated through paper; we wash the precipitate remaining

(a) It is then the same with magnesia as with the volatile alkali. When both the two are pure and caustic, they do not decompose the calcareous salts, because they have less affinity with the acids than lime has; but when they are united to fixed air or ærial acid, and in the state of ærial neutral salts, they then become capable of decomposing the calcareous neutral salts by means of the double affinities, as we have already explained in the article upon Selenite, Calcareous Nitre, &c.



maining on the filter with boiling water, in order to wash away all the vitriolated tartar which may be mixed with it. When the magnesia is well drained, we raise it from the filter, and extend it in thin layers on pieces of paper, which we carry to a water-bath. When it is dried, it presents white pieces, which fall under the finger into an extremely fine powder, that adheres to the skin. It ought to be preferred as a purgative to that which is caustic, because it is much more soluble. We give it in the dose of one or two ounces according to the case. The caustic magnesia, on the contrary, is preferable to it as an absorbent; and both kinds ought to be prepared in laboratories.

M. Butini proposes an artificial mineral water, made with mephitic water mixed with magnesia. He observes, that this fluid may contain in the pound more than three gros of magnesia; and that, besides, it is not more difficult to be prepared than the martial waters, which are acidulated or mixed with aërial acid. Lastly, the making is the same in both. Physicians may employ it in several cases with success.

### L E C T U R E XXIII.

#### GENUS V. *Neutral Salts with Base of Clay.*

##### Species 1. *Vitriol of Clay. Alum.*

**A**LUM is a neutral salt formed by the combination of the vitriolic acid with pure clay (*b*). Its taste is somewhat mild and astringent. It turns blue paper red. It is capable of taking a very regular form

Alum almost never exists in nature uncombined. Sometimes it is found in the neighbourhood of volcanoes. It is always mixed with the argillaceous earth. The mineralogists, and particularly Wallerius, have distinguished several sorts of native alum; such as solid alum,

(*b*) All the chemists are not agreed about the base of alum; some distinguish it from clay, and design it by the particular name of *Earth*.



alum, crystallized alum, alum in efflorescence, the white aluminous earths, the grey, the brown, and the black, the aluminous schisti.

We are acquainted with four sorts of alum in commerce.

1. Icy or alum of Rocca, which is in considerable transparent masses. It gets its name from the city of Roche in Syria, where the most ancient manufacture of this salt was established, and not from its form resembling that of a rock, as several authors have said. It is very impure.

2. Alum of Rome, which is prepared in the territory of Civita Vecchia, and extracted from a place called in the Italian language, *Aluminiere della Tolfa*. This alum is in thick pieces like eggs; it is covered with a reddish efflorescence, and is very pure.

3. Alum of Naples, which is extracted from a particular earth at Solfatara: It is in thicker masses than that of Rome, having one of its surfaces thickly set with pyramidal crystals.

4. Alum of Smyrna. It appears that in the environs of this city and of Constantinople, the most ancient manufactures of alum have been erected.

The preparation of alum varies very much, according to the country and the substances from which it is extracted. M. Bergman, who has given a very good dissertation on this subject, divides the substances which are employed for the preparation of it, and which are commonly called *minerals of alum*, into two kinds; those which contain it already formed, and those which contain the principles of it only. The first need only to be washed to furnish their alum. Of this kind is the earth found at Solfatara. It is put together with some water into leaden vessels fixed in the earth. The natural heat of the soil promotes the solution and crystallization of the alum. It is purified by a second crystallization. With regard to the substances which contain the principles of alum only, and which are much more common than the first,



first, they require a preliminary preparation before they furnish the alum. It is necessary to calcine them, or expose them to the air, according to their nature. The aluminous schisti require to be calcined in order to consume the bitumen with which they are coloured, and to decompose the pyrites which ought to furnish the alum. M. Bergman asserts, that before calcination of the schisti, not an atom of alum is produced by washing with water. Exposure to the air has the same effect upon the pure pyrites as the sprinkling with water. The spontaneous decomposition of these substances produces the vitriolic acid, which unites with the clay and forms alum. These efflorescing pyrites are washed: They are left at several times to deposit the iron which the ley contains. It is evaporated and set to crystallize in the vessels. The salt is deposited in big crystals. A strong ley of the soap-boilers is generally employed to facilitate the crystallization of the alum. This is the process followed in several manufactures: but the alum extracted from pyrites always contains more or less iron; that which is extracted from the stones that naturally contain it, is always purer than the alum of Rome. For some time an alum has been made at Javelle, which in no respect yields in goodness to this last, and which might be employed in dyeing with great success.

Alum in its natural form is perfectly octaëdral, formed of two tetraëdral pyramids joined by their bases. When exposed to the fire, it liquefies; with a gentle heat, it emits a great quantity of aqueous vapours, bubbles up much, and forms a very voluminous lightness of a white polish, and filled with many cavities. This phenomenon is owing, as it is in borax, to the disengagement of the water, whose bubbles gradually raise and extend the saline molecules. Alum in this state gets the name of *calcined alum*: it has lost a little more than the half of its weight; it is a little altered; it reddens the syrup of violets; its taste is much more considerable; and it seems that its acid is uncovered.

If



If we dissolve it in water, a little earth is precipitated; it may be crystallized; but, as M. Beaumé has observed, it scarcely bubbles up when calcined anew. If we calcine alum in a distilling apparatus, we obtain some phlegm, which at last turns acid; but it cannot be decomposed entirely, since M. Geoffroy kept it in a retort, with an extreme fire, during three days and three nights, without its suffering any alteration.

Alum effloresces slightly in the air, and loses the water of its crystals. In cold water this salt is soluble in a small degree only; since, according to M. Beaumé, two pounds of that fluid can dissolve no more than four gros of alum; but boiling water dissolves more than half its weight of it. Eight ounces of water in this state may hold dissolved five ounces of the salt. It crystallizes very well by cooling. Its crystals are a kind of triangular pyramids whose angles are truncated. When they are deposited upon threads in the middle of a solution, their form is octaëdral, very regular, whose preceding pyramids are only a half, cut off obliquely. Alum can unite with a greater quantity of pure (c) clay than it contains in its ordinary state. In that union it acquires, as M. Beaumé has found, the character of this earth.

Alum may be decomposed by magnesia and lime, which have a greater affinity with the vitriolic acid than clay has. Lime-water poured into a solution of this neutral salt, precipitates its base. The fixed alkalis also, as well as the volatile, have the property of decomposing alum. Mild tartar, soda, and volatile alkali, chalk, and effervescing magnesia, likewise separate its base.

The earth of alum, precipitated by these different substances, is flocculent; it is deposited gradually; it dries slowly; it is very white, and decrepitates with the fire like the clays. A strong heat gives it a considerable

(c) The clay is here supposed to be very pure, and separated by washing from the siliceous earth, which is often blended with it in so great quantity as to constitute more than half its weight.



table hardness : its volume also is greatly diminished, and it has contracted : it is not fusible even with the strongest fire, as that of the lens of the Infanta's garden. It retains the last portions of water with so great a force, that it requires the most extreme violence of fire to deprive it of them. Mixed with water, it forms a paste which has some union, and bakes by means of fire into a true porcelain.

The aluminous earth then has all the characters of argillaceous earth, as M. Macquer announces, and it is the most pure clay which can be procured.

We do not well know the action of the terra ponderosa, magnesia, lime, and the pure alkalis, upon the earth of alum. It is probable that these substances, in particular the latter, would convert it by the aid of fire into the state of a vitreous frit.

The vitriolic acid easily dissolves the earth of alum when it is cold and moist ; when dry, it dissolves with difficulty. This solution, made in the quantity of several ounces, gives crystals of alum mixed with some spangles or scales resembling those of mica. M. Beaumé also adds, that if we make this experiment in small, we obtain these last and no alum.

The other acids likewise dissolve this earth, and form with it salts little known ; of which we will speak in the following articles.

We do not know what would be the action of the aluminous earth upon the neutral salts ; but the most singular property which it shows, is that of combining to excess with the alum, and of giving it new characters. M. Beaumé, who discovered this, boiled a solution of alum with the earth precipitated from this salt by the fixed alkalis. The liquor dissolved the earth with effervescence. When filtrated, it had no more the taste of alum, but that of a hard water ; it did not redden the tincture of turnsol, but turned the syrup of violets green. By spontaneous evaporation, it furnished some crystals in scales, soft to the touch, resembling mica.

M.



M. Beaumé compares them to selenite. It is not easy to restore the alum by adding vitriolic acid to this salt already saturated with its earth; the mixture then is acid without astringency. However, by a spontaneous evaporation of three months, the solution yielded crystals of alum mixed with some micaceous spangles, similar to those which alum furnishes when saturated with its earth. This is the substance of the researches of M. Macquer and Beaumé about the earth of alum.

Alum, exposed to the fire along with combustible matters, forms a substance which takes fire with the air, called *pyrophorus of Homberg*. This chemist, who made it known *anno* 1711, employed himself in researches about human fæces, with a view to extract a white oil having the property of fixing mercury into fine silver. This work was the origin of several discoveries. A residuum of this matter, distilled with alum, took fire with the air. Homberg repeated this process several times, and always succeeded. *Annis* 1714 and 1715, Lemery the younger published two memoirs; in which he announced, that pyrophorus might be made with a great number of vegetable and animal matters heated with alum; but he did not succeed in forming it with several other vitriolic salts. These two chemists, who regarded alum as a combination of the vitriolic acid with calcareous earth, thought that this last, reduced to the state of lime, attracted the humidity of the air; and, by the heat that was raised in the mixture, set fire to the sulphur which they knew to be formed in it.

Since the time of these two chemists, M. le Jay de Suvigny, doctor of medicine, has given a very good memoir upon pyrophorus, which is inserted among those of the third volume of the *Savans Etrangeres*. There he gives a detail of a great number of experiments, by which he came to make pyrophorus, not only with alum and different combustible matters, as Lemery had done, but even with the most part of the salts containing the vitriolic acid. This physician has  
also



also given a theory on the inflammation of the pyrophorus by the air, which has been adopted by all the chemists down to these latter times. He thinks that the pyrophorus contains the oil of vitriol in a glassy form, which attracts the humidity of the air; and, being strongly heated by it, sets fire to the sulphur, and produces spontaneous inflammation.

Pyrophorus is prepared by burning in an iron laddle three parts of alum with one of sugar, honey, or flour. This mixture is dried until it grows black, and no longer bubbles up; then it is pounded, and put into a matrafs or phial luted with earth: this vessel is placed in a crucible, and surrounded with sand: it is heated until a blue flame issue out of the mouth of the phial; and when it has burnt for some minutes, the crucible is taken from the fire: it is left to cool, and the pyrophorus which it contains is put into a phial which completely excludes the air. If this pyrophorus be exposed to the air, it soon takes fire, in proportion to the greater or less moisture of the atmosphere. Its combustion is promoted by directing a moist vapour, as that of the breath, to its surface. The pyrophorus must not be too long heated; without this precaution, it no longer takes fire by the air. It is gradually loaded with humidity when kept in an untight vessel, and loses its combustibility, which may be restored by a new calcination.

This is all the knowledge we had of pyrophorus before M. Proust, *Journal de Medicine*, July 1778. This chemist having had occasion, in his experiments, to find a great number of residuums of pyrophorus in which he could not suspect the existence of the vitriolic acid, imagined that this acid is not the cause of the spontaneous inflammation of pyrophorus. He proved, by a very simple experiment, that this combustible substance does not in reality contain an atom of it in the pound; since by pouring some water on pyrophorus, no heat is produced. After the enumeration  
of



of the different pyrophori which he obtained, it appears, that all the substances which, after being decomposed, leave a charry residuum divided by an earth or a metallic calx, are susceptible of inflammation by the contact of air. But we cannot agree, that that part of his work which M. Proust made known shows the cause of the inflammation of Homberg's pyrophorus, which according to him differs from those he observed; and indeed his memoir contains nothing concerning the composition of this substance.

Mr Bewly, an English surgeon, in a letter written to Dr Priestley, ascribes the inflammation of pyrophorus to a substance which it contains, capable of attracting the nitrous acid from the atmosphere. The reason of his opinion is, because he discovered that the spirit of nitre instantly inflames a pyrophorus which has not been enough calcined, or which is loaded with humidity. But he has not demonstrated, on the one side, that the nitrous acid is contained in the atmosphere; and, on the other side, M. Proust discovered, that the inflammation of pyrophorus by means of spirit of nitre is owing to the charcoal contained in that substance; for this acid detonates with all the charry matters when very dry and divided, as we will mention more at large in the article on Charcoal. The explanation of Bewly, then, is not more satisfactory than that of the chemists who preceded him.

The only way of discovering the cause of this phenomenon, is to know well the chemical nature of Homberg's pyrophorus; but we have not yet a complete analysis of that substance. It appears that it contains the earth of alum; a very divided charry matter, furnished by the honey, sugar, &c. a little fixed alkali, and some sulphur united in part to the earth of alum and in part to the fixed alkali. By heating some pyrophorus strongly in a pneumato-chemical apparatus, a great quantity of hepatic gas is extracted: when no more can be extracted, it no longer inflames by the air. If we im-



merse some pyrophorus into pure or dephlogisticated air, it burns rapidly with a very brilliant red flame. By washing it with hot water we extract a true liver of sulphur, and there remains on the filtre the charry matter and earth of alum. The pyrophorus is then decomposed. When the pyrophorus has ceased to burn, it has increased in weight in consequence of the pure air which it has absorbed. Its ley then furnishes alum, because the sulphur has formed with the air a vitriolic acid which has united with the earth of alum; but this salt is alum saturated with its earth.

M. Pilastre de Rosier, in the *Physical Journal*, November 1780, has given some observations upon pyrophorus, in which he announces, 1. That this substance owes its combustibility to a certain quantity of phosphorus formed by the acid of the mucous matters: 2. That the distillation of pyrophorus furnishes in the ounce from five to seven grains of phosphorus: 3. That we may instantly make it by triturating in an iron mortar fifty-five grains of flowers of sulphur, thirty-six of charcoal of willows, and three grains of ordinary phosphorus. The details of the analysis made by this chemist do not exactly correspond with the results which he gives, having made no mention of his extracting any phosphorus. As for the rest of this memoir, several interesting facts are there taken notice of, such as would be useful to chemists who would attempt an analysis of pyrophorus.

Alum is of very extensive use. It is used in medicine as an astringent; but its internal administration requires many precautions. It is very often used externally as a styptic remedy and powerful desiccative. It enters into the composition of collyria, gargarisms, plasters, &c. Alum is the most useful saline substance employed in the arts. The candlemakers mix it with the tallow to render it firmer. The printers rub their balls with calcined alum to make them take on the ink. Wood, impregnated with a solution of alum, burns



with difficulty : hence it has been proposed as a means to secure buildings against fire.

The bleachers throw a little alum into their turbid water to make it clear. M. Beaumé supposes that this salt charges itself with a part of the earth suspended in the fluid, and precipitates with it by forming an insoluble compound. Some persons use this means to purify and render clear the water which they want to drink. It is used to prepare leathers, and to impregnate papers and cloths which are to receive colour by the aid of impression. A solution of alum retards the putrefaction of animal substances. It is a very good and very economical way to preserve the natural productions imported from foreign countries. The earth of alum makes the base of the crayons, and gives them consistence. Lastly, it is the soul of dyeing, as M. Macquer expresses it. It increases the brightness and intensity of the colours: it gives solidity to the extracted colouring parts; which, without it, would not be durable, and would be washed out by the water.

Species 2. *Argillaceous Nitre, or Nitrous Alum.*

M. BEAUME says, that the nitrous acid completely dissolves the earth of alum. The solution is limpid, and much more astringent than that of common alum. By spontaneous evaporation, it affords small pyramidal crystals very styptic. The other properties of this salt have not as yet been examined. We know only that it is decomposed by the same substances as common alum. M. Bucquet says, that it is very deliquescent. It has never been found in nature, and is always a production of art.

Species 3. *Argillaceous Marine Salt.*

THE marine acid dissolves the earth of alum better than the nitrous acid does. This solution, when saturated, is gelatinous; it cannot be filtrated except when largely diluted; its taste is saline and styptic; it red-

dens



dens the syrup of violets, and afterwards turns it green. By spontaneous evaporation, it yields very styptic crystals, whose form has not been examined. Lime-water decomposes it. It is deliquescent. It has always been hitherto a production of art. Its other properties are unknown.

Species 4. *Borax with Base of Clay.*

THE combination of sedative salt with earth of alum, which we call *borax with base of clay*, and which we might also design by the name of *aluminous borax*, has not been as yet examined. We know only, that if we pour a solution of borax into one of alum, a light flocculent precipitate is formed. The vitriolic acid leaves the clay to unite with the mineral alkali of the borax. The clay combines with the sedative salt, which is at the same time separated; and this new salt is gradually redissolved. This liquor being afterwards precipitated by the fixed alkali by evaporation, gives a viscous astringent mass, in which Glauber's salt and argillaceous borax is confounded. This kind of borax is decomposed by the same intermedia with alum.

Species 5. *Sparry Clay.*

WE give this name to the sparry acid united to pure clay or to the earth of alum. This neutral salt is not known, and has not been at all examined.

Species 6. *Aërial Clay.*

THE union of the aërial acid with clay has been only suspected. It is certain, however, that this acid combines with aluminous earth; since, according to the remark of M. Bergman, when we precipitate a solution of alum by the aërial alkali, the liquor, filtrated, deposits in a little time a small quantity of earth which was dissolved in it by the aërial acid, and which separates according as this last is dissipated. It was published, that Achard, a celebrated chemist of Berlin, had succeeded in cry-



stallizing the earth of alum by means of water impregnated with aërial acid, which slowly passed over it in a very ingenious apparatus; *Journal de Physique, Janvier 1778*. M. Magellan presented to the academy a very fine and very regular crystal, which had the form and hardness of rock crystal, and which, he says, had been formed by these two substances: but as this experiment, repeated by M. Briffon, Cadet, and Fontanieu, did not succeed, and as M. Achard has since that time published nothing upon the subject, we cannot as yet take any side with regard to this discovery.

GENUS VI. *Neutral Salts with Base of Terra Ponderosa.*

Species 1. *Heavy Spar.*

THE weighty spar, hitherto looked upon as a stone, because it has neither taste nor solubility, is the combination of the terra ponderosa with the vitriolic acid. This spar has been confounded with the sparry fluor by many naturalists; and indeed it has the same fracture, and does not effervesce more with the acids; but its form, its little transparency, and chiefly its extreme weight, make it very easily distinguished. A chemical character alone even suffices to distinguish it. If we pour a little oil of vitriol upon it reduced to powder, this acid moistens it without drawing from it either vapour or smell; whilst the sparry fluor, treated in the same way, gradually emits a gas of a pungent odour in a white smoke, when it comes in contact with the air, and which is very soon found to be the sparry acid.

The weighty spar is found in great quantities in nature; for the most part it accompanies metallic mines. It is either crystallized or in shapeless masses; but always disposed in beds, which are more or less thick, and more or less extensive. It is very considerably hard, although it does not strike fire with steel. Its principal varieties are the following.

1. White heavy spar, semitransparent, crystallized, in prisms with six sides, two very large, four very small,



small, terminated with two-sided tops. These crystals are placed obliquely on masses of the same nature. They resemble long square plates, whose four sides would have been cut *en biseau* on every side. They are often covered with yellow rhomboidal crystals.

2. Weighty spar, of a milky white, in tables. It is not crystallized, but formed of very thick layers, placed like boards one upon another. It is entirely incrustated with a red powder, and with a redish mineral of silver.

3. Weighty spar rounded; somewhat resembling cats-eye stones: Bolognian stone. It is formed of several converging filaments, which unite into laminæ, applied to one another. It is this variety which is the most known because of its phosphoric property.

4. Octaëdral weighty spar. It has the crystallization of alum; the tops of the pyramids are often truncated, and hence put on a ten-sided form.

5. Twelve-sided weighty spar; it has the form of certain grenats and of some pyrites.

6. Pyramidal weighty spar. This variety as well as the preceding is shown in the table of M. Daubenton.

7. Weighty spar in small scaly rhomboidal crystals; pearly spar. This variety has been placed among the spars of selenite, like most of the preceding. It is formed of small rhomboidal scales, frequently brilliant, which lie obliquely upon one another. This spar is opaque, brilliant like mica, and as if sown upon the calcareous spar, upon quartz, or upon the first variety which we have described. It is of a yellow or dirty green hue; it is sometimes of a silver whiteness.

M. Margraaf, who has examined several varieties of this spar, as the stone of Boulogne, and opaque white spar, supposed it a true selenite, mixed with a little clay, which, he said, rendered it insoluble; but M. Gahn, Scheele, and Bergman, have found the particular earth of it, which they have called *terra ponderosa*. M. Monnet, *Journal de Physique*, tom. vi. p. 214. has also discovered



vered in it a different base from that of the calcareous earth by the salts which it forms with acids: but this chemist admits sulphur to be already formed in it, and looks upon the weighty spar to be an earthy liver of sulphur crystallized.

The terra ponderosa fuses with a violent heat, such as that of the ovens for baking porcelain, &c. It gives a glass more or less coloured. Exposed to a gentle heat, it is noways altered. If we carry it into a dark place, after it has been heated, it emits a bluish and very bright light.

Much has been said of the phosphorus of Bologne, made with the stone of this country, variety 3. It may be also prepared from all the other varieties of this spar. For this purpose, it is pounded and formed into cakes, which are calcined above charcoal. These cakes shine in the dark and even in water: by little and little they lose this property, which may be restored by heating them again. But many other substances present the same phenomenon; magnesia, clay, selenite, the vitreous or sparry fluor, become luminous after being heated.

The weighty spar, heated in a retort, gave nothing to M. Margraaf. This learned chemist observed, that the weighty spar is not at all altered by this operation.

This salt is perfectly insoluble in water. The earthy and saline earthy matters have no action upon it: the pure fixed alkalis cannot decompose it; and this is the most singular property which it exhibits. The other earthy and saline earthy substances, to be sure, have less affinity with the vitriolic acid than the alkalis have. The terra ponderosa, on the contrary, has more affinity with acids. We have observed also, that, according to M. Bergman, this earth decomposes Glauber's salt and vitriolated tartar. It is the same case with the volatile alkali. The mineral acids have no action on the heavy spar, because the vitriolic acid has the strongest adhesion of them all to the earth, which is the base of this spar. The neutral salts



salts do not alter it, except aërated tartar and aërated soda. These two saline substances decompose it by means of the double affinities. The terra ponderosa is separated from the vitriolic acid, because it is attracted by the aërial acid at the same time that the fixed alkali joins with the vitriolic acid. To effect this decomposition, we expose to a strong heat in a crucible a mixture of two parts of fixed salt of tartar or aërated tartar, and one part of heavy spar reduced to powder. We wash this matter, which is semivitrefied, in distilled water; we filtrate the liquor, and obtain by evaporation vitriolated tartar. The substance remaining on the filtre is the weighty earth: it is washed with plenty of water to purify it well; and we find it in the form of a very white fine powdery substance, but impure, because it is united with the aërial acid.

The combustible substances having the property of decomposing the weighty spar, may also be employed to obtain its base. It is exposed in powder to the fire in a crucible, with an eighth of its weight of powder of charcoal: the crucible is kept red for a full hour; then it is taken from the fire, and the matter poured into distilled water. The water instantly acquires a yellow reddish colour, and has all the characters of a solution of liver of sulphur. This is what happens: The acid, which has seized on the phlogiston of the charcoal, or which has been deprived of its air by the combustible body, formed sulphur, which the terra ponderosa has dissolved. The liquor is precipitated by means of an acid. We make use of the marine acid, because with this earth it forms a soluble salt, whilst the vitriolic would reproduce the heavy insoluble spar. We filtrate the liquor decomposed by the marine acid: the sulphur separated by this acid remains on the filtre; and the filtrated water retains in solution the marine salt with base of terra ponderosa. It is decomposed by a solution of aërated tartar; and the terra ponderosa is precipitated, united



with the aërial acid, from which it cannot be separated by calcination, as we will mention in another article.

We see from these two processes, as also from the examination of all the properties of the weighty spar, how much the earth, or the saline earthy substance which constitutes its base, differs from those we are acquainted with, of clay, lime, and magnesia.

Species 2. *Nitre with base of Terra Ponderosa.*

THE nitrous acid easily unites with the terra ponderosa, a neutral salt resulting from their combination; which, according to M. D'Arcet, gives either thick hexagonal crystals, or small irregular crystals.

Nitre with base of terra ponderosa is decomposed by the fire. It attracts humidity from the air; and nevertheless it requires a very great quantity of water to keep it in solution. The pure alkalis do not decompose it. The vitriolic acid poured into its solution instantly precipitates it. The sparry acid also seizes on its base. The aërated alkaline neutral salts decompose it by a double affinity. As yet it is very little known.

Species 3. *Marine Salt with base of Terra Ponderosa.*

THIS salt has been as little examined as the preceding. M. Bergman says, that it is susceptible of crystallizing, and that it does not dissolve but with difficulty: and lastly, that it may be decomposed likewise by the vitriolic and sparry acids.

In his dissertation on the analysis of waters, he puts this salt among the number of the most powerful agents; and he proposes it as the test for discovering the smallest possible quantity of vitriolic acid contained in a mineral water. One or two drops of a solution of this salt poured into a Swedish can, which is two pints and three fourths Paris, of water, charged with 12 grains of Glauber's salt crystallized, very soon produce in it white striae of the heavy spar, formed by the double decomposition.



position of these two salts, and by the transposition of the vitriolic acid to the terra ponderosa. Some marine salt remains dissolved in the liquor.

Species 4. *Borax with base of Terra Ponderosa.*

WE are quite unacquainted with this combination of the sedative salt with terra ponderosa.

Species 5. *Terra Ponderosa combined with the Sparry Acid.*

THIS salt is not more known than the preceding; and is an object of inquiry absolutely new, as well as many other saline matters which have not yet been examined, and about which the scarcity of facts has rendered our discourses very brief.

Species 6. *Aërated Terra Ponderosa.*

TERRA ponderosa is susceptible of uniting with the aërial acid; from which union a kind of neutral salt arises, presenting particular properties, and seemingly possessing some relation to chalk.

We have already observed, that it is by means of the affinity of the terra ponderosa with the aërial acid that the heavy spar, and in general all salts, with this earth as a base, are decomposed with the aërated alkalis. In these decompositions some aërated terra ponderosa is always precipitated. This kind of neutral salt is also prepared by exposing to the air a solution of this pure earth; the surface is gradually covered with a pellicle, which effervesces with acids, and which acquires this property from the earth being charged with the aërial acid of the atmosphere.

This salt exposed to the fire loses its acid. If we heat it in a pneumato-chemical apparatus, the acid is obtained in its natural form of a gas. However, the last portions are separated with great difficulty, and not without an excessive heat.

All



All the mineral acids decompose this salt, and separate the chalky acid; which produces a brisk effervescence, that distinguishes it from pure terra ponderosa. M. Bergman estimates, that this salt contains *per quintal*, 7 parts of aerial acid, 65 of terra ponderosa, and 8 of water.

Water with very great difficulty dissolves the aerated terra ponderosa; but if the water be charged with aerial acid, it dissolves about a 1550th part of its weight. From this we see, that the aerial terra ponderosa is less soluble than when it is pure and caustic; since, in this last state, water can dissolve about a 900th of it, according to the estimate made by M. Bergman. It then very nearly resembles chalk, since, like it, it is precipitated in proportion to the evaporation of the aerial acid united with the water which dissolves it. For the rest, it differs from it in a great number of other properties, and particularly in the salts, which it forms with the other acids (c).

#### L E C-

(c) Before taking leave of the saline substances, it may be proper to enumerate the properties of some new discovered acids, although all their qualities have not yet been thoroughly investigated.

##### *Acid of Sorrel.*

SALT of sorrel contains vegetable alkali, saturated with a superabundant quantity of acid, in the same way as tartar is. The vitriolic, nitrous, and marine acids attract the alkaline basis; but it is very difficult to free the acid from them afterwards. Chalk absorbs both the free and saturated acid; but it is impossible afterwards to separate it by means of the vitriolic. Mr Scheele employs another method; he adds volatile alkali, which saturates all the free acid; he next mixes terra ponderosa, which displaces the alkali, forming an insoluble neutral salt. The vitriolic acid separates the terra ponderosa, setting the oxaline acid at liberty. This acid has not been much examined. It resembles acid of sugar, more than acid of tartar, though in many respects it is different.

##### *Acid of Citrons.*

ALTHOUGH the acid of citrons has been long known, it has been but little noticed. The expressed juice being allowed to subside some time, is freed from all mucus and feculæ; and the water being  
con-



## LECTURE XXIV.

## THIRD CLASS of MINERALS.

## COMBUSTIBLE SUBSTANCES.

WE have already spoken of *Combustion* in the history of *Air*. The order which we have adopted, requires that we recapitulate briefly what we

congealed by frost, the acid is obtained in a state of concentration. Stahl asserts, that this acid, saturated with crabs eyes, will, by the addition of some spirit of wine, be at last converted into vinegar.

*Acid of Benzoine.*

THIS resin contains an acid which is easily obtained by sublimation, but which may be extracted in a much purer state by the addition of lime-water, employing marine acid to decompose the combination. This salt is soluble in 24 times its weight of boiling water, but requires 500 at a moderate heat. It dissolves in spirit of wine either hot or cold. It is entirely resolved into white vapours by heat, though it cannot be kindled by the approach of an ignited body.

*Acid of Amber.*

UPON the distillation of amber, a volatile crystallized acid comes over along with the oil and acetous liquor. This acid may be purified, in some degree, by solution and crystallization. It more nearly resembles the vegetable than the mineral acids. It forms neutral crystallizable salts with the fixed alkalis, calcareous earths, and clay. The combination of magnesia is of a gummy consistence. The metallic substances, properly dephlogisticated, are dissolved, and in general yield permanent crystals. The calcareous earths and magnesia take the acid of amber from the fixed alkali.

*Acids from Milk.*

To obtain the acid from milk coagulated by spontaneous acescency, we evaporate the ferous liquor till only one-eighth of the original bulk remain. This residuum is to be saturated with calcareous earth, to separate the calx phosphorata; the acid of sugar is next employed to carry down the dissolved calcareous earth; and at last the acid is purified from the sugar of milk, mucilage, and fixed alkali, by the addition of highly rectified spirit of wine. This acid may be changed into the nature of vinegar. There is another distinct



we have delivered on this subject. According to Stahl, a combustible body is a compound, which contains fixed fire or phlogiston. According to his theory, combustion is only the separation of this fixed fire, and conversion of it into free fire; a separation which is manifested by light and heat. M. Macquer has greatly increased the probability of this system, by substituting, in the room of the phlogiston of Stahl, the existence of which can no way be demonstrated, light, which exists with

flinck acid obtained from the sugar of milk: 100 parts of this sugar contains  $15\frac{1}{2}$  parts of common acid of milk, and  $23\frac{1}{2}$  of a peculiar acid. This acid is obtained in the form of a white concrete, of difficult solution in water, requiring about 60 parts to one. It forms more soluble compounds with the fixed alkali; but those with the earth can hardly be dissolved in water.

*Acid of Ants.*

ANTS by maceration and expression give out an acid, which bears some resemblance to vinegar. It differs, however, in forming deliquescent salts with magnesia, iron, and zinc.

The acid of ants may be entirely converted into a vapour, consisting of aerial acid and inflammable air.

*Acid of Suet.*

WHEN suet is repeatedly distilled, two pounds of it yield an acid, whose properties are not distinctly known.

*Acidum Perlatum.*

WHEN human urine is evaporated, two kinds of salts crystallize; the microcosmic salt, and another containing a particular acid. It has mineral alkali for its basis, which makes it difficult to separate the acid in a pure state, even by the addition of spirit of wine.

*Acid of Prussian Blue.*

PHLOGISTIC alkali is a triple salt, consisting of the tinging acid, some alkali, and some iron. When this salt is distilled with weak vitriolic acid, the tinging acid flies over in the form of inflammable air, which may all be collected in water. This acid is somewhat analogous to the acidum perlatum, and is distinguished by a peculiarly ungrateful smell and taste: it seems to consist of aerial acid, volatile alkali, and water.

This general account of the new acids is intended to serve as hints to such gentlemen, whose curiosity may excite them to prosecute the subject more fully, by a series of experiments.



with the characteristic properties, and whose influence in the chemical phenomena is begun to be perceived.

According to the new doctrine, a body is only combustible, because it tends strongly to unite with pure air. Combustion is nothing but the act of that combination. This opinion is founded on the four following facts: 1. A body cannot burn without air. 2. The purer the air is, the more rapid the combustion. 3. In combustion there is an absorption of air, and an increase of weight in the body burnt. 4. Lastly, the body burnt contains the portion of pure air which it absorbed; and sometimes that air may be extracted by different methods, which will be more fully explained hereafter.

This doctrine which we have delivered, is very different from that which M. Lavoisier published, as an hypothesis indeed, in the Memoirs of the Academy for the year 1777. That chemist thinks, that pure or dephlogisticated air is composed of a base, of which he does not design the nature, and which is held dissolved by the matter of fire or of light. When a combustible body is heated in this fluid, such body decomposes the air by seizing upon its base; and then the matter of fire having become free, assumes all its qualities, and escapes with the characters which distinguish it; namely, flame, heat, and light. According to this hypothesis, pure air is the true and only combustible body. But let us observe, that this manner of explaining combustion is as difficult to prove as that of Stahl, since it differs from Stahl's only as to the place of the phlogiston or fixed fire, which M. Lavoisier admits to be in the body which is employed for kindling, whilst Stahl admitted it in the combustible body. It cannot then be admitted, but so far as the existence of the matter of fire in pure air can be demonstrated; and in that case, we shall find the same difficulties which occur in the theory of phlogiston. We likewise think that it ought to be observed, that the opinion of the simple fixation of pure air in the combustible body, seems to agree with every fact.

The



The different combustible bodies show many degrees of tendency to combine with air; and it appears that more or less combustibility depends on the varied relations which exist between that element and the combustible bodies; so that we might establish an order of their combustibility, and construct a table of their affinity with the air. This variety of affinity between combustible bodies and air is the cause of the different phenomena which those bodies present in their combination with that fluid. Hence we distinguish three sorts of combustion.

1. Combustion with flame and heat; as that of sulphur, &c.

2. Combustion with heat without flame; as that of several metals.

3. Combustion with flame without heat, as that of the phosphori.

We must observe, that besides these differences, combustion is distinguished by a great number of phenomena peculiar to each combustible body. The rapidity, the form, the colour, the extent of the flame, the smell which accompanies it, the quantity of air absorbed, the weight, the state of the residuum of the body burnt, and several other circumstances, which it would be useless to enumerate here, and which shall be treated with all the importance they merit in the article on each combustible body, establish differences that are essential and proper to characterize every one of the substances which belong to this class.

We divide the combustible matters of the mineral kingdom into five genera; namely, the diamond, inflammable gas, sulphur, metallic substances, and the bitumens. To these we might add the mineral phosphoric substances, by giving them the title of *phosphori*, or *bodies combustible with flame and without heat*. These are, magnesia, lime, calcareous nitre or phosphorus of Baldouin, calcareous marine salt or phosphorus of Homberg, fusible spar, or fluor, and the heavy



heavy spar or phosphorus of Bologna. The pyrophorus of Homberg likewise belongs to this class; but as all these matters have been examined already in the history of saline substances, and as the phenomena of their combustibility are but very little known, we shall say nothing farther about them.

GENUS I. *The Diamond.*

THE diamond is a singular substance in its kind: it is placed among the stones, because it has their hardness, insipidity, and insolubility. It is also the most transparent and the hardest of all the minerals. Its hardness is so great, that the best tempered steel has no effect upon it; and a diamond cannot be consumed except by being rubbed against another diamond: this is called *grinding*.

Diamonds are found in the East-Indies, particularly in the kingdoms of Golconda and Visapour. They are brought from Brasil also; but these seem to be of an inferior quality: In commerce they are known by the name of *Portuguese diamonds*.

Diamonds are found generally in a yellow ochry earth in rocks of free-stone and quartz; sometimes in running waters. These have been detached from their mines. Diamonds rarely exceed a small size. The Indian monarchs set a guard over the largest, that the price of diamonds may not be diminished.

The diamonds do not come out of the earth with their brilliancy. They are found brilliant in waters only. All those which are extracted from the mines are enveloped with an earthy crust; which, according to M. Romé de Lisle, covers a second layer of the nature of calcareous spar.

Diamonds often have no regular form: they are flat or round. Sometimes they present regular octaëdral crystals, formed of two quadrangular pyramids united by their bases.

Some diamonds are perfectly transparent, and of the most elegant blue. Others are stained, and have very evident



evident spots of yellow, red, blue, and black: these are very rare.

Diamonds seem to be formed of laminæ laid on one another. They are easily divided by striking on the edges of these laminæ. There are some diamonds, however, which do not appear to be formed of distinct laminæ, but of twisted fibres, like those observed in the knots of trees. These last ones are very hard, and cannot be wrought: the lapidaries call them natural diamonds.

The transparency, the hardness of the diamond, the regular crystalline form which it often assumes, have determined naturalists to rank this substance among the number of vitrifiable stones. They looked upon it as rock-crystal matter, the purest and most homogeneous. They reckoned it unalterable by the fire, because the jewellers are in the practice of heating, and even reddening, the diamonds, which are stained with yellow. By this process the stains become black, and do not affect the brilliancy of the stone. However, they know that the diamond is heavier and harder than rock-crystal, and that it has a very remarkable electric property; but they ascribe this to its extreme purity alone.

Newton in his optics has remarked, that all transparent bodies refracted the light in the direct ratio of their density; but that the combustible bodies reflected it in the double ratio of their density. He has observed, that the diamond produced a refraction almost triple of that which it ought to produce in the ratio of its density: he was then ignorant of what was one day to be discovered, that the diamond is very combustible. It seems, that on this great refracting force the singular brilliancy of the diamond depends. As it is very transparent, and the light is strongly refracted between its laminæ when we multiply the surfaces of it by cutting, every one of its facets furnishes a very brilliant bundle of light. Those which are cut in facets throughout their



their circumference, have a brightness very superior to such as are cut on one side only: for this reason, the lapidaries call the first by the name of *brilliant*, and the second by that of *rose diamonds*.

Boyle remarked, that the fire altered diamonds, and that it disengaged acrid vapours from them: but the fact announced by this philosopher has not found many partisans. However, Cosmo, the third grand duke of Tuscany, saw at Florence, in the years 1694 and 1695, diamonds destroyed by the burning mirror: many years after, the emperor Francis I. was also witness to their destruction by the simple fire of the furnaces at Vienna.

M. D'Arcet, in his elegant experiments on the stony matters exposed to the action of a violent and continued fire, did not forget the diamond. He asserted, that an evaporation took place from the sides of their laminae; and that if that evaporation was stopped designedly, what remained was nowise altered, and presented a diamond of less volume only.

M. D'Arcet, wishing to learn whether the evaporation of the diamond was any more than a simple decrepitation, thought of treating it in vessels differently closed. He took a sphere of paste of porcelain; and having cut it in two, he placed a diamond in the centre; he then adjusted the two hemispheres so that, the diamond forming to itself its cavity, there was no void space around it. Having exposed the globe to the furnace till it was baked, he broke it, and found the place empty and the diamond evaporated, although he could not perceive the least chink in the globe.

M. D'Arcet varied this experiment in several ways; sometimes taking globes of the paste of porcelain, sometimes crucibles of porcelain baked, closed with a stopper of the same kind covered with a fusible substance, which vitrifying by the fire, made an hermetical lute. M. D'Arcet always found the diamond disappear; and hence he concluded, that it was evaporable without the



assistance of air. Afterward, M. D'Arcet and Roux remarked, that it was not necessary to use fires of so great violence to effect the volatilization of the diamond; and in the year 1770 M. Roux volatilized one, before the students of medicine, in five hours time, in a cupelling furnace.

In the year 1771, Mr Macquer observed a new phenomenon relative to the volatilization of this substance.

Having a diamond to volatilize, he made use of the furnace of Pot, on which he made some improvements. This furnace, when it is terminated by a pipe of a stove ten or twelve feet high, produces a heat equal to that of a furnace for baking hard porcelain. M. Macquer placed a muffle in the centre of his furnace, with a pipe of only two feet; he put a diamond, cut brilliantly, weighing three-sixteenths of a carat, into a cupel, which at first he placed immediately before the muffle when very red. He took care to thrust it forwards only by degrees, to prevent the diamond from cracking. Twenty minutes after, looking at the diamond, he found it increased in size, and much more brilliant than the capsule in which it was: in short, he observed a slight flame, as if phosphoric, which formed a very singular shining circle round the stone; but he did not perceive acrid vapours, as Boyle had asserted. The diamond, having been put under the muffle, in about thirty minutes it was entirely vanished, and left no traces behind. In less than an hour M. Macquer volatilized a diamond of more than four grains; and he perceived that it consumed with a sensible flame, in the same way as combustible bodies.

This fact, first published by M. Macquer, has been several times since verified. In the year 1775, M. Bucquet volatilized a diamond of about  $3\frac{1}{2}$  grains. He used Macquer's furnace, but without the pipe; and the muffle remained open almost all the time of the operation, in order to see what passed during the combustion of the diamond. It remained about five minutes before



fore it took fire; and, counting from the moment of inflammation, it did not require twenty-five for its total dissipation. As none of these experiments demonstrated what became of the diamond, M. Macquer, Lavoisier, and Cadet, resolved to make some experiments in close vessels. They distilled twenty grains of diamond in a stone retort, with an apparatus proper to retain the product, if any thing should pass over. They employed a fire of the greatest violence, and obtained nothing: they found the diamonds very entire, but that they had lost a little of their weight. They suspected that this loss depended on the diamonds being in part consumed by means of the pure air contained in the vessels. The diamonds were also covered with a blackish scurf, as if charry, which disappeared very quickly by rubbing it on a grinding-stone.

Whilst the chemists were occupied in researches about the diamond, the lapidaries always believed in the perfect indestructibility of this stone. One of them, M. le Blanc, carried to M. Rouelle a diamond to be exposed to the fire. Wishing to inclose it in his own way, he put it into a crucible, with a cement of chalk and powder of charcoal; this was shut up in another, covered with its own lid, and luted with sand used by founders. This apparatus remained in the fire during four hours, and likewise several other diamonds with which M. Rouelle was working. At the expiration of that time, Rouelle's diamonds had disappeared, as also that of M. le Blanc. M. Maillard, another lapidary, went to M. Cadet, where M. Lavoisier and Macquer wrought. Having brought three diamonds, he proposed exposing them to the fire, after he should have cemented them in his own way. He filled with charcoal, pounded and well pressed, the bore of a pipe; and having put the diamonds in the centre of the charcoal, he covered the pipe with a plate of iron, which he luted with the sand of the founders: the pipe was shut into a crucible, lined with a coat of sand moistened with salt-



water. The whole was put into Macquer's furnace, and endured such a fire, that in two hours the whole apparatus was softened and ready to melt. After the operation, the crucible was vitrified and deformed: it was carefully broken, and the pipe was found quite entire: the charcoal which it contained was perfectly black, and the diamonds had lost nothing. Their surface was only blackened; but by being rubbed on a grind-stone, they became white and brilliant. Macquer repeated this experiment in the large furnace which bakes the hard porcelain of Seves; it succeeded in the same way: however, the iron which covered the pipe having been fused, part of it had stained the diamond, and had scorified one side of it, but the other was quite entire. The fire continued twenty-four hours.

M. Mitouard having had occasion to treat several diamonds in close vessels and with different cements, found that charcoal, most of all bodies, prevented the destruction of the diamond.

All the chemists have been persuaded by these facts, that the diamond burnt in the way that combustible bodies do; and that, like charcoal, it was destroyed only so far as it was in contact with the air. However, the experiments of M. d'Arcet, which were very well executed, and very numerous, seemed to establish the contrary.

M. Macquer hereupon took some charcoal in powder, and filled with it several balls of baked porcelain, and several crucibles of paste of porcelain: the charcoal was reduced into cinders in the crucibles of the unbaked porcelain; the cinders were even vitrified, whilst the charcoal inclosed in the vessels of baked porcelain remained without alteration: whence this chemist concluded, that there is a great difference between these two sorts of vessels. He thinks, that, during the baking of the porcelain, cracks happen, very imperceptible, but sufficient to facilitate combustion; and that these porcelains



celains contracting by cooling after the baking, all these openings close, and disappear entirely.

M. Lavoisier has added to these experiments some new researches, which prove that the diamond consumes only so far as it is in contact with the air. He exposed diamonds to the focus of M. de Trudaine's lens, after having covered it with a vessel, under which he made some water or mercury ascend, by sucking out the air. This chemist, in experiments on the effects of the burning-glass made in common with Macquer, Cadet, and Brisson, observed, that if he heated the diamonds briskly, they crackled and split, which does not happen when they are heated slowly and by degrees. He has also remarked the diamonds fuse and run in certain places; the surface of those which remained some time exposed to the fire of the lens, seemed to him pierced with small holes, like a pumice-stone. In heating them in the pneumatological apparatus described above, he was convinced that the diamond consumed only during a certain time, more or less long in proportion to the quantity of air contained in the vessel: he examined the air in which the diamond had burnt, and he found it quite similar to that which remains after the consumption of all the other combustible bodies.

To be satisfied more fully of the nature of the diamond, M. Lavoisier tried to burn it in a vessel full of aerial acid. The diamond suffered a little waste, in part owing to the pure air which is always mixed with that acid. This chemist thinks, that the waste in a great measure depends on the volatilization of the diamond; and he concludes, that this body might be entirely volatilized in close vessels, if we applied a sufficient heat. M. Lavoisier having wrought likewise on charcoal, had analogous results, either relatively to the combustion or relatively to the volatilization. He also observed the diamond to blacken always at the surface.

It follows from these different facts, that the diamond is a substance very different from the stones:



that, on the contrary, it is a true combustible body, susceptible of burning with flame at all times, when heated to redness with the contact of air: in a word, that it is one of the most combustible bodies in nature, since it leaves no residuum: that it perfectly resembles charcoal in the manner it is acted on by fire; yet it differs widely from it in its transparency, weight, hardness, and several other properties. All these experiments, as well as the art of splitting the diamond, have taught, that it is formed of laminæ or layers, placed one on another; that between these layers there is sometimes a foreign colouring matter, to which the charry scurf perhaps is owing with which heated diamonds are covered, particularly in close vessels. It is this coloured layer, being placed more or less deeply, that renders the process uncertain which is employed by the lapidaries for whitening the stained diamonds. If it is not deep, it may be easily destroyed, and the diamond will be whitened; if, on the contrary, it is in the interior part, it can be taken away only by the successive destruction of the laminæ which cover it; and then it is necessary to destroy the diamond almost entirely before its colour be taken away.

Notwithstanding all these labours, we still know nothing about the composition of the diamond; and, in the actual state of our knowledge, we ought to look upon it as a simple substance.

The diamond is of use only as an ornament; but the property which it has of refracting the luminous rays, of decomposing them, and presenting to the eye the most brilliant and vivid colours, render it truly precious, without being able to attribute to the caprice of fashion the estimation which it possesses. Its excessive hardness, to which it owes the unalterable polish of its surface, its rarity, and the art of cutting, still add to its price. It is used with advantage to cut on glass and the hard stones, and to give to these bodies the suitable form and size.



GENUS II. *Inflammable Gas.*

THE gas, called *inflammable air* by Dr Priestley, is an aëriform fluid, possessing all the apparent properties of air. It is lighter than air; it is unfit for combustion; it very quickly kills animals, by giving them strong convulsions. It has a very strong and distinguishable odour. Its characteristic property is that of kindling when it comes in contact with air and an inflamed body is presented to it.

Inflammable gas, both natural and artificial, has been a long time known. Metallic mines, those of coals, the surface of waters, animal or vegetable matters in putrefaction, have produced many examples of natural combustible vapours. By art it used to be produced in the solution of several metals by the vitriolic and marine acids, and by the distillation of animal and vegetable matters: but, before Dr Priestley, nobody thought of collecting these vapours in recipients, in order to examine their properties. This philosopher discovered that they formed a kind of combustible air.

Inflammable gas presents all the phenomena of combustible bodies. Like them, it cannot burn without the contact of air; it burns with a more or less red flame when it is very pure, and a blue or yellow when it is united to any substance capable of modifying its properties. It frequently crackles, and produces, in burning, small brilliant sparks, with a noise resembling that of detonating nitre. In its combustion it excites a strong heat. It kindles by the contact of the electric spark. It burns the more rapidly as it is surrounded with a greater quantity of air. As these two fluids have a similar aggregation, we know that it is possible to mix them, so that a molecule of inflammable gas is surrounded with air; and then it ought to burn with rapidity. This happens when a mixture of two parts of atmospheric air, and one of inflammable gas, is set on fire: this mixture kindled, it burns in an instant, and produces a quick explosion, resembling



resembling that of gunpowder; inflammable gas alone, on the contrary, burns but slowly, and at the surface.

It can be made to burn likewise in an instant, and with much more vehemence, if we mix two or three parts of it with one of pure or dephlogisticated air; it then produces a much more considerable explosion than in the preceding experiment.

By all these facts it is demonstrated, that the inflammable gas is one of the most combustible bodies in nature; but we are quite ignorant of what is the residuum of its combustion, or rather what is the nature of its combustion with pure air.

I have suspected more than these four years, that inflammable gas was a simple substance, incapable of decomposition, and which in its combination with air formed aerial acid; that consequently we ought to look upon it as one of the principles of this acid; and that it was in relation to it what nitrous gas is to the nitrous acid, and sulphur to the vitriolic. I thought this opinion might be supported, 1. Upon this, that in burning inflammable gas above lime-water, the water is troubled, and affords some chalk: 2. That the aerial acid in dissolving the metals often produces inflammable gas: 3. Lastly, That these two gases are frequently found together; as in the spontaneous decomposition of inorganic substances, they appear truly to be only modifications of one another.

M. Lavoisier seems to have adopted this opinion, as may be seen in his Memoir on Combustion, inserted in the last volume of the Academy for the year 1777. However it be, we propose it only as a conjecture, or as a probable hypothesis, to which several important facts are wanting in order to place it among the number of demonstrated truths. Chemists are not yet agreed on the kinds of inflammable gas. Several have been found to differ from one another in essential properties. Such are the inflammable gas obtained from iron and from zinc by the vitriolic acid, which burns red, and detonates



tonates with pure air: that which M. de Laffone extracted from Prussian blue, from the reduction of flowers of zinc by charcoal, which burns without detonating with the air; the inflammable gas of marshes, which burns blue, and does not detonate; that which is obtained from the distillation of organic matter, and which resembles the gas of marshes. An exact analysis, it is true, proved, that these last mentioned are compounds of true, pure, and detonating inflammable gas, with the aërial acid in different proportions; and that by lime-water and the caustic alkalis, they may be reduced to the state of pure inflammable gas. From this we were then led to believe, as the famous M. Macquer thinks, that there was only one substance of this kind susceptible of several modifications by its combination with different substances. However, M. Lavoisier, in a Memoir on the Combination of Alum with Charry Substances, *Academ.* 1777, p. 371, is of opinion, that three kinds of inflammable gas may be distinguished: the vitriolic inflammable gas, the marine inflammable gas, and the aërial inflammable gas. It is this last which was obtained during the reaction of alum on the charry substances. The character which he gives to distinguish them is, that every one of them is converted by inflammation into an acid analogous to that from which it was extracted. Thus the vitriolic inflammable gas gives vitriolic acid; marine inflammable gas, spirit of salt; and the third, aërial acid. This chemist thinks, that the inflammable gas which he obtained during the preparation of pyrophyrus, is formed by the charcoal itself reduced into vapour, and combined with the pure air of the vitriolic acid, which by the loss of this principle passes into the state of sulphur.

Inflammable gas does not unite with water; it may be preserved a long time above this fluid without alteration. However, through time it is altered, and is no longer inflammable. Dr Priestley has not determined this kind of change, nor the state of the water which  
pro-



produces it. It is probable that the experiment made with care would throw much light on the nature of this combustible body.

This gas does not combine with the earths, except the clays, of which it seems to be one of the colouring principles. Its action on the saline matters has not yet been examined; such experiments, however, would be of the greatest importance: and we are persuaded from our trials, that the reciprocal action of the inflammable gas on the acids, the alkalis, and even on the neutral salts, would present very interesting phenomena.

Inflammable gas is of little use. It has been imagined that it might supply the place of other combustible matters for several purposes of life; for instance, to charge some fire-arms. M. Volta has considered it in this last light, and proposed several ways of using it. M. Neret has given the description of a chaffing dish with inflammable air; *Journal de Physic*, January 1777. Messrs Furstenberger physician at Bale, Brander mechanic at Augsbourg, Ehrman professor of natural philosophy at Strasbourg, have contrived lamps which might be lighted at night by means of an electric spark. They made very agreeable fire-works with glass tubes of different circumferences, and pierced with a great number of small holes. Inflammable gas is introduced into these tubes by means of a bladder, which is filled with it, and adapted to it by a copper cock; by pressing the bladder the inflammable gas passes into the tube, and goes through all the openings which are made in it, and to which a lighted candle is applied. I have seen some of this kind at M. Bianchis, mathematical instrument-maker at Paris.



## L E C T U R E XXV.

## G E N U S T H I R D.

## S U L P H U R.

**S**ULPHUR is a combustible body, dry, very brittle, of a yellow citron colour, has smell only when it is heated; and its particular taste is weak, although very perceptible. If we rub it, it becomes electrical; if, when in thick pieces, we expose it to a gentle but sudden heat, as in squeezing it in the hand, it breaks, making a crackling noise. Sulphur is found in great quantities in nature; sometimes pure, and sometimes combined. The first only ought to be examined here. The following are the varieties of form in which it is presented to us in its state of purity.

## Varieties.

1. Transparent sulphur, crystallized into eight sides, with two truncated pyramids. It is deposited by water, most frequently on the surface of a calcareous spar; such as that of Cadiz.
2. Transparent sulphur in irregular pieces. That of Switzerland is in this state.
3. Whitish powdery sulphur, deposited in the filiceous geodes.
4. Powdery sulphur, deposited at the surface of mineral waters, like those of Aix-la-Chapelle.
5. Crystalline sulphur sublimed: it is in transparent crystals, and found about volcanoes.
6. Sublimed powdery sulphur of volcanoes: it is without a regular form, and frequently interspersed in soft stones, as is observed at Solfatara about Naples.
7. Stalactites of sulphur formed by the fire of volcanoes.

Besides these seven varieties of pure mineral sulphur, this combustible substance is found combined with different



ferent matters. It is the metals to which it is most frequently united, and which it converts into pyrites or minerals. Sometimes it is combined with calcareous substances in the state of earthy liver of sulphur: the calcareous hepatic stones, the fetid spar, the swine-stone, seem to be of that nature.

Recent discoveries still extend the prevalence of this mineral. It seems to be daily formed in all vegetable and animal matters which are beginning to putrefy. Although these kinds of sulphur do not essentially belong to the mineral kingdom, we think it necessary, however, to join them to the preceding varieties, in order to render its natural history more complete.

Varieties.

8. Crystallized sulphur, formed by the slow decomposition of animal matters accumulated; such as that which was found about two years ago in the old lay stalls near the gate of St Anthony.
9. Powdery sulphur, formed by the disengaged vapours of animal substances in putrefaction; it is collected on the walls of stables, privies, &c.
10. Sulphur extracted from several vegetables, particularly from the radix patientiæ, spiritus cochleariæ, &c. M. Deyeux, member of the college of pharmacy, and professor of chemistry, made this discovery as well as the following.
11. Sulphur obtained from the analysis of animal matters, and particularly from the white of eggs.
12. Sulphur extracted from horse-dung. A lady in the acquaintance of M. le Duc de la Rochefoucauld, found this combustible body in horse-dung the instant it was voided. It is probable that future labours will discover it in a great number of other animal substances.

These different sulphurs are not what is employed in the arts. It is extracted by distillation from metallic compounds, of which it forms one of the principles, and which are called *pyrites*. In Saxony and Bohemia  
pieces



pieces of them are put into vessels of earth placed on a long furnace. The end of those vessels which projects from the furnace is received into square boxes of cast iron, which are filled with water. Into these kind of receivers the sulphur is collected, but it is very impure. In order to purify it, it is fused in an iron pan; the earthy and metallic matters are precipitated. It is poured into a copper pan, in which another deposition of the foreign matters is formed. After having been kept some time in fusion, it is run into wooden cylindrical moulds, which form sulphur in sticks. What is precipitated during the fusion is grey, and very impure; it is very improperly called *quick sulphur*. In other countries, as at Rammelsberg, the sulphur is extracted from pyrites in a more simple manner. They content themselves with lifting with ladders what is found fused in the masses of pyrites, which they roast in the air, and purify it by a new fusion. Sulphur is not altered by the contact of light. Heated in close vessels, it softens, fuses, and frequently assumes, in cooling, a red, brown, or greenish colour, and a needled form. To succeed in this crystallization, it is requisite, according to Rouelle's process, to allow the surface to fix, and quickly pour off the fluid portion which is found below this kind of crust; then we obtain needles of sulphur, which cross in different directions. If it be gently heated while in the state of fusion, it is volatilized in small powdery parcels of a citron yellow, called *flowers of sulphur*. As it is only the pure portion which is volatilized in this operation, it is successfully employed for its purification. To make flowers of sulphur, we put some common sulphur, in powder, into a cucurbit of earth, to which earthen or Dutch-ware pots are adapted that communicate, and are called *aludels*. The last is terminated by an inverted funnel, whose stalk has a small communication with the air; the cucurbit is heated to liquefy the sulphur, which sublimes with this degree of heat, and adheres to the sides of the aludels. The flowers of  
sulphur



fulphur made in great, often contain a little vitriolic acid, formed by the combustion of a small quantity of the sulphur, which happens by means of the air contained in the vessels. They are very completely purified by washing. This is the sulphur we ought to employ in medicine, and in delicate chemical experiments. Sulphur heated with the help of air takes fire when it is fused, and burns with a blue flame if the heat applied is but inconsiderable; or with a white and vivid one, if it be strong. In the first of these combustions, a suffocating odour is emitted; and if the vapour which exhales is collected, we obtain a very strong sulphureous acid. In the rapid combustion, its odour is weaker, and its residuum has none of the sulphureous acid; it has some oil of vitriol. Stahl, who thought sulphur was a compound of this acid and phlogiston, supposed that during combustion this body lost its inflammable principle, and consequently was reduced to the state of an acid. The number of proofs which he has given of this opinion, was well calculated to persuade all the chemists that have followed him. However, since we have observed the necessity of the air in combustion, to which Stahl appears to have paid small attention, some chemists, struck with the difficulty hitherto found of demonstrating the inflammable principle, and with the facility with which all the objections made to this doctrine are answered by the new discoveries on air, have adopted an opinion entirely contrary to that of Stahl concerning the nature of sulphur and of combustion. The following are the facts on which this new opinion is founded. Hales observed, that sulphur, in burning, absorbed a great quantity of air. M. Lavoisier has demonstrated, that it is with sulphur as with all combustible bodies; that is to say, 1. That it cannot burn without the help of air. 2. That during combustion, it absorbs the purest part of that fluid. 3. That the residuum of air cannot serve for a new combustion. 4. That the vitriolic acid which results exceeds the weight  
off



of the quantity of sulphur which produced it, by the exact weight of the air lost during combustion. 5. That in consequence the sulphur is combined with the portion of pure air, which is absorbed, in order to form oil of vitriol. This acid is therefore a compound of pure air and sulphur. This last, in place of being a compound body, is only one of the principles of the oil of vitriol, and requires no more than an union with pure atmospheric air to form this acid; which is done by combustion. Heat is necessary to burn it; because by dividing and destroying its aggregation, it promotes its combination with the air: as soon as it is once burnt, or combined with pure air, it is no longer capable of inflammation, and enters the class of incombustible bodies.

From this theory we very easily understand what passes in the formation of sulphur with the vitriolic acid and any combustible substance, as we have shown happens with vitriolated tartar, Glauber's salt, selenite, Epson salt, and weighty spar, when heated with charcoal. According to the doctrine of Stahl, the phlogiston of the charcoal unites with the vitriolic acid of these salts, and forms sulphur. According to the modern theory, the charcoal seizes on the pure air contained in the vitriolic acid; and consequently only leaves sulphur, which is one of its principles. Likewise, whenever the vitriolic acid is changed into sulphur by any combustible body, this last is always reduced to the state of a burnt body, as we shall point out in the history of several metallic substances. We must recollect, that the presence of pure air in the vitriolic acid is easily demonstrated. Though our intention be to take no side; in order, however, to pay homage to the truth, we cannot refrain from observing, that in the combustion of sulphur, and in the combination of the vitriolic acid with combustible bodies, the pneumatic theory seems to have a very remarkable advantage over that of Stahl, that of going no farther than what is elucidated by experience, and  
of



of being only the result of sure facts, which are easily verified.

Sulphur is unalterable by the air, and unsoluble in water. If, when it has been kept some time in fusion, and is turned fixed, we put it into this fluid, it becomes red, and retains a certain degree of softness, so that we may knead it with the hands; but it loses these properties in a few days. It has no action on the quartz earths, but it soils the glass which results from their fusion. It gives a colour to clay without uniting to it. It combines with the terra ponderosa, and forms a fetid compound, which colours the metals, is precipitated by the acids, and is called *liver of sulphur*. This composition is prepared by the dry way.

Sulphur unites with magnesia by means of heat. To effect this combination, we generally use the neutral salt, which we have called *aërial magnesia with the chalky acid*, as being more soluble in water: we put equal parts of flowers of sulphur and magnesia into a bottle with some distilled water; we expose this vessel void of air, and well corked, to the heat of a water-bath for several hours; we then filtrate the water, which has a fetid smell of rotten eggs: it strongly colours the metallic solutions; by spontaneous evaporation, it furnishes small crystalline needles; in a word, it is a true liver of sulphur with base of magnesia. This last may be precipitated from it by the fixed alkali, which has more affinity with the sulphur than it has. As for this combustible body, its presence is easily demonstrated by the addition of the acids which separate it in the form of a white powder. This was the liver of sulphur which M. le Roi, physician at Montpellier, made to be dissolved in pure water, in order to imitate the hepatic mineral waters, though these waters contain not an atom of it. Lime unites with sulphur much more readily, and with much more vivacity, than the substances already mentioned. If we pour by degrees some water on a mixture of quicklime and flowers of sulphur, the heat which is produced by the action of the



the water on the lime suffices to promote their union. If we add some water, it assumes a reddish colour and a fetid or hepatic odour. It contains some lime and sulphur dissolved. This calcareous liver of sulphur can be well prepared only by the humid way. When the lime is not quick enough, and a great heat is not excited with the water, we are obliged to assist the combination with a gentle fire. This compound is of a more or less deep red, according to the causticity of the lime; when it contains a great deal of it, it deposits, by cooling, a layer of small needle-like crystals, of a yellow orange, disposed in tufts, which appear to have been three-sided figures, compressed and terminated by two-sided tops. These crystals gradually lose their colour, and become white and opaque, without suffering any alteration in their form. The calcareous liver of sulphur, distilled in a pneumato-chemical apparatus, is partly decomposed, and gives a great quantity of a particular gas, which M. Bergman has called *hepatic gas*, whose properties we shall examine more afterwards. If we evaporate it to dryness, and calcine it in a crucible till the fumes cease, there remains after the operation only some selenite, formed by the lime and the vitriolic acid, owing to the slow combustion of the sulphur. Calcareous liver of sulphur is very readily altered by the air. It loses its odour and colour in proportion as its hepatic gas is dissipated. Dissolved in a great quantity it suffers the same alteration, particularly when it is agitated, as M. Monet has observed in his *Treatise on Mineral Waters*. After these alterations, there remains only some selenite. Kept in bottles, in part empty, it deposits on the sides a blackish covering, and it forms crusts or pellicles, which fall to the bottom of the liquor. Calcareous liver of sulphur is decomposed by the pure fixed alkalis, which have more affinity with the sulphur than lime has. The acids precipitate the sulphur in the form of a very subtile white powder, which has got the name of *magister sulphuris*. The aerial acid affects this precipitation as well



as the others. We are not acquainted with the action of the neutral salts upon it. The two pure or caustic fixed alkalis have a very remarkable action on sulphur. They form true livers, which are with most difficulty decomposed, and are the most permanent. They may be prepared in two ways; the dry or the humid. In using the first process, we put into a crucible equal parts of lapis causticus and flowers of sulphur: this mixture is fused; we then run it on a marble plate; and when it is cooled, it is of a deep red brown colour, similar to the liver of animals. The liver of sulphur by the moist way, is prepared by heating the liquor of the soap-boilers with a half part of sulphur; the liquor very soon acquires a red colour, which turns more and more deep; it is filtrated, and is then liver of sulphur liquid or dissolved. These two combinations of the caustic alkalis with sulphur have been but little examined. Liver of sulphur has almost always been made with the fixed alkalis, saturated with aerial acid; such as aerated tartar and soda. There are, however, remarkable differences between these two kinds of liver of sulphur. In the first place, those made with the aerated fixed alkalis require more time to prepare; because these salts have a much weaker action. But the most important difference which we have had occasion to observe between the alkaline caustic or not caustic livers of sulphur, is the comparative state of saturation. Livers of the first kind, solid or liquid, are more brown, more odorous, more alterable; and the gas which they give is much more hepatic, and much more inflammable, than that of the second. The last kind is of a paler colour, often of a greenish grey, of a weak odour, and more durable composition. It seems that the aerated fixed alkalis retain their acid in their union with sulphur, since the gas of these mild livers of sulphur is inflammable, only when it has been washed with lime-water, which attracts its aerial acid. In the presence, therefore, of this acid, and in the little energy of the alkali which it renders mild, we find the  
cause



cause of the differences, that subsist between the caustic and not caustic livers of sulphur.

The solid alkaline liver of sulphur is very fusible; it is decomposed like the calcareous liver of sulphur; when it is heated for a long time, it gives a great deal of hepatic gas; and by cooling it is capable of assuming a crystalline form, which has not yet been described. As long as it is hot, it is of a brown colour; in proportion as it cools, it loses this colour, and becomes paler; when exposed to the air, it very soon becomes of a green yellow. It attracts the air's humidity, redissolves into a liquor, and is decomposed, though slowly, so as in a certain time to form vitriolated tartar. The alkaline liver of sulphur dissolves very well in water; according to its state it gives a deep red or green colour to that fluid. This solution may be decomposed by heat, by the contact of the air, and by agitation; when it is very abundant, it often deposits crystals of liver of sulphur in needles of considerable size.

The earths, and the saline-earthly substances, have no action on the alkaline liver of sulphur. The acids decompose it by uniting with the alkali, and precipitating the sulphur in the form of a very fine white powder, called *magister sulphuris*. According to M. Proust, the spirit of nitre poured on fused liver of sulphur produces a detonation. All the acids in decomposing liver of sulphur, at the same time disengage from it a gas, which we may collect in a pneumato-chemical apparatus, and which deserves a particular examination.

This gas, which is even in all the livers of sulphur, and which distinguishes them, has for a long time been known by its fetid odour and its action on the metallic calces, and particularly on those of lead and bismuth, which it turns quite black. Its fetid smell is unsupportable; it kills animals suddenly; it turns the syrup of violets green; and burns with a very slight bluish flame. If we kindle it in a large proper glass vessel, it deposits on its sides flakes, which are nothing but some



fulphur. This gas is decomposed by pure air; whenever it is in contact with the atmospheric air, it deposites sulphur. For that reason, the sulphureous waters which it mineralizes contain no true liver of sulphur; though this substance swims in flowers at their surface, and is deposited at the vaults of the fountains which contain it, as those of Aix-la-Chapelle. To this decomposition also of the hepatic gas by the air, are owing the sulphureous depositions observed in the empty parts of the vessels which contain solutions of liver of sulphur. M. Bergman attributes this to the great affinity of the air with phlogiston. He looks upon the hepatic gas as a combination of sulphur, of phlogiston, and of the matter of heat; when one of these principles is disunited, the other two separate. This opinion being only a pure hypothesis, we shall insist no more upon it, but attend only to facts, proceeding to examine its other properties. Water dissolves this gas very well; and the solution, which has all the characters of this æriform fluid, exactly resembles the sulphureous mineral waters. The earths and alkaline substances seem to have no action on it. The fuming nitrous acid decomposes and precipitates the sulphur: this is the way to prove the existence of this combustible body in the gas and in the sulphureous waters, which it is better to call *hepatic* or *hepatized*.

The alkaline liver of sulphur decomposes the earthy neutral salts as well as the metallic solutions; as we shall see hereafter.

The volatile caustic alkali, or the volatile alkaline spirit, has but very little action on concrete sulphur; however, Boerhaave asserts, that this liquor kept a long time upon flowers of sulphur acquired a golden tincture. To combine these two bodies, we must present them to one another in the state of vapour. For this purpose we distil a mixture of equal parts of quicklime and sal ammoniac, and a half part of sulphur, in Woulfe's apparatus, observing to put into the bottle no more water than is necessary to dissolve the quantity of alkaline gas to be obtained. In  
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this distillation, which we must conduct with address, we obtain a liquor of a reddish yellow, of an alkaline odour, pungent, and somewhat hepatic; in a word, a true volatile liver of sulphur, which has the property of emitting a whitish fume, and hence called *fuming liquor of Boyle*. This liver of sulphur is decomposed by heat; in a certain time, a great quantity of small needles is formed, of one or two lines, which seem to be concrete and crystallized liver of sulphur. It deposits on the sides of the vessels a slight crust, of a blackish, and often golden colour. Lime and the fixed alkalis decompose the fuming liquor. The acids likewise precipitate the sulphur from it with great facility, and separate some very inflammable hepatic gas. From these decompositions different ammoniacal salts are produced, according to the acid employed. A mistake, committed in one of my courses, brought about a discovery, or rather an accident, which I ought to communicate. Being desirous to precipitate the fuming liquor of Boyle, I took a vessel placed on my table under the title of *spirit of vitriol*; it contained only a very small quantity of fluid, which prevented me from perceiving that it was oil of vitriol quite pure. I poured some drops of it on the fuming liquor: at that very instant a rapid motion was excited; from the vessel where the mixture was, a very thick white cloud was raised, and suddenly it gave a crack resembling that of a large musket; the liquor leaped far from the glass, the vessel grew very hot, and burst in several pieces. On some of the fragments there remained only a yellowish magma, thick, and resembling sulphur. I repeated the experiment a great number of times with precaution, and I had constantly the same result; all the mixture is thrown to a distance after a violent motion: but these different phenomena succeed with such a rapidity, that it is impossible not to confound them. The most fuming spirit of nitre did not appear to me to produce the same effect on the fuming liquor. The mixture is strongly agitated, a great



heat and ebullition arises, a white cloud of nitrous ammoniac is raised; but there is no explosion as with the oil of vitriol. However, M. Proust has announced, that the nitrous acid poured on two gros of the fuming liquor of Boyle, produced as violent a stroke as two gros of fulminating powder could do (*a*).

The aërated ammoniacal salt, or the concrete volatile alkali, likewise unites with sulphur. When these two bodies meet in vapours, they unite and form a concrete volatile liver of sulphur. This liver is formed by distilling a mixture of equal parts of aërated tartar, or chalk and sal ammoniac, with a half part of flowers of sulphur. It is of a brown red, it is crystallized, it emits some white vapours when we dissolve it, it is decomposed by heat, it is altered by the air and loses its colour, and it is decomposed by the acids. The hepatic gas which it gives contains some aërial acid.

The reciprocal action of sulphur and the acids has not been examined properly. If we boil oil of vitriol on flower of sulphur, the acid gets an amber colour and a sulphureous odour; the sulphur fuses and swims like oil: by cooling, concrete globules are formed of a green colour, more or less deep according to the time employed in the solution. The acid has dissolved a small portion of the sulphur, which we may precipitate by means of the fixed alkali, as M. Beaumé has shown. This experiment, and several others of the like nature, have made M. Berthollet believe, that the sulphureous acid was nothing but the vitriolic acid, which held some sulphur dissolved. The nitrous and marine acids also dissolve sulphur; but we do not well understand these combinations.

(*a*) Perhaps the fuming liquor which I employed was different from M. Proust's. Mine was made a year before; and I can affirm that it detonated constantly with oil of vitriol, whilst it did not make a noise with spirit of nitre; and produced no more than a hissing noise, and a very considerably thick cloud. I found this cloud inflammable, as M. Proust asserted. I observed several very singular phenomena in this decomposition of the fuming liquor by the spirit of nitre, and shall give an account of them in another place.



binations. M. Proust has observed, that if we pour some spirit of nitre on fused and smoking sulphur, a detonation follows. The vitriolic neutral salts have no action upon sulphur. The nitrous salts, on the contrary, make it burn with rapidity, and even inclose vessels. Nothing is so simple as the theory of this important phenomenon. The nitre decomposed by the heat gives a very great quantity of pure air; the sulphur is a very combustible substance, or which has much tendency to unite with the air; it therefore finds in the nitre the principle necessary for combustion; there is no necessity for the contact of the atmospheric air to kindle it. We obtain very different products, according to the quantity of nitre and sulphur employed. If we set fire to a mixture of eight parts of sulphur and one of nitre in close vessels, the sulphur burns with a very vivid white flame, and is changed into vitriolic acid. It is the means that has been practised more than these 20 years in England and Holland for the preparation of this acid, which was formerly extracted from vitriol. In England they make use of great balls of glass, holding 400 or 500 pints, with very large necks. They are placed at the side of one another on a bed of sand, in two ranks sufficiently distant, so that one may easily walk between them; some pounds of water are poured into each of these vessels; by the neck there is introduced a stone pot, above which is placed a laddle of cast iron with a long handle, which previously has been made red hot. Into this last, by means of another white-iron laddle, is put a mixture of nitre and sulphur, according to the above-mentioned proportions; and immediately the aperture of the vessel is shut with a bit of wood. The heat of the laddle kindles these substances; the sulphur burns by the air of the nitre; and when the combustion is over the vessel is withdrawn, and the vapours are left to condense. The same process is repeated with each of the balloons which make up the two ranks; so that the workman, when he arrives at the first balloon which he be-



gan with, finds the vapours totally condensed, and may continue to burn a new portion of the mixture. When the water contains enough of acid, it is taken out and poured into glass retorts; the aqueous part is separated by means of distillation, and the acid is concentrated till it weighs an ounce seven gros and a half, in a bottle which contains an ounce of distilled water; it there forms the oil of vitriol in commerce. This excellent process is very expensive, on account of the price of the balloons, and on account of their brittleness. Some years ago it was contrived to burn sulphur on a kind of iron gridirons, placed in large chambers lined with lead on all sides, from whence the condensed vitriolic acid is conducted by gutters into a reservoir. Such is the process followed in the manufacture of Javelle near Paris; the establishment of which must be of great use in the arts. It is proper to observe, that the oil of vitriol procured by this process is always united with a little sulphur and vitriolated tartar; but they are in so small a quantity, that their effects are quite imperceptible in the most part of the uses for which this saline matter is employed.

If, instead of burning the sulphur with an eighth of nitre, we increase the dose of the nitre to equal parts, then, in place of having the vitriolic acid free, we obtain only some vitriolated tartar, formed by the combination of the acid with the fixed alkali, the base of the nitre. This salt, obtained in this way, has got the name of *Polychrest salt of Glauber*. It is prepared by throwing into a red hot crucible equal parts of nitre and sulphur; the residuum is dissolved in water, the solution is evaporated to a pellicle and filtrated; and we obtain, by cooling, crystals of true vitriolated tartar, called by the abovementioned name. The mixture of sulphur and nitre with charcoal form a substance, whose terrible effects are owing to its great combustibility; that is, gunpowder. It is formed, the greatest part of nitre, of much less charcoal, and of sulphur in the smallest proportion; which is 100 pounds of gunpowder of Essone, near Corbeil,



beil, contain 75 pounds of nitre,  $9\frac{1}{2}$  pounds of sulphur, and 15 of charcoal. This mixture is pounded for 10 or 12 hours in a wooden mortar, with a pestle of the same materials; and a very small quantity of water is gradually added to it. When the motion has evaporated almost all this fluid, and the powder put upon a plate of earthen ware leaves no mark of humidity, it is carried to be grained. Graining the powder is making it pass through several leather sieves, which are moved horizontally and in a direct line. These sieves have holes of different bulks, as large as to form the grains of gunpowder. The grained powder is afterwards sifted in order to separate the dust. It is carried to the drier; an apartment looking to the south, and receiving the sun's rays by a glass window. The gunpowder suffers no other operation. The powder for game is smoothed, that it may not soil the hands. To smoothe it, they fill a barrel one half, which turns by means of a square axle that pierces it, and is fixed to a wheel turned round by water. This motion of the barrel excites a continual friction, which wears down the surface of the grains of powder. This smoothed powder is put through the scarce to separate the dust; a sieve, through which it passes a second time, picks out the grains, and forms two powders of different sizes, which are equally employed for game. M. Beaumé, conjointly with M. le Chevalier d'Arcy, has composed a very great work on the manner of preparing powder, on the respective forces of this compound made with different doses of its ingredients, and on the analysis of its substance. These researches have produced a great number of facts; of which we shall take notice here of the most important only, and those which have an immediate relation with the chemical theory. 1. We cannot make good powder without sulphur, as several persons had proposed: this substance singularly augments its force. 2. All the charcoals, light or heavy, except those of animal substances, are equally fit for this composition. 3. The charcoal is one of the most useful ingredients of the powder; since a mixture  
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of nitre and sulphur does not produce near the same effects. 4. The goodness of the powder depends entirely on the accurate mixture and trituration, till the mixture fly up from the mortar by its agitation. 5. The powder has much greater effect when it is only simply dried, than when it is grained. The moisture necessary for the powder's assuming the form of grains crystalizes the nitre, which separates from the other substances: it is thus found in the heart of the grains cut through, and is observed with the magnifying glass. 6. The smoothed powder, or game-powder, is weaker than unsmoothed or gunpowder; because the molecules of the first lie closer to each other, and consequently are not so easily set on fire. With respect to the analysis of powder, M. Baumé has succeeded in it in a very simple manner. His process consists in washing gunpowder, well pulverized, with some distilled water, and in evaporating this water; by this process we get the nitre. The residuum contains the charcoal and the sulphur. The sublimation of the sulphur cannot separate it completely, because it seems to be in part fixed by the charcoal. M. Baumé employed to separate them a slight heat, capable of consuming the sulphur and not the charcoal. By this analysis, he found, that a pound of French powder contains 12 ounces of nitre, two of sulphur, and two of charcoal, which always retains a small quantity of sulphur, since, as this chemist has observed, it emits a sulphureous odour till it be entirely reduced into cinders. He valued the sulphur retained by the charcoal, at a 24th of its weight. We may also deprive the powder of the sulphur, by exposing it quite entire, and without washing it, to the action of a gentle fire. This fact was known to M. Robins, who published it in his Treatise on Artillery, written in England. The powder-makers have been for a long time in the practice of lessening the quantity of sulphur, by exposing the powder on warm ashes in a plate of tin. By experience, they are persuaded, that the powder thus treated, drives the charge much farther, and does less damage to the fire-arms.

Chemists



Chemists and natural philosophers have had different opinions on the violent effects of gunpowder. Some have attributed them to the reduction of the water into vapours; others, to the sudden expansion of the air. M. Baumé thought them owing to the nitrous sulphur which is formed in the instant of combustion. We look on this phenomenon as very easy to be explained, according to modern knowledge. To understand our theory, it is in the first place necessary to observe, that what passes in the inflammation of powder entirely depends on its great combustibility. Now, the sulphur and charcoal most minutely divided, are two bodies eminently inflammable. The intimate mixture which so greatly influences the force of the powder, according to the fine experiments of M. Baumé, is the sole cause of its effects. The nitre is found equally divided between all the molecules of these very combustible matters; as it is in much greater quantity than they are, every molecule of sulphur and of charcoal is found surrounded, and as if covered with a coat of nitre; every molecule, then, has much more air than is necessary to burn it completely, since it is demonstrated that nitre furnishes much pure air by the action of heat. In this combustion there happens, what takes place when we plunge a combustible substance into a body of air, called *dephlogisticated*. It is known that this body consumes with a spark, and in much less time than it would require in atmospheric air: we then see that all the sulphur, and all the charcoal, ought to be consumed in a single instant, because they are really plunged into an atmosphere of very pure air. From this we conceive why the inflammation of powder is so rapid; why it takes place in close vessels as well as in the open air; and why, when an obstacle is opposed to so terrible an agent, it produces explosion, and drives this obstacle with such force. The effects of this mixture of nitre, sulphur, and charcoal, are nothing in comparison to those of another preparation, called *pulvis fulminans*.  
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This powder is made with three ounces of nitre, two ounces of fixed salt of tartar, or very dry aërated tartar, and an ounce of sulphur in powder. The whole is triturated in a warm marble mortar with a wooden pestle, till the three substances are very accurately mixed. If we expose a gros of this powder to a gentle fire in an iron laddle, it fuses, and very soon detonates, with as strong a crack as that of a cannon. To understand the cause of this phenomenon, which is so much the more astonishing as the pulvis fulminans has no need of being confined and pent up like gunpowder, it is necessary to observe, 1. That it happens when this mixture is slowly heated and liquefied. 2. That if we throw some fulminating powder on burning coals, it is only fused like nitre, but without noise. 3. That a mixture of liver of sulphur and nitre, made in the proportion of one part of the first and two of the second, fulminates more rapidly, and with just as great cracks as that made with sulphur, nitre, and the alkali. It appears then, that when we heat fulminating powder, some liver of sulphur is formed before its detonation takes place. This fact alone explains the phenomenon. When we expose some nitre and liver of sulphur to the action of heat, there is disengaged some inflammable or hepatic gas from the liver, and very pure air from the nitre. Now these two gases, capable of producing a brisk detonation, as we have seen in the history of the Inflammable Gas, are inflamed by a portion of sulphur which takes fire; but as they meet with an obstacle on the part of a thick fluid through which they are obliged to pass, and as they take fire in all their points at once, they strike the air with such rapidity in their combustion, that it resists them as the sides of muskets resist gunpowder. This resistance is proved by the effect of fulminating powder on the laddle in which we expose it to the fire; the bottom of this vessel is hollowed, and the sides are bent inwards, as if it had suffered a force from above downward, and from without inward. The last mixture of nitre and sulphur which  
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we are going to consider, is that called *powder of fusion*. It is made with three parts of nitre, one part of sulphur, and one of saw-dust. We put a little of this powder into a nut-shell, with a piece of six farthings bent: this piece is covered with the same powder, and we apply the fire to it; it kindles rapidly, and fuses the piece, which we accordingly find in the shell, which is only blackened without being burnt. On this account we take care to plunge it into water as soon as the powder has ceased to burn. This experiment indeed proves, that this powder is a very good flux; but as it is owing in a great measure to the action of the sulphur on the metal, we shall resume the consideration of this fact in the history of Metallic Substances.

The neutral, marine, and sparry salts, and the different species of borax, have no action on sulphur. We have seen, that the aërated alkaline salts united with this substance, and rendered it soluble in water. Inflammable gas does not act in any remarkable degree on sulphur. It is of importance to observe, that very great analogies seem to subsist between these two bodies. The vitriolic acid, in its combination with combustible bodies, produces frequently inflammable gas, frequently sulphur. In all the places where inflammable gas is produced, as in the animal matters which are putrefying in large masses, sulphur is likewise formed. This last, combined with the alkaline substances, is altered, and passes to the state of inflammable or hepatic gas. Lastly, inflammable gas acts on a great number of substances as sulphur does. These hints on the analogies of these two substances require, as we see, a particular research, in order to confirm them.

Sulphur is susceptible of combining with many other substances; but as we are not yet acquainted with them, we shall forbear saying any thing about their union with this mineral till we treat of their properties.

Sulphur is an excellent medicine in the pituitous diseases of the lungs; and above all in the diseases of the skin.



skin. It is employed with great success in the humid asthma and scabby eruptions. It is administered either in the form of flowers of sulphur, or in tablets prepared with sugar. With the oils we make an ointment, with which we anoint the parts covered with scabs.

The livers of sulphur have been proposed for obstructions, numbnesses, palsies, the diseases of the skin, &c. Although some physicians have supposed that sulphur does not dissolve in the animal humours, it is however certain that it penetrates even to the most fine vascular extremities, since the persons who use it have their perspiration, urine, and spittle manifestly impregnated with it. The hepatic gas dissolved in the mineral waters, as those of Cauterez, Aix-la-Chapelle, Montmorency, communicates to them expectorant properties; and is very much recommended in the diseases of the skin, lungs, articulations, and in palsies.

Sulphur is of no less use in the arts: it is one of the most necessary ingredients in gunpowder; it is used to take very elegant impressions from engraved stones; combustible matches are made with it; it is used to whiten silks, and to destroy certain colours; to stop the fermentation of wines, &c.

## LECTURE XXVI.

### GENUS 4. *Metallic Substances.*

**T**HE metallic substances form an order of bodies very important and very useful in the different purposes of life, in chemistry, and in medicine. They differ essentially from the earthy and saline matters in their physical qualities, as well as in chemical properties. Previous to our entering upon the examination of each of those substances in particular, it is necessary to consider them in general. To do this in order, we shall treat, in several paragraphs, 1. Of their physical properties; 2. Of their chemical properties;



perties; 3. Of their natural history; 4. Of the art of knowing their nature and quantity, or of assaying; 5. That of working them in great, or of metallurgy; 6. Of the manner of distinguishing them from one another, and of the divisions which it is essential to establish among them.

§ 1. *Of the physical Properties of metallic Substances.*

THE metallic substances have an absolute opacity. This opacity is much greater than that of the stony matters; for the most opaque stone, when in very minute laminæ, has a kind of transparency; whereas the finest lamina of any metal is perfectly opaque, and as much so as a large mass of the same metal. The opacity of the metallic substances renders them very proper to reflect the rays of light, and no body possesses this property in so remarkable a degree as these substances; hence glass mirrors reflect objects only because they are covered with a leaf of metal. This property, particular to the metals, constitutes brightness, or metallic brilliancy; a quality which is always in the compound ratio of the density or hardness of the metals, which allows it to take a very bright polish, and of its colour. The white metallic substances reflect more rays, and are more brilliant, than such as are coloured.

The metallic substances have a specific gravity much more considerable than the other mineral bodies. A cubic foot of marble weighs only 252 lb.; a cubic foot of tin, which is the lightest of the metals, weighs 516 lb.; and a cubic foot of gold, 1326 lb. This weight, much above that of the earthy matters, without doubt depends on the great density of the metallic substances, to which they also owe their perfect opacity and brilliancy.

The greatest part of the metallic substances is susceptible of extension, by means of a repeated percussion or of a strong pressure. This property, which is particular to these substances, and which we have not had occasion



sion to observe in any substances that we have yet examined, is called *ductility*. We think that two kinds of it ought to be distinguished. The one, called *ductility by means of the hammer*, or *malleability*, is distinguished by this, that the metals having this property may be extended into minute laminæ without breaking. Lead and tin give us an example of this sort of ductility. The other consists in a successive and almost extreme elongation of certain metallic substances, so that they form a thread more or less fine. This is the ductility in wire-drawing, such as is observed in iron, copper, and gold. It has also got the name of *tenacity*. It is of the more importance to distinguish well these two sorts of ductility, as they seem to be really very different from one another; since metallic substances, which are very malleable, often possess very little tenacity; and those which are easily drawn into wire are in a small degree malleable. We estimate the tenacity of metals in a very exact manner, by marking the weight which a metallic thread of a known diameter is able to support without breaking. Both these properties seem to depend on a particular form of the integrant parts of each metal. It seems that the metals which extend into thin plates by percussion, are formed of small laminæ, which, when we come to strike them, slide on the sides of one another, and increase in size in proportion as they lose their thickness; whilst those which can be drawn present a kind of fibrous texture, whose filaments, disposed in packets, approximate, and are elongated by means of the strong pressure to which we subject them in drawing. The ductility of the metals has bounds. It is observed, that when a metal, even very ductile, has received several strokes of a hammer, it hardens and rents, in place of extending: this property is called *stiffening*. When we heat slowly and cautiously a stiffened metal, it becomes more ductile, and may be struck without breaking. It seems that the parts extend under the hammer only as they find

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find between them a space which they can fill, in proportion as they yield to the pressure. We easily conceive, that the parts, once brought so near by percussion as to leave between them no interval, could no longer yield to the hammer; and that in this case the metal will rent. Heat, by dilating it, separates its parts, and produces new spaces between them, which allow them to approach anew by means of the repeated percussions.

As ductility is found in certain metallic substances only, the chemists and naturalists have used the presence and absence of this property to distinguish those substances. Those which join ductility to opacity, weight, and metallic brilliancy, they have called *metals*; and *semi-metals*, those, which, with the metallic appearance, are not ductile. But this distinction, though exact enough, is not sufficient for dividing all the metallic substances into two classes; because, from the extreme ductility of gold to the singular brittleness of arsenic, we find this property vary by insensible degrees; and because there is perhaps a greater difference between the ductility of gold and that of lead, which is looked upon as a metal, than there is between lead and zinc, which is ranked among the semi-metals, and between zinc and arsenic; nature, it would appear, passing by insensible shades from one body to another.

The metals, considered with respect to the degree of their ductility, ought to be ranked in the following order. Gold is the most malleable of all; then silver, copper, iron, tin, and lead. The semimetals have been looked upon as possessing no ductility. However, we shall see that this property exists in a certain degree in zinc and in mercury. As to tenacity, gold has the most: then we place iron, copper, silver, tin, and lead. That of platina is not known.

The metallic substances are susceptible of assuming a regular form, either by the work of nature or the efforts of art. A long time ago, the naturalists knew this property, which nature had presented to them in



native bismuth, pure silver, and some other metals. The alchemists also had observed the ramified or starred figures which are formed at the surface of regulus of antimony and of bismuth. M. Baumé, in the second volume of his *Experimental and Rational Chemistry*, has asserted, that the metallic substances which have been well fused, assume, by a slow cooling, a symmetrical and regular arrangement. M. l'Abbe Mongez, royal canon of Saint Genevieve, has composed a work on the crystallization of all metallic substances. M. Brongniart, professor of chemistry in the Royal Garden, has also been busied upon this subject; and many chemists have repeated their processes. The result of them is, that all the metals are capable of crystallizing; and though several of them may have a crystallization different in appearance, the greatest number, however, present the same form, with some modifications.

Some metallic substances have taste and smell; as regulus of arsenic and of antimony, lead, copper, and iron. These properties are constantly found in all those which are the most alterable. Sometimes they are even in so remarkable a degree, that those substances are capable of corroding and entirely destroying the animal organs.

## § 2. *Of the chemical Properties of metallic Substances.*

ALL the chemical properties of the metallic substances seem to demonstrate that they are simple, and that they cannot be decomposed. The alterations which they undergo from the light, heat, air, and saline substances, are always owing, as we have said, to combinations; and not one of these alterations can be compared to an analysis, as we shall demonstrate by a particular explanation of the phenomena which they exhibit.

Light alters the colour and brilliancy of some metallic substances. Well shut up in transparent vessels, they are tarnished by it, and assume a different colour, which makes



makes their brilliancy gradually disappear. This kind of alteration has not been farther examined.

Heat makes them undergo only some changes of aggregation, and that with more or less facility or readiness. All the metallic substances heated in close vessels fuse, some before they are red, others in the instant they become so, others a long time after they are reddened. There are as many degrees of fusibility, as there are species of metals. If we leave them to cool after they have been fused, they crystallize; if we urge them with a violent fire, they boil like fluids, and are reduced into vapours. It is a long time since these properties in mercury were known. Several goldsmiths have assured me, that they have seen gold and silver boil in fusion. M. de Buffon has observed, that by exposing plates of silver to the focus of a large concave mirror, he raised a white fume from the surface of the plates. Messrs Macquer and Lavoisier having exposed some cupelled silver to the focus of M. Tschirnhausen's lens, saw this metal exhale in smoke; a plate of gold exposed to this smoke was perfectly silvered over. Gold exposed to the same focus likewise gave fumes which perfectly gilded a plate of silver. The goldsmiths and essayers chimneys are filled with the fumes of gold and silver. Copper, tin, lead, zinc, bismuth, and arsenic, are very easily volatilized.

All metals when fused appear convex at their surface; and when they are in very small masses, they form perfect spheres: this effect depends on the force of aggregation which makes the metallic parts approach to one another, and on their small tendency to combination with the bodies in which they are put. This property is common to all fluids; and we may observe it in oil with regard to water, and in water with regard to greasy substances. The metals exposed to the action of the fire with the contact of air suffer very sensible alterations; some sooner, others more slowly. Those which are not sensibly altered are called *perfect metals*; and those



*imperfect*, which entirely lose their metallic properties by this process. This alteration of the metallic substances, which we call *calcination*, is a true combustion; it cannot be done without the help of the air, as is the case with all combustible substances: and when it has taken place some time in a certain quantity of air, it cannot be longer continued unless the air be renewed. This air in which the metals have burnt, has become mephitic: the combustion of the metallic substances is accompanied with a more or less vivid flame; this flame is very sensible in zinc, regulus of arsenic, iron, gold, and silver; it is the same in tin, lead, and regulus of antimony, which have been strongly heated. By burning, the metals lose their metallic properties in a manner so much the more remarkable, as they have been exposed for a longer time to the action of fire and to the contact of air; some seem then to approach to the character of earthy matters: in this state therefore they have got the name of *metallic earths*. To this name we would prefer that of *metallic calces*; because it is now demonstrated, that those burnt metals are not earths, as it was some years ago believed. The metallic calces have no longer the brilliancy and fusibility of metals; they no longer have any affinity with these bodies, nor even with the metal that has been employed to suffer such a change. If we urge them with the fire, they are volatilized, or fused into a glass. The glass is so much the more transparent and difficult of fusion, as they have been more strongly calcined. The calces, or metallic glasses, unite with the earthy and saline matters. Several of them have the characters of saline matters. Arsenic well calcined becomes a particular acid, whose properties have been examined by Messrs Scheele and Bergman. M. Rouelle has informed us, that calx of antimony dissolved in water, and also arsenic. Some metallic calces exposed to the action of the fire are reduced to their metallic state; and in their reduction furnish an æriform fluid, which is the most pure air that we know. We owe the  
first



first knowledge of this fact to M. Bayen. He observed, that the calces of mercury heated in close vessels gave much air; and that they were reduced into flowing mercury. Dr Priestley having examined this air, saw that it was much better than atmospheric air; and to this discovery we ought to assign the epoch of our exact knowledge of the calcination of metals. Let us dwell a moment on the phenomena of this operation. A metal never calcines, till it be exposed to the contact of air: the greater this contact, the more the metal is calcined, as M. Lavoisier has ingeniously demonstrated, by means of a reflecting mirror, in the calcination of lead in a vessel, which contained a known quantity of air. In calcining, the metal absorbs a portion of the air which surrounds it, since the mercury, above which we calcine a metal under a vessel, mounts in this vessel as the calcination advances. It is to this portion of air absorbed, that the metallic calces owe the weight which they acquire in this calcination; since, when we extract it from the calces of mercury, they lose, in their reduction to the metallic state, that excess of weight, which we exactly find again in the air that they furnish by means of distillation. From these phenomena it seems demonstrated, that calcination is nothing but the combination of the metal with pure air contained in the atmosphere. This combination is often effected by the contact of the air alone in the metals which calcine or grow rusty. If we are under the necessity of heating the most part of the metals in order to calcine them, it is only because the heat, by diminishing the force of aggregation, augments in the same proportion the force of affinity, or of combination, and thus promotes that action, which we wish to produce between the air and the metal. In this operation then, as in many solutions, heat is only an auxiliary. The air which has served to calcine a metal can no longer support combustion, because it is deprived of this pure portion, of this virgin air, of this vital principle of the ancients, which alone can support combustion



and life. The more pure air the atmosphere contains, the more proper it is for calcining quickly a given quantity of metal. I have often observed, that a much greater quantity of metallic calx of lead, bismuth, &c. can be made by plunging them when fused into a vessel full of pure or dephlogisticated air, than can be made in the same time in the open air. All these facts, and a great number of others, which will be found in the particular history of each metal, are very proper to demonstrate, that a metallic calx is nothing else than a chemical combination of the metal and pure air; that calcination is nothing else but the very act of this combination, and that the atmospheric air is decomposed in this operation.

The reduction of the metals by means of combustible matters, clears up this theory still more, and gives it a new force. When we wish to reduce a calx to its metallic state, we are often obliged to heat it in close vessels with combustible matter, as with fats, oils, charcoal, &c. In all those cases we decompose the metallic calx, by taking from it the air which rendered it a calx. To understand well what happens in this operation, we must conceive, 1. That the metals are not the most combustible bodies in nature; or, what is the same thing, that they have not the greatest possible affinity with pure air. 2. That the vegetable or animal combustible matters have more affinity with pure air than the metallic substances have. 3. That in consequence, when we reduce a metallic calx by means of charcoal, this being more combustible than the metal, or having more affinity than it with pure air, it attracts the air, and decomposes the metallic calx, which, deprived of air, is nothing but the metal itself. These kinds of operations also do not succeed completely but in close vessels, where the combustible matter not having contact with the air, is obliged to burn by means of that of the calx. For this reason the portion of this inflammable substance which has seized on the pure air of the metallic calx,  
is



is found to be in the state of cinders after the reduction.

It would be unpardonable, in giving the history of the calcination of metals, according to the theory of some moderns, to pass over in silence that of Stahl, which has been almost universally adopted by all the chemists, and to seem to give the preference to the first, without giving particular reasons for so doing. Stahl looked upon the metallic substances as compounds of particular earths and phlogiston. According to him, calcination was only the disengagement of the phlogiston; and reduction restored to the metallic calces this principle which they had lost in their calcination. We see that this theory is absolutely the inverse of the first; since it affirms that the metals are compound substances, whilst the pneumatic theory considers them as simple. According to Stahl, they lose a principle in their calcination according to the new doctrine; and we think that they combine with another substance in this operation. In the last place, this great man thought, that during reduction the metallic calces resume the phlogiston which was disengaged by the action of the fire; on the contrary, some moderns think that the reduction is only the simple disengagement of the substance which was combined with them during calcination.

From this slight comparison of these two theories, let us try to show, to whether of the two the greatest number of facts is favourable. Let us again repeat here, that Stahl, intent solely on demonstrating the presence of phlogiston in the metals, seems to have overlooked the influence of the air in calcination. But Becher, Jean Rey, Boyle, and several other chemists, suspected that this element had the principal share in these phenomena. The theory of Stahl, however satisfactory it may have appeared till the epoch of the new discoveries on air, cannot now be found to agree with all the facts, which demonstrate the necessity and action of this fluid in calcination. There are therefore several inexplicable phe-



nomena in Stahl's theory, which even render it imperfect. Such is, for example, the weight of the metallic calces being more considerable than that of the metals before their calcination. We shall never conceive how a body can augment in weight by losing one of its constituent parts; and as weight is one of the properties which serves to demonstrate the presence of any substance, the ingenious explanation which M. de Morveau, in his Dissertation on Phlogiston, has given of the phenomenon in question, cannot be entirely satisfactory; particularly since we have discovered the existence of air in metallic calces. From these facts then it appears, that the pneumatic theory has some advantages over that of Stahl. However, M. Macquer, guided by that sage circumspection which we cannot but praise, has connected the modern discoveries with the doctrine of phlogiston, and has even thought that they serve to confirm it. According to this celebrated chemist, the metals cannot lose their phlogiston and be calcined, but as the pure air of the atmosphere is precipitated and unites with their substance; and they are not reduced till the phlogiston, aided by heat, disengages the pure air from them: so that these two substances are mutually precipitants of one another.

The metallic substances are altered by the air: their surface tarnishes: some are covered with rust. The chemists have looked upon the rust as a metallic calx. We shall have several times occasion to recur to this subject.

Water dissolves certain metals; it has no action on others: it promotes in a singular manner the rust on those, which are susceptible of it.

The earthy substances seem to have no action on the metals. We do not know the action of the saline-earthly substances on them. The alkalis dissolve some of them, but act very weakly on most of them. The acids combine much better with the metals. The vitriolic acid produces either inflammable gas or sulphureous gas, or sulphur, in uniting, according to Stahl,  
with



with their phlogiston; or by being decomposed, according to the moderns, and by losing its pure air, which is taken from it by the metallic substances.

The nitrous acid frequently dissolves them with more rapidity than the vitriolic; though, in general, its adhesion is much weaker. It produces a great quantity of nitrous gas; the metal is found more or less calcined; it is precipitated, or rather it remains united to the acid. Stahl attributed this effect to the disengagement of the phlogiston of the metals. Some chemists think that it is owing to the decomposition of the acid, and to the separation of the pure air and nitrous gas, which they look upon as the two principles of this acid. M. Proust has discovered that several metals make nitrous acid detonate. *Journal de Medicine*, July 1778.

The marine acid in general acts with less energy on these substances. However, the solutions which it makes are more permanent, and often more difficult to be decomposed, than those by the preceding acids.

Aqua regia dissolves them with particular phenomena.

The aërial acid attracts them but weakly; however, it is susceptible of combining with most of them, as is demonstrated by M. Bergman. Nature often presents combinations of this acid with the metals, and sometimes those kinds of salts are crystallized.

The sparry acid, and sedative salt, also unite with the metals; but in general those compounds are little known.

Among all the combinations of the metals with the acids, some are susceptible of crystallizing, others assume no regular form; some are decomposed by the fire, and some suffer no alteration from it. The most of them are altered by the air. All are more or less soluble in water, and may be decomposed by this fluid in great quantity; as M. Macquer has remarked. All are precipitated by clay, terra ponderosa, magnesia, lime, and the alkalis, which in general have more affinity with the acids.

The



The neutral salts are but very little altered by metallic substances, as far as their action goes by the humid way; but if we strongly heat mixtures of those salts with the metals, several of them are decomposed. Several vitriolic salts then form sulphur. M. Monet is the only chemist who has properly understood these decompositions. Nitre detonates with the most part of them, and calcines them.

Sal ammoniac is frequently decomposed by these substances.

These properties pointed out here in general, shall be fully examined in the history of each metallic substance.

### § 3. *Natural History of the metallic Substances.*

THE metallic substances exist in the earth in three different states: the first is that of a pure or native metal, that is, possessing all its properties: it is thus gold is always found; frequently silver, copper, mercury, bismuth, arsenic; rarely iron; more rarely lead, zinc, regulus of antimony; never tin and cobalt.

The second state in which the metallic substances are found, is that of earth or calx; that is, not having a metallic appearance, but rather a kind of resemblance to the ochres, or the stony matters called *spars*. Hence we call these kinds of minerals *sparry metals*. Copper is often found in the state of a green or blue calx, sometimes regularly crystallized; iron in the state of rust, or of white or coloured spar, sometimes crystallized; lead in the state of a crystallized calx, or of white, red, or green spar; tin in the same state sometimes; zinc in the state of calamine; cobalt in red flowers; and arsenic in a white calx.

The third natural state of the metals, and that which is the most common, constitutes ores or minerals. In them the metallic substance is found combined with some matter which takes its metallic properties from it, and it cannot display them until it be separated. This matter, which is called the *mineralizer*, is either sulphur, or  
another



another metal, or some saline substance. Zinc, iron, copper, are often, lead seldom, found combined with the vitriolic acid. Some chemists even assert, that sulphur is the most common mineralizer. It is united with silver in vitreous silver; copper mines almost always contain a very great quantity of sulphur: iron is combined with this mineral in the martial pyrites, lead in galena, mercury in cinnabar, zinc in blend, regulus in antimony; lastly, we sometimes find bismuth combined with sulphur, and frequently arsenic. It is proper to observe, that all the metals have not the same affinity with sulphur. There are some which contain a great quantity of it, and easily part with it; their metallic brightness appears to be a little altered by it; such as copper, lead, regulus. Others contain very little of it, but it adheres very closely to them; and though it be in small quantity, it makes almost all the metallic qualities disappear: such is the case with cinnabar. Metals may be found joined with other metals, but it is arsenic in particular which mineralizes them. Iron, tin, and cobalt, are often found combined with arsenic; sometimes the metal is united at the same time to arsenic and to sulphur, as in the red mineral of antimony and red silver. Lastly, there are metallic ores composed of several metals and of several mineralizing substances; as the grey ore of copper, the grey mineral of silver, and some others.

The metallic substances are much less abundant in the terrestrial globe than the stony matters. In the mountains they form veins or ridges, which cut the beds of earths and stones more or less obliquely. This is the most ordinary state of the mineralized metals. Those which are found in the earthy state, are often in masses which the water has carried along, and sometimes crystallized. We find also some metallic ores in shapeless masses; then they owe their formation to some particular accidents. The metallic ridges are accompanied with stony matters, which seem to have been formed at the same time with them. These stones are generally quartz and spar. They



They form two layers: the one on which the ore is placed, is called the *bed* or *soil*; the other, which covers it, is called the *roof*. These stones constitute what is called the *matrix* of the mine, which ought not to be confounded with the mineralizer; for this is combined with the metal in a manner that it cannot be separated from it except by chemical processes, whilst the matrix may be separated from it by mechanical means. Neither must we confound the matrix, which is formed of crystallized stones, with the rock which forms the mass of the mountain in which the metallic ridges are found. These last are divided into rich or poor, into roofed or veined ridges; into ridges of a true course, which continue in the same direction; or into uneven ridges, which turn, and are interrupted in their course.

All the metallic substances seem to owe their formation to water. In short, most of them are found crystallized, or mixed with substances, which the fire could not have failed to alter; as the calcareous stones and sulphur: and we find among them bodies which have preserved the vegetable or animal organization; an organization which fire would not have regarded. Perhaps there are some metallic ores which might have been formed by fire; such seems to be the ore of iron of the island of Elbe: but these cases are rare. Mines are found more commonly in mountains than in plains; and almost always in those which form continued chains. It is observed, that the plants, which grow at the surface of the mountains that contain these matters, are parched; the trees are twisted, and have a bad appearance; snow melts on them almost as soon as it falls; the sand often presents metallic colours; springs of metallic mineral waters are found in the neighbourhood: the examination of these waters, and of the sands which they carry along, furnish very good marks of the presence of the metallic matter which is in the neighbourhood. When we see some metallic veins appear at the surface of the earth, these marks should be sufficient to cause



cause the earth be founded. Sounding, or ascertaining the substances which compose the heart of the mountain along with the metallic mineral matter, serves to show what is the nature of this substance, and the resistance which we are to expect from the soil.

§ 4. *Of the Art of assaying Ores (a); or, Of Docimasia.*

WHEN we have extracted a certain quantity of ore, it is necessary to make a trial of it, in order to know exactly the nature and product. Those trials form one of the most important parts in chemistry; to which we give the name of *docimasia*. They ought to be varied according

(a) The blow-pipe is at present much employed to enable chemists to form a ready judgment of the properties of mineral bodies. This instrument consists of a tube six inches long, with a ball at the end, from the side of which a lateral pipe comes out an inch in length. The purpose of the ball is to collect the vapours, and the opening at the extremity should be no larger than will give admission to a small pin. A candle or a lamp supplies the heat. The blow-pipe is brought near to the flame, and the air issuing through the aperture propels it to a great distance. The flame is of a conical form, and of two colours. In the external part it is white; in the internal blue. The extremity of the blue part of the flame is the hottest point; and in order that the body may not cool during the operation, the blast must be uniformly supported, by inspiring thro' the nostrils, while the cheeks are kept constantly full of air. The objects to be examined are placed on supports of different materials: in most cases charcoal answers best; but then we must be careful that it be not of a nature to fly off with the heat, and that it be sufficiently burned, lest it take fire and disturb the process. In other cases, when the charcoal absorbs the essays, we employ a small cup of gold, which is to be preferred to all other metallic substances, as it does not calcine by heat, and is not attacked by sulphur, or by the saline fluxes. We add fluxes according to the nature of the body to be examined, mineral alkali, phosphoric acid, and borax. A small fragment of the specimen assayed is placed on a support with the proper additions, and the flame directed to it. Volatile bodies, such as arsenic, are known by the smell; the more fixed, by either the appearances which they exhibit during the act of fusion, or after they are cold. Almost all metals and stones may be known by trials in this way: but the particular treatment requisite for the essay of all the different species, would require too much room for this place, and therefore must be omitted.



according to the nature of every ore; however, there are certain general processes which it is proper to follow in all trials.

We take specimens of ore, which we choose among the richest, the poorest, and those of a middle richness. This operation is called *choosing the ores*: it is indispensable, because if we attempt the assaying of a rich specimen only, too flattering hopes might be conceived; if we assay very poor samples, we might be discouraged. The ores being chosen, we must pound them well, and then wash them with plenty of water. This fluid carries off the matrix reduced into powder; the mineral, as being more weighty, remains at the bottom of the vessel where the washing is performed. The washed ore ought then to be roasted, in order to take off by sublimation the greatest possible quantity of the mineralizer: this should be done in a small earthen vessel, covered with one of the same kind. This precaution is necessary, because certain ores crackle with the fire, and jump out from the capsule in which they are roasted: this accident is capable of rendering the result uncertain. As this roasting, done in open air, generally leaves the metal in form of a calx, and may even make part of it be lost if the metal be volatile, we should prefer burning the ores in a stone retort. This operation has the advantage of discovering the nature and quantity of the mineralizer, and of affording a much more complete analysis of the ore which we are assaying. When the ore has been kept red for some time, and no vapour has exhaled, the roasting is finished. As we have weighed the ore before and after washing, to determine the quantity of matrix which it contained, we weigh it again after roasting, in order to know how much it has lost in this operation.

The roasted ore ought to be fused. For this purpose we mix it with three parts of black flux and a little decrepitated marine salt; we put it into a crucible, shut with its cover, and place the crucible in a good fusing furnace.



furnace. The alkali of the black flux fuses the metal, and absorbs the portion of mineralizer which remains in the ore. The charcoal of the tartar, which is found in the black flux, serves to reduce the calcined part of the metal; the marine salt prevents the mixture from suffering any loss during the fusion, because this salt being more light than the other matters, always flies to the upper part of the crucible, covers the mixture, and alone supports the waste. The fusion being ended, we must leave the crucible to cool very slowly: we know that the matter has been properly fused, when the metal is collected into a single button, convex at its surface; when we find no grain in the scoriæ; and the scoriæ themselves are in a vitreous mass, compact and uniform, covered with a layer of fused marine salt. We weigh exactly the metallic button, and we know in what proportion metal is contained in the ore which we are assaying.

There are minerals which are more hard and refractory: then we add more active fluxes, and in greater quantity; as borax, beaten glass, the fixed alkalis, &c. It often happens that the same mineral contains perfect metals along with imperfect: they are separated by heating the metallic button with the contact of air. The imperfect metal is calcined and dissipated; the perfect metal remains pure: this operation is generally called *refining*. The perfect metals which we get by this process is almost always a mixture of gold and silver. These two metals are separated by means of a solvent, which attracts the silver and leaves the gold untouched: this operation is called *parting*. The residuums which all these processes furnish ought to be weighed with the assay-balance.

This labour, however accurate it may appear, often is less useful to guide us in exploring an ore than a slighter one; because in works in great we do not employ materials so expensive; and besides, we do not go to work with so great care: we must then endeavour to fuse the  
ore



ore across the coals in a fusing furnace. The coals reduce the metallic calx; the fixed alkali produced in their combustion absorbs a portion of the substance, which mineralizes the metal. It is necessary to add sometimes a little filings or scoriæ of iron, or some glass gall, to facilitate the fusion of the very refractory ores.

There is a kind of essay by the humid way, which may be practised when we want to know the metals contained in specimens of ore which we propose to keep in cabinets of natural history. We take a small bit of the specimen; we digest it in the acids which dissolve the metals, and separate the mineralizer. The salt which results from the union of the metal with the acid discovers the quality of the metal: but this kind of essay cannot be used for all sorts of ores, because they are not all susceptible of being affected by the acids.

§ 5. *Of the Art of extracting and purifying in Great the Metals; or, Of Metallurgy.*

WHEN by a proper essay we have ascertained that the ore may be smelted to advantage, we proceed in the following manner. We dig square perpendicular shafts, large enough to place in them straight ladders for the workmen to descend and ascend. Above these pits we generally put axles to draw up the buckets charged with ore: sometimes also pumps are used to draw off the water which is collected in them. If the mine be too deep for one pit to lead to the bottom of the ridge, we make a horizontal gallery, at the end of which we dig a new pit, and so on until we come to the bottom of the mine.

If the rock in which we dig is very hard, and capable of supporting itself, the mine has no need of being supported; but if we work in soft rock, or in earth which may fall in, we are obliged to prop the galleries, and to line the pits with pieces of timber, which we cover with planks throughout the surface. It is essential to renew the air in mines: when it is possible to make a hole through a gallery, which from the bottom of the pit leads  
straight



straight up to the plain, the current of air is easily established; when that cannot be done, we make a vent which ends at the extremity of the gallery, opposite to that where the first pit ends. When one of the two pits is deeper than the other, the air very easily circulates; but if the two pits are of an equal height, a current of air cannot be brought about: in this case we kindle a fire in a furnace above one of the pits, and the air forced to pass through the combustible matters is continually renewed in the gallery.

Water, too, is a very great inconvenience in mines: if it issues out gradually between the earths, we endeavour to find an outlet for it into the plain, and from thence into the neighbouring stream, by means of a level through the earth. If it collect in greater quantity, we draw it off by means of pumps. Sometimes in piercing the rocks there issues an enormous quantity of water, capable to fill in an instant all the galleries: the workmen are warned of this by the sound which they hear in striking the rock; then they make a door in one of the galleries, which may be shut by any person; a workman strikes the rock to give vent to the water; and retiring, shuts the door on himself, and has time to get to a distance, before the water can overtake him.

In the subterranean mines, vapours of the aerial acid and of inflammable gas rise, disengaged, or formed by the reaction of the mineral and metallic matters on one another. Frequently also the fires, which the workmen kindle with the design of softening the rock, favour the disengagement of these gases; the dangerous effects of which cannot be prevented except by rapid currents of air, or by detonation.

The ore taken out of the earth is next pounded, washed, roasted, fused, and refined. The ore is pounded by great pestles moved by a current of air; the pestles are called *bocards*. When pounded, it is washed upon tables inclined so that the water runs and carries off the



matrix. The ores which contain much sulphur should be roasted in the air; those which contain little of it should be roasted in furnaces, which afterwards serve to fuse them. Some ores are fused alone; others require to be fused across coals, and with different fluxes. The furnaces for fusion differ according to the country, and the more or less refractory quality of the ore. Those which serve for refining are not essentially different from the first. Sometimes even these two operations are done in the same furnace. When the metals have been thus reduced, several are for the most part united together; for their separation, we have recourse to processes entirely chemical, which we shall mention in the article of each metal.

§ 6. *Distinction of the metallic Substances, and the particular History of each of them.*

THE number of metallic substances being very great, it is necessary to establish among them an order, which unites those whose properties are similar, and separates those which differ from one another. Ductility serves for the first character. The metallic substances which have none of it at all, or which have it in a very limited degree, have been called *femi-metals*; on the contrary, those which are very ductile are called *metals*. The femi-metals are either very brittle under the hammer, or susceptible of slight extension; which occasions a subdivision in these substances. The metals also may be very much subdivided, relatively to the manner in which the fire acts upon them. Some heated with the concurrence of air are easily calcined; others, on the contrary, when treated in the same way, suffer no alteration. The first are the imperfect, the second the perfect metals. In order not to multiply divisions in the treatment of them, we here give a Table, in which the metallic substances are disposed in the rank that each of them ought to hold. Afterwards, we shall give the particular history of each metal according to this view, and without referring



referring to the division to which it belongs; which would be of no use after the preliminary table.

The METALLIC SUBSTANCES.

| Either but little Ductile,         | Or very Ductile.  |
|------------------------------------|---|
| I. <i>Section.</i>                 | II. <i>Section.</i>   |
| SEMIMETALS.                        | METALS.   |
| 1. <i>Division.</i>                | 1. <i>Division.</i>   |
| Some break under the Hammer.       | Some are easily calcined when heated with the contact of Air. |
| Arsenic.                           | IMPERFECT METALS.   |
| Cobalt.                            | Lead.   |
| Bismuth.                           | Tip.  |
| Regulus of Antimony.               | Iron.   |
| Nickel.                            | Copper.   |
| Manganese.                         | 2. <i>Division.</i>   |
| 2. <i>Division.</i>                | Others are not calcined by the same Process.                  |
| Some have a kind of Semiductility. | PERFECT METALS.   |
| Zinc.                              | Silver.   |
| Mercury.                           | Gold.   |
|                                    | Platina.  |

LECTURE XXVII.

Species 1. *Arsenic, or Regulus of Arsenic* (A).

**A**RSENIC ought to be placed first in order of the semi-metals, because it has great relation with the salts. Kunckel looked upon it as a coagulated aquafortis. Becher and Stahl thought it a saline matter. M.

A a 2

Bergman

(A) We give the name of *arsenic* to the semimetallic substance known ordinarily by that of the *regulus of arsenic*. This last denomination is improper, and ought to be disused. What is called *white arsenic* is the calx of this semimetal.



Bergman thinks that it is capable of forming a particular acid. M. Baumé has an opinion not very different; however, Messrs Brandt and Macquer have proved that this substance was a true semi-metal. Arsenic, furnished with all its properties, in reality has all the characters of metallic matters: it is perfectly opaque; it has the brightness and brilliancy peculiar to these substances; and it is very weighty and fusible.

Arsenic is often found native: it is in black masses, not brilliant, and very heavy. Sometimes it has the metallic lustre, and reflects several colours of the rainbow. When it is broken it appears more brilliant, and seems to be composed of a great number of small scales; when these scales are perceptible on the outside of specimens, they are then called *testaceous arsenic*, or improperly *testaceous cobalt*: because formerly, as the metallic character of arsenic was not known, and as a great quantity of calx of arsenic was extracted from mines of cobalt, testaceous arsenic was looked upon as an ore of cobalt. Pure arsenic is very easily known, when it has the metallic lustre, and is in small scales; but when it is black, and its fracture appears composed of fine compact grains, it can be distinguished only by its weight, which is very considerable, and because, if we expose it on burning coals, it is entirely dissipated in the form of white fumes, which have a strong odour of garlic. This last metal is found in great plenty at Sainte-Marie-aux-Mines. It is mixed with the grey ore of silver; it is found also among the ores of cobalt in Saxony, and at Andrarum in Scania.

Sometimes nature presents arsenic in a white calx, having even a vitreous appearance; but for the most part in the form of flowers, or mixed with some earths. This calx also is found at Sainte-Marie-aux-Mines; it is known by the white fumes and odour of garlic which it emits, when it is thrown into the fire.

Arsenic is often united with sulphur; in this form it is orpiment and realgar. Native orpiment is in masses,  
more



more or less bulky, yellow, brilliant, and as if talky: there are some of them more or less brilliant; it is often mixed with realgar; it sometimes approaches to green. Realgar is of a transparent red, more or less lively. Much of it is found at Quito and on Vesuvius. These two matters appear to differ only in the greater or less degree of fire which has combined them.

Mispikel, or arsenical pyrites, is the last mineral of arsenic. This semi-metal is found combined with iron. Sometimes mispikel is crystallized in cubes; sometimes it has no regular form. This ore is of a white and cat's-eye-stone colour. Wallerius calls it *white cubic ore of arsenic*.

Arsenic is found also in mines of cobalt, red antimony, tin, iron, copper, and silver.

Pure arsenic, likewise called *regulus of arsenic*, is of a blackish grey colour, reflecting the colours of the rainbow; it is very weighty and friable.

Exposed to the fire in close vessels it is sublimed without suffering any decomposition; it is even one of the most volatile metallic matters. When slowly sublimed, it is susceptible of crystallizing in triangular pyramids. Arsenic heated with the contact of air is calcined very quickly; its calx is dissipated in the form of white fumes, which smell strongly of garlic. When arsenic is made red hot, it seems to burn with flame.

The calx of arsenic differs essentially from all metallic calxes. It has a very strong, and even caustic taste; it is a very violent poison. If we expose it to the fire in close vessels, it is volatilized by a moderate heat into a white crystalline powder, called *flowers of arsenic*; if the heat be a little stronger, it is vitrified by sublimation: there results a very transparent glass, susceptible of crystallizing into a flat triangular solid, whose angles are truncated. This glass is easily tarnished by the air. No metallic calx is volatile of itself; and that of arsenic alone presents this property. It is both very fusible and



very vitreifiable. M. Brandt advances, that arsenic is diminished in weight by calcination: but this fact is not well proved. Beccher attributed the weight and volatility of arsenic to a particular principle, which he called *mercurial* or *arsenical earth*; the existence of which Stahl has not been able clearly to demonstrate.

Arsenic in the state of a regulus does not act in any sensible degree on the combustible bodies; but the calx and glass of arsenic evidently alter them, and assume the metallic lustre. Stahl thinks, that in this case the phlogiston which the arsenic has lost in calcination is restored to it by the combustible body. The partisans of the doctrine of the gases, on the contrary, suppose, that the calx of arsenic is a compound of arsenic and pure air; and that the combustible body, by taking this air from it, restores it to the metallic state. To be sure of success in the reduction of the calx of arsenic, we make a paste of this calx in powder and black soap; we put this paste into a matrafs on a sand bath; we first heat gently to dry the oil; when it emits no more humid vapours, we increase the fire to make the arsenic sublime. We break the matrafs, and we find at its upper part a crust, having the appearance and metallic lustre of arsenic; the greatest part of the charcoal of the oil remains at the bottom of the matrafs.

Arsenic exposed to the air is sensibly blackened; the glass of arsenic loses its transparency, and becomes milky.

Arsenic seems not to be affected by water; but its calx dissolves very well in this menstruum, in a little greater quantity in hot than in cold water. With regard to the rest, the solubility of this substance varies according as it has been more or less calcined. The calx of arsenic furnishes, by the slow evaporation of its solution, yellowish crystals in triangular pyramids. We know of no metallic calx which dissolves in so great quantity in water. This property, joined to its strong taste, makes it approach to the saline substances.

The calx of arsenic unites very well with the earths  
by



by means of fusion. It is fixed with them, and accelerates their vitrefication; but all the glasses into which it enters have the inconvenience of being tarnished by the air in a short time. We do not know the action of the saline-earthly substances on arsenic, nor on its calx. The caustic fixed alkalis, which have no sensible action on it, very readily dissolve its calx. M. Macquer, in his elegant work on this substance, (Acad. 1746), has observed, that in boiling the calx of arsenic in powder in the liquor of fixed nitre, or in a solution of a fixed vegetable alkali nearly caustic, this substance is completely dissolved in it, and forms a brown gelatinous fluid, whose consistence gradually augments. This compound, to which he has given the name of *liver of arsenic*, does not crystallize; it becomes hard and brittle; it is deliquescent, and soluble in water, which precipitates from it some brown floccules. Urged with a great fire, the liver of arsenic parts with this last substance. It is decomposed by the acids. The mineral alkali presents the same phenomena; but its solution gave to M. Macquer irregular crystals, whose form he was unable to determine.

The vitriolic acid, even concentrated, does not affect arsenic in the cold; but if we boil them together in a retort, at first the acid gives some sulphureous acid, then it sublimes a little sulphur, and the arsenic is found reduced to the state of a calx, but not dissolved. In like manner, the oil of vitriol, concentrated and boiling, dissolves the calx of arsenic; but when the solution becomes cold, the calx is precipitated, and the acid does not seem to retain any more of it. In this combination it requires a considerable fixity. M. Bucquet asserts, that in washing it in order to carry off the little acid which it may contain, it resumes all its qualities.

The nitrous acid attacks arsenic violently, and calcines it. This acid likewise, when assisted by a gentle heat, dissolves the calx of arsenic in very considerable quantity. When saturated with the one or the other of these



stances, it retains its peculiar smell; strongly evaporated, it forms a salt which, according to M. Bucquet, has no regular form; and which M. Baumé says, is in part cubic, and in part cut into points of diamonds. Wallerius says, that its crystals are like those of lunar nitre. Nitre of arsenic powerfully attracts humidity from the air: it does not detonate on the coals; it is decomposed neither by the acids nor by water; the alkalis occasion no precipitate: however, according to M. Bucquet, they decompose it; since by evaporating a nitrous arsenical solution, to which we have added an alkaline ley, we get some nitre and some neutral arsenical salt.

The marine acid, assisted by the action of the fire, dissolves arsenic and its calx, according to M. Bucquet. This combination may be precipitated by fixed and volatile alkalis. Baumé says, that this regulus dissolves in the boiling marine acid, and that it is precipitated in a yellow powder like sulphur. Messrs Bayen and Charlard, in their researches on tin, have asserted, that the marine acid has no action on arsenic in the cold, and that with heat its action is but very weak, and scarce perceptible.

We do not know the action of the other acids on arsenic and its calx. Arsenic mixed with nitre, and thrown into a red-hot crucible, occasions a brisk detonation: the nitrous acid calcines and burns it. After the operation, we find in the crucible the fixed alkali which was the base of the nitre, and the arsenic reduced to a calx combined in part with it. If we mix equal parts of calx of arsenic and nitre, and distil the mixture in a glass retort, we obtain a spirit of nitre in very red vapours. This acid cannot be condensed unless a little water be put into the ball, which makes it appear of a blue colour. Beccher, Stahl, and Kunckel, have described this operation. M. Macquer, who has repeated it with care, having examined the residuum, of which the chemists have not spoken, discovered that it was  
formed



formed by the combination of the calx of arsenic with the vegetable fixed alkali. He gave it the name of *arsenical neutral salt*. This salt, dissolved in water, and evaporated by the air, gives crystals in three-sided prisms, terminated by pyramids with three equal sides: sometimes the form of these crystals varies.

The arsenical neutral salt, exposed to the action of the fire, easily fuses, remains in tranquil fusion, without being alkalized, and without any portion of the calx of the arsenic being volatilized. It suffers no sensible alteration by the air. It is much more soluble in water than the pure calx of arsenic, and dissolves in much greater quantity in hot than in cold water. It cannot be decomposed by any pure acid, but it can by the double affinities. If with the solution of this salt we mix a little of a solution of martial vitriol, a double decomposition and combination takes place: the vitriolic acid quits the iron to join with the fixed alkali; and the calx of arsenic, separated from the alkali, combines with the iron.

The combustible matters decompose this salt very well.

The calx of arsenic likewise decomposes rhomboidal nitre by means of distillation, and forms with its base a mineral neutral arsenical salt; which, according to M. Macquer, differs a little from the neutral arsenical salt with base of vegetable alkali, and which crystallizes exactly in the same way. This calx also acts on the nitrous ammoniacal salt; united with its base, it forms an ammoniacal arsenical salt. This operation requires several precautions, on account of the property which the nitrous ammoniacal salt possesses, of detonating in close vessels without addition.

The calx of arsenic does not decompose the marine salt: it separates with difficulty, even as arsenic itself does, the volatile alkali of sal ammoniac.

The action of the combustible mineral matters on arsenic has not been examined. The calx of this semi-metal



metal combines very well with sulphur. When these two substances are fused, there results a yellow or red volatile body, which has a weaker taste than the pure calx of arsenic, and is more soluble in water. This compound is called *factitious orpin* or *orpiment* when it is yellow: it is capable of crystallizing in triangles, like the glass of arsenic. When it is red, we call it *factitious realgar*, *realgar*, *rizezal*, or *red arsenic*. Some chemists have thought that realgar differed from orpiment only in its containing more sulphur: but M. Bucquet has demonstrated, that the compound of sulphur and calx of arsenic is red when it has been fused; since to expose orpiment to a brisk heat is sufficient to make it pass to the state of realgar. I am convinced that realgar is much less volatile than orpiment, as there remain at the bottom of the matras in which we sublime the mixture of calx of arsenic and sulphur, red bubbled-up laminae, which have been manifestly fused. Artificial orpiment and realgar do not differ from natural. They are decomposed by lime and the alkalis, which have more affinity with the sulphur than the calx of arsenic has. However, this calx, like the acids, has the property of decomposing the livers of sulphur.

All the properties of the calx of arsenic prove that this semi-metallic and combustible substance, united to pure air, has assumed the characters of a saline substance. The theory which we have given in treating of the salts in general, is then found to be confirmed by these experiments. M. Macquer, in his beautiful discoveries on the arsenical neutral salt, has already observed, that the calx of arsenic did the part of an acid in this salt. But it was difficult to conceive why the calx of arsenic, immediately dissolved in the fixed alkali, differed so much from the same combination made by the decomposition of nitre by means of this calx. Mr Scheele, conducted by the discovery of the marine acid which he calls *dephlogisticated*, thought that something similar happens when we distil nitre with calx of arsenic. He supposes



supposes that the nitrous acid attracts the phlogiston still inhering in the calx; and that then this calx passes to the state of a particular acid, which he called *arsenical*. Messieurs the academicians of Dijon have adopted this opinion. The Upsal chemist confirms his assertion, by preparing the arsenical acid, by the processes similar to that, by which he forms the dephlogisticated marine acid. One of these processes consists in distilling a mixture of dephlogisticated marine acid and calx of arsenic. The marine acid attracts the phlogiston of this calx, which then passes into the state of an acid. He also succeeded in preparing arsenical acid, by distilling on the calx of arsenic four parts of nitrous acid. This last gives much nitrous gas; and the calx of arsenic assumes the characters of an acid: it is very strongly and very long heated, in order to disengage all the superabundant nitrous acid. What passed in these operations greatly favours the doctrine of the gases. On the one side, it is difficult to admit, according to the theory of Stahl, the existence of phlogiston in the calx of arsenic; and on the other, nothing is so easy to be conceived, according to the new doctrine, as the passage of this calx to the state of an acid by the action of spirit of nitre, or of the dephlogisticated marine acid of M. Scheele. The calx of arsenic seems to have a great affinity with pure air. When it is distilled with the nitrous acid, or with the marine acid dephlogisticated or saturated with the air which it has taken from a metallic calx, it seizes on the pure air, which enters as a principle into both these acids. The more air it contains, the more it approaches to the nature of saline substances; and when it is entirely saturated with it, it assumes all the characters of the acids, which, as we have shown, are only combustible matters charged with air, to which they owe all their saline properties. From this theory we understand why the calx of arsenic, not saturated with air, and such as it is by the simple calcination by fire, does not form the arsenical neutral salt

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of



of M. Macquer; and why it cannot constitute this salt unless it has been previously heated by the acids which it decomposes, and from which it carries off the air by means of the heat (*a*). The arsenical acid greatly differs from the ordinary calx of arsenic. Its taste is stronger. It is fused in the fire; and by this process we may completely separate this acid from the portion of calx of arsenic which it may contain. Undoubtedly it is in passing to the state of an acid that the calx of arsenic assumes fixity when we unite it with the vitriolic acid. This acid is susceptible of fusing into a transparent glass. In its fusion it carries along the earthy matters; it even seems capable of corroding glass. It weakly reddens the blue colours of vegetables. Exposed to the air, it loses its transparency; alters and scales into fragments, frequently pentagons; and gradually attracts humidity. It dissolves in two parts of water. It combines easily with lime, more difficultly with terra ponderosa and magnesia.

(*a*) The acid of arsenic may be obtained by three different processes. It may be obtained by the two processes mentioned by M. Fourcroy; and it may also be separated from the neutral arsenical salt of M. Macquer by decomposition. The acid of arsenic is here united to the alkali of the nitre, but yields up its basis to the superior attraction of the vitriolic acid; though the decomposition was long unobserved, as no precipitate fell to the bottom. The vitriolic acid and fixed alkali form vitriolated tartar, a salt not soluble in spirit of wine, and which therefore falls down, when a sufficient quantity of spirit of wine is added, to absorb the water. Upon this addition, we obtain a mixture of acid of arsenic and spirit of wine with a saline precipitate, consisting almost entirely of vitriolated tartar. The supernatant liquor is decanted, and the spirit of wine expelled by heat; for the acid of arsenic, being a fixed substance, remains unaltered in the retort. Yet although it be in this case unaffected by the heat, it is subject to a very curious change, if the heat be raised to the degree of ignition, and continued to be applied for some length of time. By some chemical effect, the acid recovers all the properties it had lost, and is then restored to the state of white arsenic. The acid of arsenic may thus be converted into a regulus by successive alterations; and the regulus may be reciprocally deprived of its metallic lustre, and reduced to the form of a pure acid. So that in this instance we have an example of at least one metallic substance whose calx is a true and perfect acid.



magnesia. When it unites with the alkalis, it forms neutral salts, which, according to M. Bergman, lime decomposes. Terra ponderosa and magnesia, according to the same chemist, seem to have more affinity with this acid than the alkalis have. There are also many experiments to be made to discover all the properties of the arsenical acid. The academicians of Dijon and M. Berthollet are the only chemists in France who have begun to examine it.

Arsenic is employed in several arts, and particularly in painting. The neutral arsenical salt is also used, since M. Bucquet prepares a great quantity of it.

The facility with which the calx of arsenic dissolves in water, and in all the aqueous fluids, renders it a very dangerous poison. When a person has been poisoned, we know it by the following symptoms: The mouth is dry, the teeth set on edge, the throat rough; an involuntary spitting comes on, a sharp pain at the stomach, a great thirst, nausea, vomitings of slimy matters, bloody violent colics, accompanied with cold sweats, and convulsions. These symptoms are very soon followed with death. We easily ascertain that arsenic is the cause of it, by examining the suspected aliments. The presence of this poison manifests itself, when, by throwing on the coals a parcel of those aliments dried, a white fume arises, with a strong smell of garlic.

It has been the custom to give to persons poisoned with arsenic mucilaginous drinks, or milk or sweet oils, in great doses, to relax the stimulated viscera, and to dissolve and carry off the most part of the arsenic. M. Navier physician at Chalons, who was employed in searching for counter poisons to arsenic, has found a substance which combines with this substance in the humid way, saturates it, and destroys the greatest part of its properties. This substance is the calcareous or alkaline liver of sulphur, and still better the liver of sulphur which contains a little iron. By pouring this martial liquor into a solution of arsenic, the liver of sulphur is de-



decomposed without emitting any smell; because the arsenic combines with the sulphur, with which it forms orpiment, and it unites at the same time with the iron. M. Navier prescribes a gros of liver of sulphur in a pint of water, which he desires to be given in glassfuls to persons poisoned. We may also give them five or six grains of dry liver of sulphur in pills, and above every pill a glass of warm water. When the first symptoms are over, he advises the use of the sulphureous mineral waters. Experience has taught him, that they are very proper to destroy the tremblings and palsies, which are generally the effect of arsenic, and which threaten phthisis and death. M. Navier also approves of the use of milk, because it dissolves arsenic much better than water; but he condemns oils, which cannot dissolve it.

Species 2. *Cobalt.*

COBALT, or cobolt, is a semi-metal of a white colour, inclining a little to red, of a fine and very compact grain, which we may pound with a pestle. Weighed in the hydrostatical balance, it loses about one-eighth of its weight. It may be crystallized into bundles of needles laid on one another. Cobalt is found in the earth in the state of a calx, or in that of an ore. Cobalt, in the state of a calx, is known by its red colour, inclining to that of the flowers of the peach-tree or of lees of wine: it is sometimes in needles, in bundles, in stars, in striæ. For the most part, it forms a simple efflorescence, which is called *flowers of cobalt*. The ores of cobalt are of two kinds. The grey or the ash-coloured. It is of a whitish grey, crystallized in cubes entire or truncated, so as to form solids, with fourteen, eighteen, or twenty-six facets. At the surface, it sometimes presents dendrites, like leaves of fern: in this state it is called *weaved ore of cobalt*. Frequently the ores of cobalt have no regular crystallization; but they are always distinguishable by their whitish grey colour,



lour, lightness, and red efflorescence, which almost all of them have at their surface. M. Romé de Lisle makes two kinds of the ore of cobalt, white and grey.

The black ore of cobalt, vitreous or in form of scoriæ, is of a deep black colour, like the ores of arsenic: it is heavier than the grey ore of cobalt: it is found either compact, and as if vitreous; or shining, and resembling a mirror; or spongy, friable, blackening the fingers like soot. In these different states it has got the names of *specular ore of cobalt*, of *black flowers of cobalt*, &c. The most part of mineralogists think that the cobalt in them is mineralized by arsenic. Monnet supposes, that in the grey ore of cobalt the arsenic is in the state of a regulus or of a metal; and that it is in the state of a calx in the black ore of cobalt. It is found in great abundance in Saxony and Bohemia: sometimes its ores contain a little bismuth.

To essay ore of cobalt, we begin with pounding and washing, then roasting it to separate the arsenic. The cobalt remains in the state of a reddish-grey calx: we mix this calx with three parts of black flux and a little decrepitated marine salt: it is set to fuse: we take care that the fusion be complete, and that the matter be perfectly liquid, so as to leave it to cool in the crucible. It is slightly agitated, in order to precipitate the metal, which is collected in the form of a button at the bottom of the vessel. This button is often formed of two metallic matters: the cobalt is placed above, and the bismuth below: they are easily separated by the stroke of a hammer.

In great works, the cobalt is not extracted in the metallic form. After having pounded and washed the ore of cobalt, it is roasted in the furnace.

This furnace is terminated by a long horizontal gallery, which serves for a chimney: in this gallery the calx of arsenic sublimes, condenses, and is fused into a glass, which is sold, in commerce, by the improper name of *white arsenic*. If the ore contain a little bismuth,



muth, as this metal is very fusible, it is collected at the bottom of the furnace. The cobalt remains in the state of a dark-grey calx, called *zafre*. The *zafre* in commerce is never pure; we mix it with three times its weight of pulverized flints. The *zafre* thus mixed and exposed to a great fire, is fused into glass of a dark blue, called *smalt*. This *smalt* is reduced into powder in mills, and washed in water. The first portion of glass which is precipitated is the most impure; it is called *gross azur*: we decant the water, which is still turbid; it forms a second precipitate: thus we decant it four times, and then the deposition which it gives is finer than all the rest; it is improperly called *azur of four waters*. This *azur* is employed in several arts, to give a blue colour to metals and glasses.

The *zafre* in commerce, fused with black flux and marine salt, gives the semi-metal known by the improper name of *regulus of cobalt*. The reduction of *zafre* is very difficult. It is necessary to employ a great quantity of flux, and to take care to keep the crucible in a white heat for a very long time, in order that the matter may be very fluid and tranquil, and that the scoriæ may be fused into a blue glass; then the cobalt is precipitated, and collected in a button at the bottom of the scoriæ.

Cobalt exposed to the fire does not fuse till it is very red. This semimetal is very difficult of fusion, and seems very fixed in the fire. Its volatilization in close vessels is not ascertained: but we know, that if we leave it to cool slowly, it is crystallized in needles like prisms, laid on one another, and united in bundles; and, as M. Mongez has observed, they resemble much a mass of shaken basaltes. In order to succeed in this crystallization, it is sufficient to fuse cobalt in a crucible, till it suffer a kind of ebullition, and, after having taken it from the fire, to incline this vessel while the surface of this semimetal is congealing. By this inclination the portion still fused is poured out, and that which adheres to the sides of the kind of geod, formed  
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by the cooling of the surfaces of cobalt, is found covered with crystals.

Cobalt, fused and exposed to the air, is covered with a dark and dull pellicle, which is only a calx of this semi-metal formed by the disengagement of its phlogiston, or by the combination of dephlogisticated air, or, according to M. Macquer, by these two causes united. A greater quantity of calx of cobalt is obtained more easily by exposing this semimetal, reduced into powder, in an earthen vessel, to be roasted under the muffle in a cupelling furnace, taking care to agitate it, in order to present new surfaces. This powder, kept red for some time, loses its brilliancy, increases in weight, and becomes black. This calx requires a fire of the most extreme violence to be fused into a very deep blue glass.

Cobalt is tarnished a little by the air, and is not acted on by water. This semi-metal does not combine with the earths, but its calx unites to them by fusion, and forms with them a beautiful blue glass, of the greatest fixity in the fire. On account of this property of the calx of cobalt, this substance is of great use in the painting of smalts, and porcelain, and Dutch ware.

We do not know well the action of terra ponderosa, magnesia, and lime, on cobalt. The alkalis manifestly alter it: but as yet we have not investigated those alterations.

This semimetal dissolves in all the acids, but with different phenomena, according to its state and that of the acid.

Cobalt in the metallic state dissolves in oil of vitriol only when it is concentrated and boiling. This solution is made in a glass-vial, or in a retort: when almost all the acid is evaporated in sulphureous gas, we wash the residuum; a portion is dissolved in the water, and communicates to it a rosy or greenish colour; this is vitriol of cobalt: the other is cobalt calcined by the acid, whose pure air is combined with the semimetal. M. Baumé says, that we obtain from the solution of vitriol of co-



balt, by proper evaporation, and cooling, two sorts of crystals: some white, small, and cubic; the others greenish, square, six lines long, and four broad. The last he looks upon to be vitriol of cobalt; the first depend on some other foreign metallic matters united to the cobalt. The crystals of vitriol of cobalt, which we obtain most frequently in the form of small needles, and which M. Sage calls *three sided rhomboidal crystals, terminated by a two-sided top, with plain rhomboids*, are decomposed by the fire; there only remains a calx of cobalt, which cannot be reduced alone. Terra ponderosa, magnesia, lime, and the three alkalis, likewise decompose this salt, and precipitate the cobalt in the form of a calx. The vitriolic acid diluted with water acts on zafre, and dissolves a portion of it, with which it forms vitriol of cobalt.

The nitrous acid dissolves regulus of cobalt with effervescence by means of a gentle heat: when the solution is at the point of saturation, it is of a rosy brown, or clear green. By a strong evaporation it gives a nitre of cobalt in small needles united. This salt is very deliquescent: it bubbles upon the coals without detonating, and leaves a violet calx. It is decomposed by the same saline intermediums as the vitriol of cobalt. If in these decompositions we add more alkali than suffices to precipitate the cobalt, this substance dissolves in the excess of the salt, and the precipitate disappears.

The marine acid does not dissolve cobalt in the cold; but with the aid of heat it dissolves a portion of it. This acid acts better on zafre; it forms a solution of a brown-red, which becomes green as soon as it is heated. This solution, evaporated and well concentrated, gives a salt which crystallizes in small needles, and which is very deliquescent: heat presently gives it a green colour, and decomposes it.

Aqua regia dissolves cobalt a little more easily than the marine acid does, but less so than the nitrous. This solution has been long known as a kind of sympathetic ink,



ink, which does not appear till heated; the writing which was not visible, seems of a fine sea-green, and disappears as the paper cools. This property belongs to the solution of cobalt in the marine acid; the nitrous acid which we add to make aqua regia contributes nothing to it. It had been believed, that the green colour produced by the ink of cobalt when heated, and which it loses when cold, was owing to the metallic salt which the heat made crystallize, and which being exposed to the cold air, greatly attracted enough of humidity to dissolve it, and make it disappear entirely; but it is proved that the marine salt of cobalt, even dissolved in water, assumes the same colour as soon as we expose it to a certain degree of heat.

The acid of borax does not immediately dissolve cobalt; but when we mix a solution of this salt with a solution of the semimetal in one of the preceding acids, a double decomposition takes place. The mineral alkali unites with the acid which dissolved the metal, and the sedative salt is combined with this last, and precipitated: this combination we may collect by filtrating the supernatant liquor.

Cobalt has no action on most part of the neutral salts. When exposed to the fire with some nitre it is calcined. If we throw into a red hot crucible a mixture of one part of cobalt in powder, and of two or three parts of very dry nitre, a brisk detonation does not take place, but small sparks, very remarkable, are excited; afterwards we find a portion of the cobalt changed into a calx of a more or less deep red, and often greenish. This experiment, as well as all those on the reciprocal action of nitre and the metallic substances, would require to be prosecuted.

Cobalt does not decompose sal ammoniac. M. Bucquet, who made this experiment with much care, did not obtain an atom of volatile alkali; this depends on the small action of the marine acid on this semi-metal.

We do not know the action of inflammable gas on



cobalt. Sulphur does not unite with this substance but with very great difficulty, but the liver of sulphur favours the combination; there results a kind of artificial ore in facets of a larger or lesser size, of a grain more or less fine, of a whitish or yellowish colour, according to the quantity of sulphur combined. M. Baumé, who has given an excellent account of this combination, *Experimental and Rational Chemistry*, Vol. II. p. 288 to 297. observes, that it can be decomposed only by the acids, and that fire is not capable of separating all the sulphur. Cobalt is not of any use.

## LECTURE XXVIII.

### SPECIES 3. *Bismuth.*

**B**ISMUTH, or tin glass, is a femimetal of a yellowish white, very heavy, disposed in great laminæ. It is a little hollowed by the strokes of a hammer; but it breaks very soon into small spangles, and ends in being reduced into powder. In water it loses one-tenth of its weight. It is susceptible of crystallizing in polygonal prisms, which are disposed in square Grecian volutes, or entirely like those of marine salt. It has no remarkable smell nor taste. Bismuth is often in a metallic form in nature. It is known by its colour and softness, so that it can be cut by a knife; by its form, and particularly its great fusibility. It is generally crystallized in triangular laminæ, which are laid above one another. I am in possession of some specimens, in which the femimetal is in the form of very regular octaëdrals. Its matrix is generally quartz. Bismuth is mineralized either by arsenic or sulphur. The arsenical ore of bismuth is like a cat's-eye stone, often in small shining laminæ of a clear grey. It is almost always mixed with native bismuth and cobalt, whose reddish efflorescence makes it be remarked sometimes at the surface of the specimens. This ore differs



differs from that of cobalt in being heavier and of a duller colour.

The sulphureous ore of bismuth is of a whitish grey, sometimes inclining to blue, with facets, or in needled prisms. It is very similar to the first, but contains neither arsenic nor cobalt. This very rare ore is found only at Bastnaës in Sweden; and it was M. Cronstedt who made it known.

The same mineralogist also speaks of a martial ore of bismuth, which he says is found in thick cuneiform scales at Konigsberg in Norway.

Lastly, bismuth is sometimes found in the state of a calx; it is in the form of a granulated efflorescence, of a greenish yellow, and never red, at the surface of the mines of bismuth.

In order to essay an ore of bismuth, we content ourselves with fusing it by a gentle heat in a crucible, with the assistance of a certain quantity of reducing flux: as the bismuth is volatile, we should fuse it as soon as possible; it is also better to make this essay in close vessels, as Cramer recommends.

The fusion in great of the ores of bismuth is not more difficult: we make a ditch in the earth, and cover it with sticks, which we place near one another; we set fire to the wood, and throw the ore broken upon it; the bismuth fuses and runs into the ditch, where it is moulded into a round piece.

In other works they place, in an inclined posture, the trunk of a pine, hollowed like a canal, in which they put a layer of wood; they throw the bismuth on this combustible matter, which is then kindled. This semi-metal fuses, and runs along the canal, which leads into a hole in the earth, in which is placed the extremity of the trunk of the pine. They collect the bismuth in this kind of box, and pour it into iron moulds or ingots.

Bismuth is but very little altered by the contact of the light: however, through time it acquires a violet hue.



It is extremely fusible; it fuses a long time before it is red. Heated in close vessels, it sublimes entirely. If we allow it to cool slowly, it crystallizes in Grecian volutes. It is one of the metallic substances which crystallizes the most easily. M. Brongniart is one of the first chemists who properly succeeded in this crystallization.

If we keep bismuth in fusion with the contact of the air, its surface is covered with a pellicle, which is changed into an earth of a greenish grey or brown, called *cinder* or *calx of bismuth*. Nineteen gros of bismuth calcined in a capsule of glass, gave to M. Baumé 20 gros 35 grains of calx.

Bismuth heated to redness burns with a small blue flame scarce perceptible; its calx evaporates under the form of a yellow smoke, which is condensed at the surface of cold bodies in a powder of the same colour, called *flowers of bismuth*. This powder owes its volatilization to nothing but the rapidity with which the bismuth burns; for if we expose it alone to the action of the fire, it is fused into a greenish glass without subliming. Geoffroy the son observed, that about the end these flowers of bismuth become of a fine orpiment-yellow. The grey or brown calx, the yellow flowers, and the glass, are only combinations of this semi-metal with pure air; they are not reduced without addition, because there is much adherence between the two principles which compose them: but all the combustible matters of organic substances are capable of decomposing and restoring to them their metallic state. M. d'Arcet having exposed some bismuth in an unbaked porcelain ball to the heat of the furnace which bakes that substance, the semimetal flowed out by a crevice; the portion remaining in this vessel formed a glass of a foul violet, whilst the bismuth fused on the outside of the ball was yellow. From these, and other like facts, it seems that the glasses made with or without the contact of the air, differ from one another.

Bismuth is a little tarnished by the air, and a whitish  
rust



rust forms at its surface. It is not attacked by water; it does not combine with the earths; but its calx unites with all the earthy matters, and facilitates their fusion.

We do not know the action of the saline-earthly substances and of the alkalis on this semi-metal.

The oil of vitriol boiling acts on bismuth; it is decomposed and dissipated in sulphureous gas. The mass which remains in the vessel after the evaporation of the acid is white: that portion which is only calcined is separated by water from that which is in the saline state; the ley evaporated furnishes a vitriol of bismuth, which is very deliquescent. This salt may be decomposed by the fire, by the saline earthy substances, by the alkalis, and even by a great quantity of water.

The nitrous acid dissolves bismuth with astonishing rapidity. The mixture turns prodigiously hot, and exhales in very dense thick vapours. If we make this solution in a pneumato-chemical apparatus, a very great quantity of nitrous gas flies off; it is a very ready and commodious way of procuring this gas. During this solution a black powder is precipitated, which Lemery took for some bitumen, and Pott looked upon as calcined bismuth. M. Baumé suspects that it may be some sulphur. The nitrous solution of bismuth is without colour; when it is very copious, it deposits crystals without evaporation. By evaporation and cooling, a nitre of bismuth is produced, about the form of which the chemists are nowise agreed. M. Baumé says, that this salt is disposed in coarse needles, like the points of a diamond at one end. M. Sage defines these crystals three-sided prisms, a little compressed, and terminated by two obtuse three-sided pyramids, whose plains are a rhomboid and two trapeziums. By a slow evaporation I have obtained flattened rhomboids very like the calcareous spar of Iceland.

Nitre of bismuth detonates weakly, and in reddish sparks; it fuses and bubbles up, and leaves a calx of a greenish yellow; this calx cannot be reduced without



addition. This salt exposed to the air loses its transparency as soon as the water of its crystallization is dissipated. When we attempt to dissolve it in water, it becomes white and milky, and gives a precipitate of a calx of bismuth.

The same thing happens if we add some water to the solution of bismuth in nitrous acid; the greatest part of the calx of this semimetal is precipitated in the form of a white powder, called *white paint* or *magistery of bismuth*. In order to have this precipitate very white and fine, we must prepare it with a great quantity of water. The ladies use it to whiten the skin, but it has the inconvenience of blackening when it is in contact with odorous and combustible bodies; it is also one of the metallic calxes which has this property in a most sensible manner. Though the nitre of bismuth be in a great part decomposed by the water, there however remains a portion dissolved, and this portion cannot be precipitated but by lime and the alkalis. This character of being precipitated by water belongs to all the solutions of bismuth.

Marine acid acts with difficulty on bismuth; it requires this acid to be concentrated, and to be kept a long time in digestion with it. This solution succeeds still better by distilling a great quantity of marine acid upon bismuth. An hepatic smell is emitted from this mixture; we wash the residuum with water, which charges itself with the portion of the metal united to the acid. The marine salt of bismuth crystallizes with difficulty; it is susceptible of subliming and forming a kind of butter. It strongly attracts humidity from the air; water decomposes it, and precipitates a white powder from it.

We do not know the action of the other acids on bismuth. Bismuth is calcined by nitre, but without any sensible detonation. This semimetal does not at all decompose sal ammoniac; but its calx completely separates the volatile alkali from it. In this experiment we obtain



tain a great quantity of alkaline gas; and the residuum is the combination of the metallic calx with the marine acid. M. Bucquet observes, that bismuth does not act on sal ammoniac, on account of the small action which the marine acid has upon this semimetal; but the property which its calx has of decomposing this salt is very remarkable, and proves that it approaches in nature to the saline substances. Inflammable gas alters the colour of bismuth, and gives it a violet hue. Sulphur combines with it by fusion. There results a kind of needled bluish ore. This semimetal does not unite to cobalt.

Bismuth is employed by the pewterers (*a*). It might be substituted in the place of lead in the art of cupelling the perfect metals; as, like that metal, it has the property of fusing into a glass, which the cupels absorb. M. Geoffroy the younger found a great relation between this semimetal and lead. The effects of bismuth on the animal œconomy can only be conjectured: we believe, with sufficient probability, that it would be as dangerous

(*a*) Bismuth is remarkable for the facility, and for the tenuity of its fusion. It flows thinner and more readily than any of the metallic substances; and communicates these properties to all the other metals with which it is mixed. On this account it is extremely useful in the composition of solders, employed to unite fusible metals; such as lead and tin. The low degree of heat requisite to melt the solder does no injury to the piece of work, while the tenuity of the fusion enables the solder to insinuate itself between the smallest crevices of the sides to be joined. For the same reason a portion is commonly added in all compositions of type-metal, in order that the type may carry off the impression of the mould, in which it is cast, with perfect accuracy. It does this the more completely, from the increase of bulk which it receives upon congelation; as bismuth expands upon fixing, which no other metallic substance, except iron, is known to do. Bismuth, when long exposed to heat, is changed into a brownish glass. This glass is very fusible itself, and contributes much to promote the vitrification of earthy matters and imperfect metals. When united with copper, it forms a compound, possessed of very high dissolving powers, which is readily absorbed by the cupel; so that many prefer it even to the glass of lead itself in the cupellation of silver and gold.



dangerous as lead. We know also of several bad effects from this semimetal applied externally.

The calx of bismuth, called *white paint*, is made use of to whiten the skin; but it is then requisite carefully to avoid all the very odorous matters, and particularly those which are fetid. The vicinity of shambles, lay stalls, sinks, privies, and also strong smells, has such influence on this calx, that it is rendered more or less black. The vapour of the livers of sulphur, even the smell of eggs, is frequently sufficient to produce this effect.

#### Species 4. *Nickel*.

NICKEL has been looked upon by M. Cronstedt as a particular semimetal, which he made known in the Transactions of the Academy of Stockholm in the years 1751 and 1754. According to him, this semimetal is of a white brilliant colour, inclining to red, in particular externally. It is very brittle; and seems to be compounded of facets in its fracture, which distinguishes it from cobalt. M. Arvidson, who, in conjunction with M. Bergman, published a thesis on the properties of nickel, translated and inserted in the Physical Journal, October 1776, observed, that nickel obtained by the roasting and fusing of its ores, as M. Cronstedt had shown, is just this semimetal pure; and that it contains sulphur, arsenic, cobalt, and iron. As, by a great number of ingenious processes, these two chemists have discovered how to extract the greatest part of these strange matters, and to obtain nickel, different in several of its properties from that of M. Cronstedt, it is that which we shall relate, after having given the history of its ores.

Nickel is found combined with sulphur and arsenic. Its ores have a red copper colour; they are almost always covered with an efflorescence of a greenish grey: the Germans call it *kupfer nickel*, or *false copper*. This mineral is very common at Freyberg in Saxony. It is often mixed with the ore of grey cobalt; but its red colour,



colour, and its greenish efflorescence, distinguish it from this ore, which is grey or black, and whose efflorescence is red; it is often crystallized in cubes. Wallerius distinguishes the kupfer nickel by the name of *ore of cobalt*, of a coppery red: he supposes it a compound of cobalt, iron, and arsenic. The Chevalier Von Linné looked upon it as copper mineralized by arsenic. M. Romé de Lisle, with Wallerius, ranked it among the ores of cobalt; and thinks, like him, that it is an alloy. M. Sage having tried this ore with sal ammoniac, extracted from it some iron, copper, and cobalt. He thinks that it is formed of a mixture of these three metallic substances with arsenic. According to this chemist, a little gold also was found in it. It is proper to observe, that he had results different from those of Mr Ardvison. He worked upon kupfer nickels of Biber in Hesse, and of Allemont in Dauphiné.

M. Cronstedt affirms, that we may separate from the nickel the metallic matter called *speiss* by the Germans, which is collected in the crucibles in which the smalt is fused. M. Monnet asserts, that the speiss of the manufacture of Gengenback, 14 leagues from Strasbourg, is true nickel; and as the ore of cobalt which is employed in this place to make smalt is very pure, he concludes from this, that nickel is necessarily produced by cobalt itself, as we shall see afterwards. But M. Baumé extracted nickel from almost all the ores of cobalt by means of the liver of sulphur. See *Experimental and Rational Chemistry*, Vol. II. p. 288. It appears then that the ore of cobalt which is wrought at Gengenback, contains nickel, which it is impossible to discover by the eye, on account of the intimate union of these metallic matters.

To extract the nickel from its ore, we roast it slowly in order to raise a portion of the sulphur and arsenic. It is changed into a greenish glass; the greener it is the more nickel it contains, according to M. Arvidson. It is then fused with three parts of black flux and some  
marine



marine salt: a regulus is extracted, such as M. Cronstedt described it, but which is very far from being pure nickel; its scoræ are brown or blue. Many chemists, since the work of M. Arvidson, still look upon this substance as a natural mixture of iron, cobalt, and arsenic. With regard to copper, we have not extracted any of it, by the most delicate experiments in the art of assaying. M. Monnet thinks, that nickel is only cobalt deprived of iron and arsenic. In proportion as we examine the properties of this semimetal, we shall take notice on what these different opinions are founded. We believe with M. Bergman, that that which has here imposed on the chemists, is the extreme difficulty we experience in obtaining pure nickel; a truth well demonstrated in the dissertation of M. Arvidson, already mentioned. As it is certain, that, brought as nearly as it is possible to this state of purity, it possesses very particular properties; and we have not as yet been able either to separate it by analysis into different metallic substances, or recombine it by any alloy whatever; we must look upon it as a particular semimetal, till future experience convince us of the contrary.

The semimetal which the simple fusion of kupfer nickel roasted furnishes, is in facets of a reddish white, and very brittle. It contains much arsenic, copper, and iron. M. Arvidson exposed it to six calcinations, each of which continued from six to fourteen hours; he reduced the regulus after each calcination: he observed, that in calcining it, some arsenical, and also some white vapours, which do not smell of this semi-metal, were exhaled. The powder of charcoal which is mixed in these operations, facilitates the volatilization of the arsenic. The nickel, which was much diminished in weight by these six calcinations, still smelt of arsenic, and was magnetic. It was fused six times with lime and borax, and calcined a seventh time, by adding charcoal, till it emitted no more arsenical vapours. This calx was ferruginous variegated with green spots; reduced, it afforded martial scoræ



scoriae and a button, still attracted by the magnet. The success was constantly the same with several nickels of different countries. Sulphur, the liver of sulphur, detonation with nitre, solutions in nitrous acid and volatile alkali, employed by M. Arvidson, never could raise all the iron from the nickel. From these experiments he concluded, that it is impossible completely to purify this semimetal; that the sulphur is separated by repeated calcinations only; that the arsenic adheres more closely to it; that it may be extracted from it by means of powder of charcoal and nitre; that cobalt is still more intimately combined, since nitre discovered it, tho' nothing else indicated its presence; and that it is impossible to deprive it of all the iron which it contains, since, after the nickel has been treated in all these ways, it is sometimes more attracted by the magnet than before. Hence M. Arvidson believes, that it is nothing else than iron in a particular state; and he gives a description of several of the properties of this metal, compared with those of cobalt, of the magnet, and of nickel, from which he regards these three metallic substances as different modifications of iron. But the principal properties of nickel which led M. Arvidson to this conclusion, is its magnetism. It is not impossible that this property serves to confound two metallic matters different in all their other properties, since in other respects it is possible that magnetism is not peculiar to iron, but that it exists in several metallic substances. I think, then, that notwithstanding the property of nickel's being attracted by the magnet, it ought to be considered, when it has been purified by the processes of M. Arvidson, as a particular semimetal, since we can neither extract all the other metallic substances from it, nor perfectly imitate it by any mixture; and in the last place, since it possesses properties which belong only to itself, which we now proceed to consider.

It does not present facets, as M. Cronstedt had shown; but its fracture is granulated: it is nine times heavier  
than



than water; it is not brittle, as M. Cronstedt announced; on the contrary, it possesses ductility in a degree remarkable enough to make M. Bergman hesitate whether it should be ranked among the metals or semimetals: it is almost as difficult to fuse as forged iron; it is very fixed; it calcines when it is heated with the air; and it gives a calx, which is so much the greener as it is more pure. We do not know if this calx can be fused into a glass: it is reduced by means of fluxes and combustible matters, which decompose it like all the rest. We do not know the action of the air and of water on nickel. Its calx fused with matters proper to make glass gives them a hyacinth colour, more or less red. The action of lime, magnesia, and the pure alkalis, is unknown. M. Sage says, that in distilling four parts of oil of vitriol on one part of regulus of kupfer nickel in powder, there passes over some sulphureous acid; the residuum is greyish, and when dissolved in distilled water it is of the finest green colour. It gives leafy crystals of the colour of the emerald. According to M. Arvidson, the vitriolic acid forms with the calx of nickel a green salt in ten-sided crystals; these are quadrangular pyramids, united and truncated at their base. This same calx dissolves very well in the nitrous acid. According to M. Sage, the nitre of kupfer nickel crystallized in rhomboidal cubes: all the other solutions of nickel, or of its calx in the marine and vegetable acids, are more or less green. The fixed alkalis precipitate it in the form of a greenish white powder, and redissolve it; the liquor becomes then yellowish. The volatile alkali, poured into an acid solution of nickel, produces in it a fine blue colour: this salt presents the same phenomenon when we mix it with the precipitates of this semimetal by the fixed alkalis. As the solutions of copper present the same colour with the volatile alkali, and as this colour has been even admitted to be a test very proper to show the presence of this metal wherever it is found, it has been supposed, and some persons still suppose, from this circum-



circumstance, that nickel contains copper. However, M. Cronstedt attempted in vain all the known means of extracting this metal from the solution of nickel coloured blue by the volatile alkali. Besides, this salt does not immediately dissolve nickel as it dissolves copper. Hence, then, it is demonstrated, that this property belongs, as M. Bergman thinks, to nickel itself; and that it does not owe it to copper. M. Bergman observed no certain signs of the solution of nickel in the ærial acid, after keeping this metal eight days in water impregnated with it.

Nickel detonates with nitre; by this detonation M. Arvidson learned the way of finding out the presence of cobalt in this semimetal, which no other proof had rendered perceptible. Accordingly nickel is more or less calcined, according to the quantity of nitre which we employ. This salt has also the property of increasing the intensity of the hyacinth colour which the calx of nickel communicates to glass, and of making it appear again when it has been dissipated by fusion; which very often happens in this calx, and likewise in the calx of the semimetal which we are to examine after it.

The calx of nickel fused with borax likewise communicates to it a hyacinth colour.

It in part decomposes sal ammoniac. The flores martiales which M. Sage obtained in this experiment, depend on his using a regulus which was not so pure as that of M. Arvidson; for this last chemist asserts, that the flowers which were sublimed were white, and showed no mark of iron by the gall nut.

A little volatile alkali and marine acid passed over; the residuum reduced gave a nickel which had lost a little of its magnetism.

We do not know the action of inflammable gas on nickel. This semimetal combines well with sulphur by fusion; it then forms a kind of hard mineral of a yellow colour, and in small brilliant facets. When we heat it strongly, and in contact with the air, it jumps, and  
emit



emits very luminous sparks, like those which come from forged iron. Cronstedt, who first made this experiment, did not follow it farther: he only observed, that this phenomenon did not take place if we take care to exclude the air, by covering this mineral in fusion with a glass; which shows that this effect is owing only to the rapid combustion of the nickel occasioned by the sulphur. The same chemist informs us, that this semi-metal dissolves in liver of sulphur, and forms a compound similar to the ores of yellow copper. The sulphur cannot be separated from nickel, except by various fusions and calcinations.

Nickel combines with arsenic, to which it strongly adheres. M. Monet, who at first looked upon nickel as a particular semi-metal, after the example of M. Cronstedt, having observed, that when it is united with arsenic, it forms a blue glass like that of cobalt, thought from this that nickel is only cobalt deprived of arsenic and iron. From this opinion it follows, that M. Monet looked upon cobalt as well as nickel as a true alloy. M. Bergman thinks, that if by adding arsenic to nickel, this last can give blue glass, it is, because the cobalt that the nickel always contains, and whose properties are covered by the nickel, which is in much greater quantity, is calcined and separated from the nickel by the arsenic; and then it possesses its own properties, and particularly that of fusing into glass more or less blue. The nickel can be properly separated from the arsenic by the aid of repeated calcination only, with powdered charcoal. Nickel unites still more intimately with cobalt than with arsenic; and it cannot be separated from it without the greatest difficulty: it may even be combined with it without manifesting its properties; and only nitre, borax, and arsenic, can show its presence by fusion.

M. Cronstedt says, that nickel forms with bismuth a brittle and scaly regulus. Solution in the nitrous acid may separate, though imperfectly, these two semi-metallic



tallic matters, by means of the property, which we know nitre of bismuth has, of being decomposed by water.

Nickel has not as yet come into any use.

Species 5. *Manganese.*

UNDER the name of *black magnesia*, or *manganese*, a mineral has been long known, of a grey dull colour, which soils the fingers, and is employed in glass-houses for colouring or whitening the glass. On account of this last property, the workmen call it *soap of glass*. The most of naturalists took it for a scanty ore of iron, on account of its colour, and of the martial earth with which its surface is often covered. Messrs Pott and Cronstedt, from an accurate analysis, thought it not a ferruginous substance. The latter says, that he found a little tin in it. M. Sage has ranked it among the ores of zinc; and he thinks that it is formed by the combination of this semi-metal and cobalt with the marine acid: he adds, that from his trials, some iron or lead is now and then found in it.

The weight of manganese, the property of colouring glass, and that of giving a whitish precipitate by pouring the phlogisticated alkali on its solutions in the acids, made M. Bergman suspect, as he tells us in the last paragraph of his Dissertation on the Elective Affinities, that this mineral contained a particular metallic substance. His suspicion has been fully confirmed by one of his own students, M. Gatin doctor of physic at Stockholm, to whom, jointly with M. Scheele, we owe the discovery of the phosphoric acid in bones. This physician is the first who has got a regulus from manganese, probably by treating it with a reductive flux. Without doubt, the degree of heat necessary to this operation is excessive: for I have seen M. Brogmart, a very able and experienced chemist, in vain attempt to reduce this mineral in a furnace which produced at the time a very violent heat. I was assured that it was done at Paris by using the flux of M. de Morveau, with which this chemist obtains iron in a button very well fused.



According to our principles, this substance ought to be looked upon as a particular femimetal, since it cannot be analyzed; and besides, it presents properties which belong to no other metallic substance. M. de Morveau, in his translation of Bergman, calls it *manganese*; and he proposes to call the substances from which it is extracted, and which seem to contain the metal in the state of a calx, *ore of manganese*. As I have not seen metallic manganese extracted from its ore, and know no chemist in Paris who has obtained this femimetal and inquired into its properties, I borrow from the works of M. Bergman, and in particular his Dissertation on the Elective Attractions, all that is contained there relative to this singular metallic substance. It will be mentioned hereafter, that as yet we have very little knowledge of the subject.

The ores of manganese are known by their deep grey colour, and their form. A great many varieties may be distinguished.

Varieties.

1. Ore of manganese crystallized, in prisms, three-sided, rhomboidal, striated according to their length, and apart from one another.
2. Crystallized ore of manganese, whose prisms are disposed in bundles.
3. Ore of manganese, crystallized in small needles, which are disposed in stars.
4. Ore of manganese, flowered, black, and friable. It stains the fingers like foot.
5. Velvet ore of manganese. It is in small flowered needles, whose fine black unpolished colour imitates velvet.
6. Ore of manganese, compact, without any regular form: it is of a black grey, often cavernous, very heavy. It soils the fingers; sometimes brilliant needles are found in it. The stone of Perigueux belongs to this variety.

Man-



Manganese extracted from its ore is white and brilliant in its fracture. Its texture is granulated like that of cobalt. It is hard and brittle, without any kind of ductility; and by this character belongs to the semi-metals. Its infusibility is so great, that it is more difficult to fuse than iron; which made M. Bergman at first conjecture that it had some relation with platina. If we heat it with the contact of the air, it is changed into a calx, at first whitish, but becoming more and more black as it is more calcined.

The action of manganese on the earths and saline-earthly substances has not been examined. The calx of this semimetal gives to glass a violet or brown colour, susceptible of a great number of modifications, and easily destructible by the action of the combustible substances.

We do not know how the alkalis act on manganese; but the calx of this semimetal combines with them, and is revived by the volatile alkali. M. Bergman observes, that in this combination a particular gas is disengaged, which he looks upon as one of the principles of the volatile alkali, on which he makes no observations.

The vitriolic acid dissolves manganese and its calx. This solution is coloured, and loses its colour by the addition of combustible matter; it gives a transparent vitriol in parallelopiped crystals.

The nitrous acid dissolves it, emitting red vapours. Its calx is not affected by this acid unless it be smoking, or unless a combustible body is added, as honey or sugar. The alkalis precipitate from these solutions a white calx, soluble in the acids, which blackens, and becomes more calcined when it is heated. M. Bergman supposes that this calx is charged with the phlogiston of the acid; and he observes, that the black calx of manganese is very soluble in the phlogisticated acids. He shows also, that this semimetal is one of the metallic substances which has most affinity with the salts, since he places it



almost at the head of the columns of his table of affinity which comprehend the elective attractions of the acids. The marine acid likewise dissolves manganese. We have seen in the history of Aqua Regia, that by distilling this acid over upon the calx of this semimetal it becomes white, and recovers its metallic state, either by giving a part of its air to the marine acid, or by taking from it the phlogiston, which M. Scheele admits in this saline substance. It appears that the marine acid has more affinity with manganese than the vitriolic acid has, since a solution of this semimetal by the vitriolic acid, poured into the spirit of salt, forms a precipitate which M. Bergman took for a marine salt of manganese, on account of the property which it has of dissolving in spirit of wine; a property which is not shown by the vitriol of the same semimetal.

We are quite unacquainted with the action of manganese on the neutral salts. We only know, that it gives a violet colour to borax, and that nitre revives the same colour of this metallic calx, in the glass which contains it.

To these properties M. Bergman adds, that manganese cannot be completely separated from the iron which it always contains: this semimetal is then very like nickel. We are not yet acquainted with it in its state of purity.

The calx of manganese, called *black magnesia*, is used in the glass-houses, either to take the stains of yellow, of green, or of blue, from the white glasses, or to give them a violet colour. It appears that this mineral deprives the glass of its colour, by seizing on the combustible matter to which these colours are owing (a).

LECT.

(a) The relation of manganese to inflammable bodies, renders the knowledge of its properties extremely useful in explaining the doctrines of chemistry. Like other metals, manganese is exhibited either under the form of a regulus or of a calx; and the calx varies in its appearance, according to the degree of calcination which it has undergone. When highly calcined, manganese is of a black colour.

In



## LECTURE XXIX.

Species 6. *Regulus of Antimony.*

**R**EGULUS of antimony, *stibium*, which ought simply to be called *antimony*, is a weighty semimetal of a white brilliant colour, very much resembling that of tin,  
 C c 3 or

In this state it does not readily dissolve in the strongest acids. Vitriolic acid scarcely makes any impression; but if a bit of sugar, or gum, or of any other substance supposed to contain phlogiston, be added to the mixture, the acid soon begins to act upon the manganese, and a portion of it is continually dissolving until a saturation takes place. A similar power is acquired whenever the acid is blackened by any phlogistic matter. After the solution is complete, a precipitate may be formed by the addition of an alkali. If the alkali be mild, the precipitate proves extremely white. It becomes black, as formerly, by the action of a calcining heat; and never recovers its whiteness again, until it be brought into contact with some body into whose composition phlogiston enters. But by whatever means manganese is provided with phlogiston, it returns to the state of a white calx, and is again soluble in acids, which had no power before to act upon it. The solubility of the manganese seems then to depend entirely upon the quantity of phlogiston which is united to the metallic earth. When calcined to the utmost degree, it becomes almost altogether insoluble in acids, from the loss of phlogiston; but instantly acquires solubility upon the addition of any substance capable to furnish a fresh supply of phlogiston: so that the proportion of phlogiston determines the efficacy of the solvent.

This series of facts fully confirms the conjecture, of phlogiston being the chain of connection between the metallic substances and the acids. Other metals are influenced by it in an inferior degree; tho' in none is it so remarkable, because not one of them attracts phlogiston so strongly. The effect of this strong attraction for phlogiston is beautifully illustrated in the change which the black calx of manganese produces upon the marine acid. The marine acid has been long believed to contain phlogiston, as a constituent part, which is visibly exemplified in the decomposition which it seems to undergo when distilled from this black calx, and in the alteration which the manganese suffers in the process; because here we find all that portion of the manganese, which has been acted upon by the marine acid, is converted into the white calx; a change which we know can be



or that of silver. It is made up of laminæ adhering to one another; and shows at its surface a kind of crystallization, like stars or fern-leaves. It crystallizes too in the form

be produced only by the acquisition of phlogiston, while the acid flies off in volatile vapours, possessed of properties entirely new. These vapours are most intolerably suffocating; and utterly incondensable, unless when they meet with a phlogisticated substance. By the abstraction of part of its phlogiston, they form with it such compounds, as the marine acid does in its ordinary state. By its superior attraction, in this state of dephlogistication, for the inflammable principle, this acid becomes capable to act upon substances over which it enjoyed no power before. It decomposes sulphur, by robbing the vitriolic acid of its phlogiston. At the beginning of the distillation volatile sulphureous vapours arise, in consequence of the partial decomposition of the sulphur from the incipient action of the dephlogisticated marine acid. After this, pure vitriolic acid is found at the bottom of the receiver, owing to the more complete decomposition of the sulphur. From the same circumstance, the dephlogisticated vapours act upon reguline gold; as shall be more fully explained in the article upon that metal. Manganese takes phlogiston from marine acid; marine acid from gold. And in every series of operations, manganese is always the substance to which we recur, as the most powerful agent upon this principle. It is even able to display this power in a state of combination. When manganese is vitrified by means of saline fluxes, the colour of the glass varies according to the quantity of phlogiston which it has an opportunity to attract. From penury of phlogiston, the glass exhibits a red tint; after saturation, it becomes colourless; and from the addition or abstraction of phlogiston, it may be made to run through continual variations. Upon this principle we are to explain the use of manganese in freeing glass from colour. The iron which is often found in the materials of which glass is made, the ashes, and the flint, seldom fails to communicate a green colour to the whole mass, and to render it impure. Manganese, added in just proportion, removes this imperfection entirely, by depriving the iron of the phlogiston which still adhered to it. From this new acquisition, each particle of manganese becomes sufficiently saturated with phlogiston to form a transparent colourless glass; while the iron being, on the contrary, robbed of all that was left, is converted into a black calx, which proves invisible for want of colour, and from insolubility is quite unable to convey any false tinge to the mass. This seems to be the ratio of the action of manganese in purifying glass: and this, and all the other phenomena, do every one of them depend solely upon the very powerful attraction of the manganese for the inflammable principle.



form of three-sided pyramids, like mill-hoppers laid on one another. It loses in water one-seventh of its weight: it is easily pounded: it has a very sensible effect upon the stomach, possessing strong emetic and purgative qualities.

The regulus of antimony is rarely found native: it has been discovered by M. Antoine Schwab at Sahlberg in Sweden. M. Cronstedt and several other mineralogists acknowledge it.

This semimetal is for the most part combined with sulphur; and then forms what is called improperly *antimony*, but what should be called *ore of antimony*. This mineral is of a blackish grey, having laminæ or needles dispersed or reunited under different forms. It is sometimes mixed with other metals, and particularly with lead and iron: it is common in Hungary, France, Bourbonnois, Auvergne, and Poitou. Naturalists have multiplied the varieties of antimony according to the direction of its filaments, whether parallel, starred, irregular, or in other forms. When antimony is mixed with a portion of arsenic, or has been altered by alkaline or hepatic vapours, it appears in needles of a deep red, very like the beautiful flowers of cobalt, but a little more opaque. Hence, we may consider several varieties of this mineral.

#### Varieties.

1. Antimony crystallized into hexaëdral prisms, terminated by four-sided, obtuse, and detached pyramids.
2. Antimony striated, or formed of thick shapeless needles, adhering and united into irregular bundles.

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3. An-

ciple. They have opened our eyes with regard to many obscure and mysterious points; so that we may regard the recent experiments upon this metallic substance as the most instructive, and such as afford a clear and satisfactory explanation of many of the most abstruse doctrines in chemistry.



3. Antimony with starred striæ; its needles seem to diverge from a common centre.
4. Antimony lamellated; it is made up of laminæ, more or less extended, imitating the ore of lead called *galena*. Sometimes this species is brilliant, and is then transparent.
5. Red antimony. It appears in the form of a granulated efflorescence at the surface of the needles of antimony; sometimes it is crystallized.

The ores of antimony are not made use of for the sake of separating this semimetal from them: we content ourselves with fusing this mineral, with the view of separating it from its matrix and the other metallic matters with which it may be united. For this purpose we take two earthen pots; into the one, which has several holes pierced in its bottom, we put the mineral to be fused; the other pot, placed below the former, and destined to receive the antimony as soon as it is fused, is fixed in the ground. A fire is then applied round about the upper pot: at the beginning the fire is gentle, because the antimony is very fusible; but towards the end it is augmented, that all which the mineral contains may be extracted. A portion of other metals then passes through, and particularly of iron, which is discovered in this ore; these metals form a bed of scoriæ on the surface of the antimony. Although the antimony of Hungary be esteemed the purest, it is certain that all fused antimony, when formed well into needles and free of scoriæ, is equally pure, and adapted to all the uses for which we have been accustomed to employ this mineral. It is only necessary to observe, that antimony frequently differs in the respective proportion of sulphur and regulus which it contains; and it is of the utmost importance to make trial of that substance which we use for the preparation of antimonial medicines, whose strength, it were to be wished, was always the same.

Antimony is very fusible, as we may observe after the process for separating it from its matrix. If we urge  
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it with the fire, when it is fused in open vessels, it loses its sulphur, which is dissipated in yellow flowers; the metallic part is also easily calcined, and sublimes in white flowers: but with a gentle heat, incapable of fusing the antimony, the sulphur mixed with it, is dissipated slowly by degrees; the metal loses, too, a portion of its phlogiston, and forms the grey calx of antimony. This operation cannot be well performed, unless the antimony be very well divided, and present a large surface to the air. For this purpose, we pound it, and expose it to a gentle fire upon an earthen varnished pot. It is necessary also to proceed slowly at the beginning, as the antimony possesses a great degree of fusibility; but as the operation advances, and the sulphur is dissipated, the antimony becomes more refractory, and the fire may be increased so as to redden the vessel containing the mineral. We know that all has gone on well, when we smell nothing but sulphur, which sublimes during the roasting, and when the matter does not concrete; but when the antimony runs together, and the sulphur is decomposed and rendered volatile, which we perceive by the smell of the suffocating volatile sulphureous spirit, the heat then is too great, and must be diminished.

Although the sulphur seems to adhere but slightly to the regulus in the antimony, it is, however, impossible to separate it entirely by roasting; and the grey calx of antimony retains always a considerable quantity of it, in spite of the calcination being carried to the point of depriving the regulus of its metallic properties.

The grey calx of antimony, urged by the fire, fuses without addition into a glass of a brown-red or hyacinth colour. This glass is more or less fusible, more or less transparent, according to the degree of the calcination to which the calx has been subjected.

If the calx contain little sulphur and much air, the glass produced is transparent and difficult to fuse; it is the glass of antimony, properly so called. If the calx contain much sulphur, and if it approach nearer to the character



character of the metal, it produces a more fusible and more opaque glass: it is called *liver of antimony*, in consequence of its red, dusky colour, which resembles the colour of the liver of animals. When the calx of antimony has been calcined to such a degree that it is fused with difficulty, we only need to throw into the crucible, into which it is set to fuse, a bit of sulphur, or crude antimony, and it fuses instantly.

The grey calx of antimony, the liver, or the glass, heated in a crucible with their weight of black flux and a little black soap, or oil, are reduced, and afford pure regulus of antimony. The black flux in this operation serves two purposes: the alkali that it contains unites with the sulphur, which these substances have not been able to destroy by the action of the fire; and the charry matter favours the reduction of the metallic calx. In this way the regulus of antimony is prepared in great for sale. The regulus fuses into circular and flattened loaves: these loaves present at their surface a crystallization in form of leaves of fern.

The regulus of antimony suffers little alteration by light. It requires a red heat for its fusion; and if heated strongly in close vessels, it sublimes entirely without being decomposed. If we allow it to cool slowly after it is fused, when we pour off the fluid portion after the surface is fixed, we find the remainder crystallized in the form of pyramids or mill-hoppers, as we have mentioned before.

The regulus of antimony fused in open vessels calcines readily; it rises in white thick fumes, which precipitate on the surface of the fused metal, or adhere to the cover of the crucible in the form of small white needles. This is a perfect metallic calx, called *silver flowers of regulus of antimony*, or *snow of antimony*. In order to prepare a certain quantity of it, we place horizontally a crucible in a furnace, so that its sides may fit the door of the grate, to which it is luted by means of furnace-earth. We put into this crucible some regulus of  
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of antimony; the fire is raised so that the metal fuses and smokes: we receive the fumes into a second crucible adapted to the first; there it condenses in very fine needles, white and brilliant, which seem to be prisms of four-sides.

The snow and the flowers of antimony are not only susceptible of being volatilized during the deflagration of the semimetal, but they sublime alone when we urge them with the fire. This calx may be also fused into a glass of the colour of a hyacinth; this glass is more pale and more transparent than that made with the grey calx of antimony, but it is also more difficult to fuse.

The regulus of antimony undergoes no alteration by the admixture of combustible substances; but the snow of antimony may be decomposed by them, and may resume the state of the regulus. In consequence of the vast calcination which this calx has undergone, and the great quantity of air which it contains, it passes with very great difficulty into a metallic state; and as it is likewise very volatile, the reduction can only be effected in close vessels.

The regulus of antimony is but very little altered by the air. We observe only the surface of it tarnished. It is insoluble in water; some physicians, however, think that it communicates a very remarkable emetic quality to it. The flowers and snow of antimony dissolve in water, in small quantity indeed, but sensibly enough; and they impart to it an emetic virtue. From this action of the calx of antimony, and its solubility in water, and volatility, it appears to be somewhat analogous to the calx of arsenic.

We are not acquainted with the action of the saline substances with earthy bases, or of that of the alkalis, upon regulus of antimony; scarce even do we know that of the acids.

The oil of vitriol made to boil slowly upon it, reduces it in part into a calx. A great quantity of sulphureous gas exhales, and towards the end a little sulphur



phur is sublimed. The mass which remains after the evaporation of the acid is a compound of a good quantity of metallic calx, and a small portion of the semi-metal combined with the acid, in the state of vitriol of regulus. We may separate the saline part by means of distilled water. This salt, well freed from its water by evaporation, is very deliquescent, and cannot be made to crystallize: it is decomposed easily by means of fire. Pure water, the saline substances with earthy bases, and the alkalis, also separate its principles.

The nitrous acid strongly attacks the regulus of antimony; it calcines the greatest part, and dissolves a portion of it. This solution succeeds with cold; the salt resulting, when separated from the calcined portion by washing and evaporation, is a nitre of regulus very deliquescent, which is decomposed by the fire, and by the same intermediate substances as the vitriol of regulus.

(a) The marine acid seems to act with greater difficulty than the other acids on the regulus of antimony. It does dissolve it, however, by the help of a long digestion, and calcines it less than the vitriolic and nitrous acids do. The marine salt, which we obtain in form of

(a) The solution of antimony is best known by the name of *butter of antimony*. It is a combination, which cannot well be made directly by the application of pure and liquid marine acid to the antimony, as the acid dissolves but a small portion, however strong it may be. Its action is here described as very slow and weak; and is indeed much promoted by using the acid in its highest degree of concentration, almost in a dry state, as it is when united with a metallic basis. The union with mercury furnishes it in this state; and by a superior elective attraction, it forsakes the mercury to attach itself to the antimony. To accomplish this decomposition, the mercurial salt and antimony are put into a retort and distilled, when the antimony and marine acid come over together, and often concrete on the neck of the retort in the form of a soft mass like butter, which liquefies upon exposure to the air. The addition of more water occasions a decomposition, by attracting the acid. The product is the same, whether reguline or crude antimony be used, though the residuum differs, as will be more fully explained under the article Mercury.



of small needles, by a strong heat employed in the evaporation, is very deliquescent. It fuses with fire; it is volatilized and decomposed by distilled water, like the butter of antimony; which we shall know in the sequel, and from which it differs but very slightly. M. Monnet, who has given a good account of this combination, observes, that that which is made with a calx of antimony, as the argentine flowers, differs greatly from that which is prepared from the regulus, in its fixity, and manner of crystallizing in laminæ, like selenite or sedative salt. Besides, this salt may be decomposed by the fire. We have had occasion to observe, that in the solutions of the regulus in marine acid, there is always a saline part which is not volatilized by the action of the fire, and resembles that of which M. Monnet makes mention. This depends on its being very strongly calcined by the acid. This observation may be equally applied to almost all metallic solutions, which occur in several different states, according as they contain the metal more or less calcined. M. Monnet has asserted, that 12 grains of calx of antimony are sufficient to saturate a half ounce of ordinary spirit of salt, the strength of which he has not determined. M. Bergman says, that the marine acid has a greater affinity with antimony than the other acids have.

Aqua regia dissolves regulus of antimony more effectually than either of the acids which compose it; because the force of the nitrous acid is so moderated as to be hindered from entirely calcining the regulus; and on the other hand, the force of the marine acid is augmented. The salt which is formed of aqua regia and the regulus, is very deliquescent, and may be decomposed as the other saline combinations of this semimetal.

Antimony, or the natural combination of sulphur with the regulus, is generally dissolved in greater quantity in the acids than the semimetal. The sulphur seems partly to defend the regulus from the action of these saline substances. Aqua regia acts gently upon this mineral. It is



is a very good means of freeing it from the sulphur, which precipitates in form of a white powder. M. Baumé advises to employ in this operation an aqua regia composed of four parts of nitrous acid and one part of the marine. When the action of this acid is over, we filtrate the solution: the sulphur remains on the filter; we weigh it; and in this way we learn the respective quantity of sulphur and regulus contained in the antimony which we are examining.

We have not yet examined the action of the other acids on the regulus of antimony.

This semimetal decomposes several neutral salts. M. Monet, in his treatise on the Solution of the Metals, p. 239. has described an operation, by which he demonstrates that the regulus decomposes vitriolated tartar. He fused in a crucible a mixture of an ounce of this salt and half an ounce of this semimetal. He got a yellow, vitriform, very caustic mass, which was just an antimonial liver of sulphur: this mass, washed in warm water, gave in the cold a reddish antimonial sulphur, or a true kermes. He thinks, that the phlogiston of the regulus is united to the vitriolic acid, with which it forms a sulphur; and that the alkali of the vitriolated tartar, combined with this sulphur, produced a liver of sulphur, which dissolved the calx of antimony. According to the new doctrine, we apprehend that the semimetal has seized the pure air of the acid, which, consequently, is converted into sulphur. A set of experiments which I have begun on this subject has already proved, that several metallic substances in like manner decompose the vitriolic salts.

Nitre is decomposed still more rapidly by the regulus of antimony. If we throw into a red-hot crucible equal parts of this semimetal and nitre in powder, the salt detonates with a vivid flame, and burns the regulus by means of the air which it furnishes: after this process, we find in the crucible the fixed alkali, the basis of the nitre, and the antimony in the state of a white calx; which



which calx is called *diaphoretic antimony*. For the most part, we do not employ the regulus of antimony to make this preparation; but antimony itself serves the purpose. We only need to add a greater quantity of nitre, as three parts to one of the mineral, in order to burn not only the regulus, but also all the sulphur united to it. The reason, why we prefer here the ore to the semi-metal, is, because the sulphur of the antimony renders the detonation of the nitre more rapid and more complete, and in a singular manner facilitates the combustion of the regulus.

The matter which remains in the crucible after the detonation, is composed of the calx of antimony, united to a part of the fixed alkali of the nitre, and of a portion of the nitre which has escaped the force of the detonation: it contains frequently a little vitriolated tartar, formed by the acid of the sulphur and the fixed alkali of the nitre. This composition is called *flux of Rotrou*, or *unwashed diaphoretic antimony*. We throw this matter into pretty warm water: it is washed, and the saline part dissolved, and the metallic calx remains suspended in it. We decant the troubled liquor, and let it deposite the white or fixed calx; this is what is called *washed diaphoretic antimony*: we then dry it with caution, after having moulded it into little troches. The water which swims above the sediment contains the saline matters which were in the mixture, dissolved, and a portion of calx united to the alkali of the nitre. If we pour an acid into this liquor, it unites with the alkali, and the calx of the antimony precipitates. This calx is called *ceruss of antimony*, or *pearled matter of Kerkringius*. The liquor which remains after the precipitation of the pearled matter, contains a little nitre which has escaped the detonation, a little vitriolated tartar produced during the detonation, and the new neutral salt, formed by the union of the acid with the alkali which held the metallic calx dissolved. Although this last salt varies according to the acid which we employ, it is called by the



the very improper name of *antimonial nitre of Stahl*; for the most part this salt is not nitre, and never contains antimony.

The diaphoretic antimony and the ceruss of antimony may be fused into a glass, like all the calces of this semimetal; but as they are very much calcined, it requires some pains to bring them into fusion. For the same reason, they are difficult of reduction into a regulus: they appear more irreducible even than the snow of antimony, although they have remarkable medicinal properties: they are also less soluble in the acids and in water. The regulus of antimony seems also capable to decompose the marine salt; since, if we heat a mixture of these substances in a retort, some butter of antimony, according to the remarks of M. Monnet, pass over into the receiver. This chemist has not given an account of the residuum in this operation.

This semimetal does not readily decompose sal ammoniac, according to M. Bucquet; and we do not obtain butter of antimony in this decomposition, as Juncker had advanced.

All combustible matters exert a more or less remarkable effect on this semimetal. Inflammable gas alters its surface and colour. It acts in a more forcible manner upon its solutions. I have made this gas, produced from iron in the vitriolic acid, pass into a solution of antimony in aqua regia; this is troubled instantly, and deposits a substance of a yellow orange colour, resembling sulphur auratum, but never like kermes. The flowers of antimony, and diaphoretic antimony, exposed also to inflammable gas, whether they be dry or immersed in water, are not altered.

Sulphur combines very well with the regulus, and forms an artificial ore, which perfectly imitates native antimony. To make this combination, we fuse quickly in a crucible equal parts of sulphur and regulus; and we obtain a needled mineral of a dark grey, which never has half of its weight made up of the sulphur, unless we  
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have employed a part and a half to one of the semi-metal. I have even observed, that an ounce of regulus, fused in a retort with an ounce of sulphur, gave ten gros of antimony, which consequently only contained two gros of sulphur; and that the rest of this combustible matter had come over into the receiver by its puffing up during the fusion. It is then impossible for one part of sulphur to give to four of regulus the characters of antimony: and we see after that, how important it is to make trial of that which we use in pharmacy, in order to appretiate the effect of the different substances which we combine with this mineral. The liver of sulphur dissolves completely the regulus of antimony, and forms a yellow matter, from which we can precipitate the antimonial sulphur by means of an acid, which gives it instantly an orange-colour. The hepatic gas acts upon the solutions of this semi-metal entirely in the same manner, as the inflammable gas obtained by the vitriolic acid.

The regulus of antimony unites with arsenic and to bismuth; but we have not examined these combinations.

These are the principal properties of this semimetal. We come next to consider the properties of the ore, to which the name of *antimony* has been improperly given. As it is this mineral which is most commonly used to make a great number of very important pharmaceutical preparations, we apprehend that its properties ought to be much better known than those of the semimetal which it contains. The alchemists, who have bestowed a good deal of pains about it, have extended our knowledge of antimony; and no substance has been the subject of a greater number of experiments. We have already seen, that by means of heat we can separate a portion of sulphur from it; that the result of this operation is a grey calx, which may be fused into a glass or into a liver of antimony, according to its colour and transparency; and that the nitre, in burning the sulphur, calcines also the metallic matter. But roasting



and combustion by means of nitre are not the only ways of carrying off the sulphur from the antimony; we can do it likewise by presenting to this mineral a body which has a greater affinity with the regulus than the sulphur has, or which has a greater relation with the sulphur than the regulus has.

We have an example of the first decomposition in the addition of acids to crude antimony: these salts, and chiefly aqua regia, dissolve the semimetal, and separate the sulphur from it which seems at the top of the solution: the regulus in the antimony appears to possess more complete solubility, than when it is pure, as we have already more fully remarked.

Nitre is successfully employed in the preparation of several very important antimonial medicines. We have already seen, that when we detonate one part of antimony with three of nitre, the sulphur and the regulus are consumed, and there remains only a white metallic calx mixed with the alkali. If we detonate equal parts of antimony and nitre, this detonation is less vivid, because there is less nitre: for this reason, we are obliged to throw this mixture into a red hot crucible by spoonfuls, whilst that of the diaphoretic antimony has need of being kindled only once; and accordingly it detonates all, till it be entirely reduced into a white mass. When the detonation of the antimony and the nitre in equal parts is over, we urge the whole with a melting heat; and in place of diaphoretic antimony, we find in the crucible a brown, opaque, brilliant, very brittle mass; in short, a true liver of sulphur covered with scoræ.

We apprehend, that in this process there has not been a sufficient quantity of nitre to consume all the sulphur. The portion of this last, which has not been destroyed, has in its fusion carried along the calx of the antimony. When we do not urge the mixture with a fusing heat, we obtain only a vitreous scoria, which has been called the *false liver of antimony of Rulland*. This matter, pounded and washed in water, forms the *crocus metal-*  
lorum,



lorum, which is nothing else but the liver of antimony, pulverized, and separated from the saline matters, arising from the detonation of the nitre.

Besides this, we make two other antimonial preparations analagous to the preceding, and which are at bottom true livers of antimony. The one is the ruby of antimony, or *magnesia opalina*, which is made by fusing equal parts of decrepitated sea-salt, nitre, and antimony. This fusion, which takes place without detonation, produces a vitreous mass, which is of a light brown, very brilliant, and covered with white scoriæ. The other, called very improperly *medicinal regulus*, is prepared by fusing a mixture of five ounces of antimony, twelve ounces of decrepitated sea-salt, and three ounces of tartar. We obtain a black glass, bright, very opaque, and very dense, which has no metallic lustre. These two kinds of compounds, which differ in some properties from the true liver of antimony, doubtless owe their differences to the marine salt which enters into their preparation, but whose effects upon this mineral we have not as yet been able to appretiate. If we want to prepare the regulus of antimony in small in laboratories, we ought only to employ as much nitre as is requisite to consume the sulphur, and to add to the mixture some matter which may favour the reduction of that part of the regulus which is in the state of a calx. For this purpose we take eight ounces of antimony in powder, six ounces of tartar, and three ounces of nitre: these materials are accurately mixed, and thrown by spoonfuls into a red-hot crucible; the nitre detonates with the tartar and antimony, a black flux is formed, and the regulus of antimony fuses. When the matter is well fused, we pour it upon a cone of iron, heated and greased; we strike the plate a little whilst we pour out the mixture: it is left to cool, and the regulus of antimony is found at the bottom of the vessel in a pyramidal form. This semimetal is covered with black and reddish scoriæ, which readily attract humidity from the air. The



regulus is pure, when its upper surface is convex, and when it exhibits a regular star. This star, which had exalted the imagination of the alchemists, depends on the manner in which the regulus crystallizes in cooling. The cooling begins at the edges; and the fluid matter being thrown back from the centre to the circumference, produces this crystallization, which is only observed in the small masses of regulus of antimony; for in the great loaves of this semimetal, as the undulations of the fluid matter go out from different centres, we find, in place of a star, impressions resembling fern-leaves. M. Reaumur has shown, that a sudden cooling hinders this crystallization in form of a star, and that by cooling one of the sides of the cone hastily, we obtain only half of a star (*a*). The quantity of regulus which we extract by this process does not make up half the quantity of the antimony employed, although this mineral frequently contains equal parts of regulus and of sulphur, because a portion of the semimetal is combined with the saline matters which form the scoriæ.

The scoriæ which lie above the regulus of antimony are of a compound nature. They consist of the fixed alkali of the nitre and tartar united with the sulphur of the antimony, and in the state of liver of sulphur. This liver of sulphur holds a great quantity of regulus in solution, and is mixed with a little vitriolated tartar, formed by the vitriolic acid, which is produced during the detonation, and united to a portion of the fixed vegetable alkali. Lastly, these matters contain a charry matter, furnished by the tartar. If we boil them in a great quantity of water, and filtrate the boiling liquor, the charry portion is left on the filtre. This solution, which  
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(*a*) There is without doubt a relation between the manner in which the metallic buttons crystallize at their surface, and the form which they assume, when art endeavours to give them the form of detached crystals, by a well-conducted cooling and the separation of the fluid portion, from that which is fixed. M. l'Abbé Mongez will determine this relation, in a work which he is to publish immediately, upon the crystallization of the metals.



is clear as long as it is hot, grows turbid when it cools, and deposits a reddish matter, which has hitherto been looked upon as a liver of antimonial sulphur. This precipitate is called *kermes mineral by the dry way*. When the liquor precipitates no more, it may be evaporated, and we obtain a matter less coloured than the kermes, and is a true antimonial liver of sulphur. It also furnishes some vitriolated tartar. If, in place of evaporating this liquor, we pour upon it any acid, a yellow orange precipitate is produced, to which we give the name of *golden sulphur of antimony*: it seems but little different from the kermes.

If we boil a few minutes some antimony broken into small pieces in some water charged with mild fixed alkali, the alkali attacks the sulphur of the antimony, and forms with it a liver of sulphur which dissolves the regulus. We filtrate the liquor boiling: it is allowed to precipitate by cold, the kermes (a) which it contains. This liquor being filtrated, we may precipitate some golden sulphur by means of the acids. If we boil new alkaline ley upon the residuum of the antimony, we may extract still some kermes: but this kermes is more pale

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(a) The praises which M. Fourcroy bestows upon the kermes mineral, would tempt the reader to believe, that it is by far the most useful preparation of antimony; yet, with all these encomiums, the practitioners in Britain, and in many nations on the continent, have almost universally preferred the use of tartar emetic. Kermes mineral is not always uniform in its strength, and therefore liable to vary in the effects produced upon the patient. Were it even more constant in this respect, as it consists of a metallic substance partially calcined, but uncombined with any saline matter, the efficacy of a dose must vary according to the state of the stomach. When any deranged digestion generates acidity, the operation becomes too powerful, whether it acts as an emetic or as a purgative; in other cases it is almost inert, giving scarcely any sensible proof of its presence; so that the preparation often disappoints the practitioner from its inefficacy, or alarms his fears from the violence of its effects. Tartar emetic is a neutralized soluble metallic salt, not liable to so many irregularities; so that it can be administered in all cases with more safety and greater certainty. For a further account of it, see *Cream of Tartar*.



than the first; and the oftener we repeat the process, the less kermes is produced: it would appear that the alkali dissolves more of the sulphur than of the regulus, and the antimony ought to undergo one or two boilings only in the alkali: this process is generally called the *preparation of kermes by the humid way*.

This name has been given it by Frere Simon a Carthusian friar; without doubt on account of its colour, which resembles that of the animal-shell called *kermes*, employed in dyeing (a).

Kermes mineral has also been called *the powder of the Carthusians*, because it was afterwards prepared in pharmacy by this religious order. The discovery of this medicine would seem to have been made by Glauber, who prepared it with antimony and the liquor of nitre fixed by charcoal. But he has described his process in an unintelligible way, and under alchemical emblems. Lemery may then be esteemed the true inventor of it. However, this remedy was presented as entirely new several years after the publication of the work of this chemist; and it entirely owed its reputation to the singular cures which it performed in the hands of Frere Simon. This person learned the composition from a surgeon called *La Ligerie*, who was not himself the author of it. This latter person said he had received it from M. Chastenay king's lieutenant at Landau, to whom it had been communicated by an apothecary, supposed to be an apprentice of Glauber. M. Dodart, at that time first physician to the king, applied to *la Ligerie* to publish the receipt of the kermes; and it was published by this surgeon in the 1720. Lemery the son asserted the discovery as his father's; and with so much

(a) The kermes, or scarlet grain, which is used in dyeing, is nothing else than the skin of a female insect which attaches itself to the holm oak, and rises gradually in the form of an arch. It has lost the form of the rings which distinguish those animals. Under this arch, the eggs, which are hatched, are contained; and they pierce through it to attach themselves to the plant in the same way as the other.



much the greater justice, as, in making this preparation, most part of apothecaries still follow the process which was described by this chemist.

The process described by La Ligerie consists in boiling during two hours a pint of rain-water, with four ounces of liquor of nitre fixed by charcoal, and a pound of antimony broken into small bits; in filtrating the boiling liquor; in boiling the same antimony with three ounces of new liquor of nitre fixed by charcoal in a pint of rain-water; and lastly, in making the second residuum undergo a third boiling in preceding leys, with the addition of two ounces of the liquor of nitre fixed, and a pint of rain-water. We filtrate, and allow it to deposite the kermes: we wash it till the water which is added comes off insipid; we dry it; we set fire to some aqua vitæ put on the top of it, and then pulverize it. The process is long; it furnishes but very little kermes, since we obtain at most but two gros of a liver of antimony: it is, besides, troublesome on account of the long boiling and the évaporation of the water.

M. Baumé, who has adopted that of Lemery, proposes two methods of easily preparing a great quantity of the kermes in a short time; one by the dry way, and the other by the humid way. According to the first method, we fuse in a crucible one pound of antimony, two pounds of very fine salt of tartar, and one ounce of sulphur; which is all previously reduced into fine powder. We pour this mixture, when fused, into an iron mortar; when cold, it is reduced into a gross powder; we boil it in a sufficient quantity of water, and filtrate the liquor through grey paper; we obtain a kermes of a red-brown colour when it is cold: we wash it first with cold water, and then with boiling water, until it be sufficiently deprived of its saline parts; we then dry it, pulverize it, and pass it through a silken sieve. In order to prepare the kermes by the humid way, we boil five or six pounds of pure fixed alkali, in fifteen or twenty pounds of river-water; into the boil-



ing liquor we throw four or five ounces of porphyrized antimony: we shake the mixture; and when it has boiled a little time, we filtrate it; after cooling, it deposites some kermes; and we wash it in the same manner as that made by fusion. This process affords, according to M. Baumé, twelve or thirteen ounces of kermes for the pound of antimony. This chemist assures us, that these two kermes are both alike.

The theory of this operation, and the nature of the kermes, are not as yet perfectly understood, notwithstanding the labour of several celebrated chemists. We think in general, that the alkali dissolves the sulphur of the antimony, and that the liver of sulphur which it forms dissolves likewise the regulus of antimony. This semimetal, however, is not wholly dissolved; since, in the process of Lemery by the humid way, a grey powder is precipitated during the ebullition, which fuses without addition into a true regulus. The precipitation of the kermes by the cooling of the ley, which is at first reddish and transparent, and which loses its colour in proportion as the kermes deposites, is even a singular phenomenon. We take this compound to be a kind of antimony overcharged with sulphur, and soluble by means of heat in the fixed alkali. Accordingly, if we heat a ley which contains some kermes deposited, it is redissolved by the heat. The ley which deposited some kermes by cooling, contains still some antimonial liver of sulphur: when we pour an acid into it, an orange matter precipitates, called *sulphur auratum antimonii*, and which is much more emetic than the kermes. It is our opinion it contains less sulphur and more regulus than the kermes.

Geoffroy, who in 1734 and 1735 presented to the Academy several memoirs upon kermes, used several methods of analyzing it. The action of the acids is the most effectual means which we can employ. These salts dissolve the semimetal, and leave the sulphur detached. By this means we can appretiate the respective quantity of these two substances. One gros of kermes contains,  
accord-



according to Geoffroy, from sixteen to seventeen grains of regulus, thirteen to fourteen of fixed alkali, and forty to forty-one of sulphur. Many chemists at present think, that the kermes does not contain an atom of alkali. M. Baumé thinks that this salt is not one of its constituent principles, and that it may be freed of the alkali by only washing it in a good quantity of boiling water. M. Deyeux, who has prosecuted this object, is of the same opinion. Upon an investigation of the kermes, conjunctly with M. le Duc de la Rouchefoucauld, we have had an opportunity of observing the same thing. But what seems to be of the greatest importance in this object is, that the kermes seems to be very different from itself, according to several circumstances of its preparation. It contains more or less sulphur and regulus; and we apprehend that its effects, in consequence of these differences, ought to vary very much. In general it appears, that the state of the antimony, the variety of the proportion of its principles, its greater or less division, the greater or less causticity of the alkali, its quantity, the quantity of the water, the time of the ebullition, and several other analagous circumstances, may greatly change the nature of the kermes. It were then much to be wished, in pharmacy, that this medicine could be prepared in an uniform manner; and we can only obtain this perfection by a set of experiments, made with all the precision and all the accuracy which a matter of so great delicacy requires. Without entering, at large, upon the phenomena, which the kermes exhibits when treated with a great number of different intermixtures, we shall only add, that the alkalis change it singularly, and dissolve it; that the acids act with a very varied force upon it; and that it is very difficult to determine in an accurate manner the state of the semimetal, and of the sulphur which enters into its composition.

The caustic alkalis exert a much greater force upon antimony than the mild alkalis do; they form a kermes  
in



in much greater abundance, and of a much deeper colour. Lime-water, digested with antimony in powder, affords, even in the cold, in the space of some days, a kind of kermes or sulphur auratum, of a beautiful red colour. The volatile alkali changes it in the same manner. By distilling some sal ammoniac with antimony, we obtain a powdery purple sublimate, which appears to be a kind of antimonial liver of sulphur with base of volatile alkali.

In the last place, to finish the history of the decomposition of antimony, we observe, that several metallic substances possess the power of depriving it of its sulphur, with which they have a greater affinity than the regulus has. Tin, iron, copper, and silver, may effect these decompositions. It is sufficient to heat and fuse the tin and silver with the antimony. These two metals unite to the sulphur, and leave the regulus. The iron and copper produce the same effect, if, after they are reduced into filings, and made red-hot in a crucible, the antimony is added to them. This mineral accelerates the fusion, and the regulus separates. The semimetal obtained by these processes is not pure: it retains a part of the metallic substances which we have employed for the separation of the sulphur; its colour and form constantly shew this alloy: it is called *regulus Jovis, Veneris, or Martis*, according to the metal to which it is united.

The regulus of antimony is employed in several arts, and particularly to cast the types for printing. It was used formerly for a purge. Some water or wine was kept for a night in vessels made of it; next day the liquor was ready for use. But as the temperature of the place where this operation was performed, the greater or less acidity of the wine, necessarily produce differences in the quantity of regulus dissolved, this medicine has with reason been abandoned as very uncertain in its effects. We have likewise renounced the perpetual pills, being only balls of this semimetal, which were employed



employed as a purge. The state of the digestive juices, the nature of the saburra in the first passages, the sensibility of different individuals, rendered their effects uncertain, and often dangerous.

We only employ now the crude antimony, the flux of Rotrou, the washed diaphoretic antimony, the kermes mineral, and sulphur auratum. The crude antimony is used as a sudorific in diseases of the skin. We suspend it, wrapped up in a linen cloth in form of a knot, in the vessels in which we prepare the ptisans appropriated for such diseases: some physicians deny, that, when given in this form, they possess any virtues. We exhibit it also in substance, minutely porphyriized and formed into pills, for the same indications. The flux of Rotrou is very much recommended in diseases of the lymph, which depend on the thickening of this liquor; as in scrophulous affections, and in general in obstructions of the glands. Several physicians repose no confidence in the efficacy of washed diaphoretic antimony: they look on this as a true calx of antimony, without virtue. In the mean time, we ought not to forget, that this calx, which M. Rouelle found to possess a sensible enough solubility, may produce effects in consequence of this property. It is besides certain, that as we do not know the action of the gastric and intestinal juices upon the metallic calxes, we cannot say that a substance, insoluble and insipid to appearance, cannot possess any other virtue. Here reasonings ought to yield to observation: this medicine has been observed to produce often good effects on the ringworm eruptions, and in the most obstinate diseases of the skin, when it is employed for a length of time. We ought to prefer, in the case of these diseases, the unwashed diaphoretic antimony or the flux of Rotrou, which is much more active than the foregoing preparation, in consequence of the alkali which it contains. In these affections also we make use of a medicine called *powder of Chevallera*y. This is diaphoretic antimony calcined  
seven



seven times successively with fresh nitre for two hours, and washed after every operation: it does not sensibly differ from washed diaphoretic antimony; because this semimetal, once well calcined, as it is when deflagrated with three times its weight of nitre, is not susceptible of any farther calcination in this operation; likewise we do not observe any more detonation.

The kermes mineral is one of the most precious medicines, which the medical art possesses. It is an expectorant, and is employed with the greatest success in pituitous affections of the stomach, of the lungs, of the intestines, and even of the urinary passages. It is used most commonly in diseases of the breast, with a view to assist expectoration: we ought, however, not to administer it till the inflammation has abated. It does also much service, when exhibited in little doses, in the catarrh of the breast, the humid asthma, diseases of the skin, glandular obstructions, and other diseases. We employ it only in the dose of a half grain to that of two or three, in proper drinks, or in the form of pills. It is sometimes emetic: it often excites a sweat, or increases the flow of the urine.

The sulphur auratum, as it is a violent emetic and cathartic, is not in use. We sometimes exhibit it in the same cases as we do kermes; but its effects are much more uncertain.

There are still several other preparations of antimony from which medicine derives many advantages; but as they are made with vegetable matters, we will take notice of them in another part. This metallic substance is of the greatest importance to physicians, and they cannot study too much all its properties. It is one of those substances upon which the alchemists and chemists themselves have been the most exercised; and it is that circumstance which has given rise to the numerous preparations which we have just described.



## LECTURE XXIX.

Species 7. *Zinc*.

**Z**INC is a semimetallic substance, brilliant, of a blueish-white, crystallized in straight laminæ: it has neither any taste, nor any particular smell. It cannot be reduced into powder like the other semimetals: it may be flattened under the hammer, and may even be split into laminæ very completely, provided it has not been previously too much stiffened by the hammer. When we want zinc very much divided, we must grain it; that is to say, pour it fused into cold water, or file it. It has the disadvantage of stuffing the file and filling the teeth. M. Macquer says, that when we give it the greatest heat possible, without fusing it, it becomes very brittle, and may then be pulverized in a mortar. This property is very different from that of the metals, which become more ductile by the action of the fire; and it furnishes us with an advantageous process to have this semimetal very much divided.

Zinc loses in water about a seventh of its weight. The particular facets which the pigs of the zinc in commerce present in their fracture, indicated that this semimetal had the property of crystallizing in a particular manner. M. l'Abbé Mongez has succeeded completely in obtaining this crystallization. It is formed of bundles of small quadrangular prisms, disposed on all sides, of a blue colour, which changes if exposed to the air.

M. Sage looks upon zinc as the most common of the metals next to iron. He says, that he found it in all the martial pyrites: and M. Grignon asserts, that the cadmy of the furnaces, in which the earthy ores of iron are treated, contains much zinc. Zinc is rarely found. M. de Bomare says, that he has seen it in the mines of calamine stone in the duchy of Limbourg, and in the  
mines



mines of Goslard: it was in small pliant filaments, of a greyish colour, and easily inflamed. This semimetal is oftenest in the state of a calx; it then constitutes the calamine stone, whose form varies greatly. Sometimes it is crystallized in cubes, in prisms, in leaves, or in laminæ: for the most part it is in irregular masses. Its colour also varies. It is often white, sometimes grey or yellow, at other times reddish. It is found in very considerable quarries in the dutchy of Limbourg, the counties of Namur, and of Nottingham and Somerset in England. In these calamines we often find marine bodies and calcareous spar; which proves that they have been deposited by the water. It is also called *calamine stone, natural or fossil cadmia*.

Zinc in the state of a calx, combined with sulphur, forms blend or false galena. Generally, this blend is disposed in scales; sometimes it seems crystallized in more or less truncated cubes: it varies in colour; often it inclines to that of lead; most frequently it is black and reddish: there is likewise found at Konigsberg in Norway, at Goslard, and Saint Maria, a kind which is yellow and transparent. Almost all the blends are phosphoric when rubbed in the dark; some are so even to such a degree, that rubbing them with a toothpick suffices to discover this property. Blend has got the name of *sterile nigrum*; because, when it was fused in order to extract the lead which it seemed to contain, nothing was procured; on this account, that the zinc was volatilized in the fusion. All the blends, when rubbed or dissolved in an acid, emit a very sensible smell of liver of sulphur. M. Cronstedt looks upon them as zinc, united to sulphur by the intermedium of iron. M. Sage thinks, that they contain an earthy liver of sulphur.

Zinc is found in a saline state also, combined with the vitriolic acid: then it forms either rhomboidal crystals or white stalactites; or rather it is crystallized in fine needles, and in filken filaments, like amianthus:  
in



in this state it is called *plumed alum*: it is found in Italy, and in the mines of Goslar at Hartz. After these details, the ores of zinc may be exhibited in the following manner, according to the state in which this semi-metal is found.

State 1. *Native Zinc.*

Varieties.

1. In filaments, flexible, greyish, and inflammable.
2. In masses composed of laminæ, of a yellowish grey, and ochry. I have seen in cabinets specimens of ores sent for native zinc, which had the form that I have just described; but as their scarcity has hindered them from being examined, there is nothing decided about their nature. The existence of native zinc still is a problem among naturalists.

State 2. *Zinc in a calcined state. Calamine.*

Varieties.

1. White calamine, in three-sided prismatic crystals, short, in confused groups. It sometimes inclines to green.
2. Calamine crystallized in pyramids, similar to calcareous spar, with swine's-teeth; of a white, grey, greenish, or reddish colour. M. Sage and Romé de Lisle thought that this calamine was produced by decomposition of calcareous spar. In fact, it is often found in part calcareous, and hollowed in the inner part.
3. Calamine, solid and as if worm-eaten. It is ridged, cellular, and as if in dendritical crystals.
4. Solid and compact calamine, lapis calaminaris. That which comes to us from the county of Namur is always calcined. It is not exported, till it has undergone this operation.
5. Calamine in greenish or yellowish stalagmites.

State 3. *Zinc mineralized by Sulphur. Blend.*

Varieties.

1. Octaëdral or cubic blend, whose angles are truncated. It is of a red or brown colour.

2. Blend



2. Blend in large vitreous laminæ. Its colour is yellow, red, or brown.
3. Blend, colour of pitch, like nipples or leaves.
4. Blend of a blueish grey, composed of very small leaves.
5. Blend which is decomposed: its laminæ or leaves are separated; its brilliancy is lost; it passes to the state of calamine.

STATE 4. *Saline Zinc.* White Vitriol.

Varieties.

1. Vitriol of zinc in native rhomboidal crystals. This vitriol is very rare.
2. Vitriol of zinc in stalactites.
3. Vitriol of zinc in filken filaments, improperly called *plumed alum*.

In order to essay calamine, it is sufficient to pound it, to mix it with powder of charcoal, and to heat it in a crucible covered with a plate of red copper. This last is not long of turning yellow, and of being converted into brass. The blend, after having been roasted, may be essayed in the same manner. M. Monnet says, that it may be essayed conveniently by dissolving it in aqua-fortis, which unites with the metallic substance, and separates the sulphur. The calx of zinc is reduced, after being separated from the nitrous acid by distillation.

The ores of zinc are but little wrought to extract this semimetal. It is by fusing the ores of lead mixed with blend that zinc is extracted in the form of a calx, which sublimes in the chimneys of the furnaces, and produces greyish incrustations, called *tutty* or *cadmia of the furnaces*. Another part of it is gotten in a metallic state: for this purpose care is taken to cool the anterior part of the furnace, which is called *la chemise*. The zinc, reduced into vapours by the action of the fire, comes to condense in this place, and falls in grains among the powder of charcoal, with which a stone that is placed at the bottom has been covered. This semimetal is preserved from calcination by the charcoal: it is fused anew in a crucible,



and run into loaves. This is the process by which the greatest part of the zinc in commerce, either in a calcined or a metallic state, is extracted at Rammelsberg. This zinc is always united with a certain quantity of lead, which changes it: it seems that that which is prepared in China, and which we get from the Indies under the name of *tutenag*, is much purer; but we do not know the manner in which this last is prepared. M. Sage says, that the English extract it in great from the calamine stone in the way of distillation; but that their apparatus is still unknown.

Zinc, exposed to the fire in close vessels, fuses as soon as it reddens, and is volatilized without being decomposed. If we allow it to cool slowly, and in a vessel which will favour the running off of a portion of this semimetal fused, the rest of the zinc crystallizes in needled prisms. M. Mongez uses for this purpose a potsherd for roasting, pierced at the bottom and in the sides with several holes, which he shuts up with earth of bones. When the zinc cools at the surface, the holes are opened by degrees, and the metal agitated with a red hot iron introduced through these openings. This simple process makes the portion of fluid zinc run out; then the vessel is agitated, till no more of the fused metal escape, and the cooled portion be crystallized. If we leave it in the vessel, it has the metallic colour; if we expose it to the air, it assumes the colours of the rainbow. When fused zinc is in contact with the air, it is covered with a grey pellicle, which is very quickly converted into a yellowish earth or calx, not very refractory, and easily reduced. This calx weighs more than the zinc employed. But if this semimetal is strongly heated, it burns with a white flame, or of a yellow colour slightly tinged with green, very brilliant, resembling that of phosphorus. The current of this flame carries along with it and volatilizes the zinc, which is condensed by the air in the form of white flocci very light, called *flowers of zinc*, *pompholix*, *nihil album*, *lana vel xylos*



*philosophorum*. It is a perfect calx of zinc: it is heavier than the metal employed for its formation; for from every pound of zinc, M. Baumé obtained 16 ounces 6 gros and 54 grains of flowers: it is not volatile of itself; and its sublimation is only in consequence of the rapidity with which the zinc burns; for if we expose it to the fire after being volatilized, it remains very fixed: it preserves for some time a phosphoric light, visible in the dark: it may be fused into a glass; but for this it requires a fire of the greatest violence. The glass of zinc is of a fine pure yellow. The calx and the glass of zinc are nothing but the combination of this semi-metal with pure air. The glass does not seem to differ from the white calx, except in the more intimate union of these two principles. This compound is in the number of metallic calxes which heat cannot destroy; and it cannot be reduced to its metallic state without addition. We must put it in contact with combustible bodies, that it may be decomposed. A mixture of pompholyx and charcoal, or any other combustible matter, being strongly heated, zinc is obtained, and the charcoal is found in part burnt by means of the dephlogisticated air which it took from the metallic calx. Therefore zinc has less affinity with pure air than charcoal has, though it seems more combustible than it. This operation does not succeed well except in close vessels: on that account the English reduce the calamine stone by distillation. Zinc is not changed by the air; its surface only tarnishes a little. It is not acted on by water, nor does it combine with the earths; but its calx may be united to these last, and form with them yellowish glasses.

Magnesia and lime have no action on zinc. The caustic fixed alkali made to boil on it, blackens its surface, gives it a dirty yellow hue, and dissolves a certain quantity, which may be separated by pouring this liquor into spirit of vitriol, as M. de Laffone has shown. The volatile alkaline spirit acts less powerfully, no doubt, on  
account



account of its volatility: this salt digested with zinc in the cold, disengages some inflammable gas.

The vitriolic acid diluted with water, dissolves zinc in the cold. In proportion as the acid acts, the semi-metal becomes of a blackish grey; during the solution, a black powder is precipitated, which has not as yet been examined: a great quantity of inflammable gas is disengaged, which burns with a very bright flame, and detonates with pure air. This gas has an odour similar to that disengaged from the solution of iron in the same acid. This odour changes when the effervescence ceases, and perfectly resembles that of grease a little rancid: the liquor is whitish, and a little turbid: it becomes transparent by dilution with water, and by evaporation furnishes a white vitriol, which is a little more soluble in hot than in cold water, and of which a portion crystallizes by cooling. Very regular crystals of vitriol of zinc are very easily obtained, by exposing some days to the air a solution of this salt made in boiling water, and evaporated a little; three-sided prisms are formed, terminated by pyramids likewise with four sides. The sides of these prisms are smooth. This is the form remarked by Messrs Sage and Romé de Lisle, and which I have obtained myself. M. Bucquet observed, that these prisms were rhomboidal. M. Monnet, however, says, that this salt crystallized with difficulty; and that we must evaporate it strongly, and expose it to cool quickly, in order to obtain regular crystals without consistence. The white calx of zinc is also dissolved in the vitriolic acid, and gives white vitriol.

This salt has a very strong styptic taste. According to M. Hellot, it loses a part of its acid by the action of the fire. This acid has the characters of the sulphureous acid: it grows warm with the oil of vitriol, according to the remark of M. Macquer. The vitriol of zinc, when very pure, is but little altered by the air; it is decomposed by lime and the different alkalis. The calx of zinc precipitated by these substances, may be redissolved in the



acids, and even in the alkalis. In this solution the volatile alkali takes a dirty brown colour. The vitriol of zinc decomposes nitre, and is decomposed by this neutral salt. By the distillation of this mixture we obtain two distinct kinds of nitrous acid, and some glacial oil of vitriol. We shall say more of this subject in the article on Martial Vitriol.

We find in commerce, under the name of *white copperas*, a vitriol of zinc, which is prepared in great at Goslard. The blend is roasted; a portion of the sulphur burns, and furnishes vitriolic acid, which dissolves the calx of zinc: the roasted ore is washed; and the ley, after being allowed to settle, is decanted, evaporated, and crystallized. This salt is fused with a gentle heat, that it may lose the water of its crystals, and then it is left to cool. By this process it is condensed in white masses, opaque, and grained like sugar. The vitriol of Goslard, dissolved in boiling water, crystallizes by cooling: its crystals are a little reddish. This colour is attributed to the impurities of this salt, which is supposed to contain a little lead and iron. In order to purify it, we may throw some zinc into its solution: this semimetal precipitates the iron and lead, because it has more affinity than they with the vitriolic acid; we filtrate the liquor, which then contains nothing but pure vitriol of zinc. We are still more induced to believe, that the alteration in the vitriol of Goslard is often owing to iron, because sometimes the zinc in commerce is attracted by the magnet, undoubtedly owing to a little iron which remains united to it. If then we wish to make experimental inquiries into this semimetal, it would be proper to use only the zinc which we prepare ourselves, by reducing the precipitate of the white vitriol, purified, as we have just now described.

The nitrous acid, weak and diluted with water, combines with zinc in the cold, and with great rapidity. A considerable heat is produced, as in the solution by the vitriolic acid. The brisk effervescence which accompanies th s  
com-



combination, disengages a great quantity of nitrous gas, which suddenly reddens with the air, when we perform the operation in an open vessel; but which is without colour of itself, and may be collected above water, by putting the extremity of the vessel, which contains the mixture, under this fluid. If the zinc is mixed with a little iron, it is covered with a reddish ochry powder; if it is pure, some tufts of a black matter are precipitated, as we observe with the vitriolic acid. The nitrous acid dissolves much more zinc than the vitriolic. M. Baumé says, that six ounces of this acid dissolves five gros and a half of zinc in less than two hours. The nitrous solution of zinc is of a greenish yellow, and a little turbid after it has just been made; it loses this colour, and becomes transparent by rest. Though made with a diluted acid, it is very caustic, and very soon frets the skin. By evaporation joined to cooling, it gave me crystals in three-sided prisms, compressed and striated; terminated by pyramids with four sides, likewise striated. The nitre of zinc put upon coals fuses immediately, and in portions which are dried. In detonating it emits a small reddish flame. It does not present the same phenomenon when heated in a crucible; we cannot dry it, even with the most gentle heat, without altering it. The vapours of nitrous acid escape from it; it turns of a red brown, and takes the consistence of a gelly. If we cool it in this state, it preserves its softness during some time; if we continue to heat it, it dries totally, and leaves a yellow calx. I never distilled this salt, and I do not know if it gives pure air. Hellot extracted from it a very fuming nitrous acid; and he observed the red colour which it assumed in fusing. The nitre of zinc readily attracts humidity from the air, and loses its regular form. After some days no more than striated and pointed prisms remain, without any determined figure. We are not certain if it can be decomposed by the other acids. Messrs Pott and Monnet say, that zinc has much affinity with all the salts, without giving preference to any in



particular. According to Hellot, the flowers of zinc absolutely form the same salt with the nitrous acid.

The marine acid acts on zinc with as great rapidity as the nitrous acid: during the brisk effervescence which accompanies this combination, a great quantity of inflammable gas is disengaged, possessing all the properties of that made with the vitriolic acid; a substance is gradually deposited in blackish flocci, which some have thought to be sulphur, others iron, and M. de Laffone a calx of zinc. This matter dissolved in the acids cannot be reduced into a metal, and calcines on burning coals. M. Monnet supposes, that it proceeds from some foreign metallic substances, as iron or copper, which are often found in zinc: it would merit a particular examination. The solution of zinc by the marine acid is void of colour; it cannot be crystallized by evaporation. When we heat it, it becomes of a blackish brown, emits acrid and pungent vapours of the marine acid, and grows very thick; exposed in this state during eight days to the air, it did not give crystals. By distillation it gave a little very fuming acid, and true butter of zinc. Messrs Hellot and Monnet have very well described this experiment: I have repeated it several times in my courses; and after a little yellowish acid, I obtained a congealed matter in the body and in the neck of the retort. This butter was much whiter than milk, very solid, and formed of small shining needles, as a stalactite: it fuses by a gentle heat. I have kept a glass flask of it for a year well closed up; it is but slightly moist, and the part which touched the glass is a little yellowish: the bottom of the flask presents the colours of the rainbow. This alteration undoubtedly depends on the light. In the retort there remains a blackish vitriform and deliquescent matter. The butter of zinc which M. Hellot obtained was yellowish; and he says the vitriolic disengages the marine acid from it. The marine acid has the same effects upon the calx of zinc. The aerial acid, in which is put some zinc, or calx of zinc, to digest in the cold,  
dissolves



dissolves in about 24 hours, according to M. Bergman, a very great quantity of this metal. This solution, exposed to the air, is covered with a pellicle which reflects different colours, and is nothing but a chalk of zinc, called *aërated zinc* by this celebrated chemist.

All these solutions of zinc in the acids are precipitated by lime-water, the solution of magnesia, the fixed and volatile alkalis. Then the metal appears under the form of white or yellowish flocci, according to the state of its solution, or the purity of the precipitant. In this experiment the zinc is reduced to a calx, and draws along with it a portion of the air contained in the acid. This calx may be reduced by means of the combustible substances; it is soluble in the acids, and in the fixed or volatile alkalis. By adding more of these last than is necessary to precipitate the zinc, the metal gradually disappears, and the liquor acquires a dirty yellow colour, which indicates the solution of the calx of zinc in the alkalis. When, instead of employing the pure or caustic alkalis, we employ the aërated tartar, natrum, or ammoniac, for the precipitation of the zinc, there is but very little effervescence, the precipitate is whiter, and it appears that the acid is carried back to the calx of zinc; so that in this case there are two decompositions and two combinations.

Zinc has the property of decomposing several neutral salts. Perhaps by exposing it to the fire in a crucible along with some vitriolated tatar, it would decompose this salt, and would form some liver of sulphur, as we have seen was the case, according to M. Monnet, with the regulus of antimony. This might be supposed with so much the more probability, as it is much more combustible than this regulus. The same would happen with Glauber's salt and vitriolic ammoniac. Filings, or the powder of zinc, detonate with nitre with singular rapidity. This mixture, very dry, thrown in spoonfuls into a red-hot crucible, produces a red and white flame. The activity of this inflammation is so great, that burn-



ing sparks shoot to a great distance from the crucible, and it requires much precaution on the part of the artist. The zinc burns by means of the pure air furnished by the nitre decomposed; and accordingly it is found in the state of a more or less perfect calx, according to the quantity of nitre. A part of this residuum is soluble in water: it is the vegetable fixed alkali, combined with the calx of the zinc, which may be precipitated by means of the acids. Respour attributed to this solution the property of dissolving all the metals, if we believe Hellot, who gave it as the alkahest of this alchemist. From the works of M. Pott, zinc appears to be capable of decomposing the marine salt. Sal ammoniac, particularly, is very easily decomposed by it. M. Monnet asserts, that in triturating this semimetal with this salt, some volatile alkali is disengaged. M. Bucquet observed, that in distilling sal ammoniac and zinc, we get much alkaline and inflammable gas, produced by the combination of the marine acid with the semimetal. He observed, that it was in consequence of the brisk reaction which the zinc exerts on the marine acid, that the volatile alkali is so easily disengaged. According to M. Hellot, the calx of zinc likewise disengages it.

A solution of alum boiled with filings of zinc is decomposed, and some white vitriol is produced. The base of this salt, then, has less affinity with the vitriolic acid than the calx of zinc has. This fact is due to M. Pott. We shall have occasion to observe it in several metallic substances.

The effects of inflammable gas on zinc have not been examined. I have only observed, that plunged into this gas, after some time it acquired a blue and changeable colour of the greatest beauty; but I have pursued this alteration no farther.

Zinc does not appear capable of immediately combining with sulphur. These two substances fused together, are separated without contracting any kind of union. This phenomenon is so much the more singular,



lar, as this semimetal is almost always combined with sulphur in its ores. We have formerly observed, in speaking of blend, that this union is probably owing to some other substances; and perhaps to calcareous earth, as several chemists have said. However, M. Malouin could not succeed in combining zinc with alkaline liver of sulphur, either by the humid or dry way, and varying the quantities of these two bodies. Could the calcareous liver of sulphur have this property exclusively? This is a good ground for experiment. M. Malouin combined zinc with the regulus of arsenic. He observed, that this regulus did not combine so well as the calx with this semimetal. However, in an experiment, in which he distilled a mixture of this calx, tallow, and zinc, he obtained a blackish mass like blend, and more tender than this ore. It appears also that zinc attracts the air from the calx of arsenic when we distill them together; and that part of this semimetal is in the state of flowers, whilst a portion of the arsenic is converted into a regulus. It would be of importance to make a set of experiments on this subject, in order to learn what is the reciprocal action of the metals, and of their calxes on one another.

We do not know if zinc is capable of being mixed with cobalt. It does not combine with bismuth; and when we fuse these two semimetals together, the bismuth, as being more heavy, precipitates under the zinc. They are separated with a stroke of a hammer.

Zinc fused with regulus of antimony, gives a hard and brittle alloy, which M. Malouin only mentions.

Zinc is of great use in the arts: it is employed in several alloys, particularly in that which constitutes tombac, similor, or prince's metal. Fine filings of zinc are mixed with powder, in order to produce beautiful and brilliant artificial fire-works. Some persons have proposed to substitute this semimetal to tin in tinning, which they have looked upon as dangerous. M. Malouin, after having compared these metallic substances, in two memoirs,



memoirs, inserted among those of the Royal Academy of Sciences for the years 1743—44, gives an account of his experiments on tinning with zinc. He infers from his researches, that this kind of tinning would be more accurately laid over the copper, would be much harder and less fusible than tin, and consequently more durable, and less subject to leave the copper uncovered. M. Macquer, who knew its advantages, made, however, very important observations on the use of zinc for kitchen-vessels; and he thinks it dangerous, because it is soluble by the vegetable acids, as vinegar, verjuice, &c. and because it has a very strong emetic property. He proves it by the vitriol of zinc, which was formerly used as a vomit, under the name of *Gilla vitrioli*; and by the testimony of M. Gaubius, who took a reputed remedy in convulsive diseases, called *Luna fixata Ludemanni*, for flowers of zinc. This pretended luna fixata was a strong emetic, and in very small doses. But may we not be allowed to presume, that these reproaches which fall on the vitriol and flowers of zinc, are not more applicable to the semimetal itself, than to the salts formed by the combination with the vegetable acids. M. de la Planche, doctor of medicine of the faculty of Paris, has converted this presumption into certainty, by experiments made with much care, and on himself. He took the salts of zinc, formed by the vegetable acids, in a much stronger dose than the aliments prepared in copper vessels lined with zinc could have contained, and he felt no dangerous effects from them. However, as the objects which interest the health and life of mankind cannot be treated with too great wisdom and circumspection, I think it prudent, and even necessary, not to decide on this subject, till a great number of experiments are made on the nature of zinc, on the black matter which is precipitated during its solution in the acids, and which not being properly known, might contain some hurtful substances; and till, above all, we know, by a great number of experiments, what may be the action of zinc in  
its



its natural state, and of the salts, which it forms with the vegetable acids employed in our aliments, on the animal œconomy. The German physicians employ the flowers of zinc with success, as antispasmodic, in convulsions and epileptic fits. We do not make great use of it in France; it appears, however, that this remedy might be useful, exhibited in pills, in the dose of one half grain a-day. I have been told, that at Edinburgh it is used in much more considerable quantity, and that no sensible effect was obtained. This fact is contrary to what M. Gaubius says of the emetic property of this calx of zinc.

Pompholyx, tutty, &c. are used as very good deficcatives in diseases of the eyes.

## LECTURES XXXI. XXXII. and XXXIII.

### *Of the METALLIC SUBSTANCES.*

#### Species 8. *Mercury*.

**M**ERCURY has opacity and metallic brilliancy: except gold and platina, it is the weightiest substance that we know. A cubic foot of very pure mercury weighs 947 lbs.; it loses  $\frac{1}{11}$ th of its weight in water. As it is constantly fluid, we are not acquainted with either its tenacity or its ductility; and we are still at a loss to know what rank to assign to it. In fact, it is volatilized like the semimetals; it has a kind of ductility as the metals have. However, its enormous weight, its habitual fluidity, its extreme volatility, and the singular alterations which it is capable of suffering in many combinations, occasion its being regarded, with probability, as a particular substance; which seems to belong to the metallic substances only in its brilliancy, its weight, and its combustibility, and ought to be ranked separately



separately. We place its history between that of the semimetals and metals.

It was for a long time believed that mercury cannot lose its fluidity. But the academicians of Petersburg have proved the contrary. These learned men took advantage of the excessive cold in the year 1759; they also increased the natural cold, by means of snow and fuming spirit of nitre; and by this means brought the mercury in Reaumur's thermometer down to the 125th degree, below 0 (*a*). Observing, that at this degree the mercury no longer descended, these gentlemen broke the bulb of the glass, and found the metallic fluid congealed, forming a solid body, which bore compression with a hammer. This experiment demonstrates, that mercury, like all the other metallic substances, may become concrete; that it possesses then a certain degree of ductility. We do not know how far this last property may go; because, as soon as it loses this great degree of cold, it resumes its fluidity. M. Pallas, who has succeeded in congealing mercury by exposing it in the open air, and towards the north, in the very cold country which he inhabits, has observed, that it then resembled soft tin; that it might be beat out into laminæ; that it was easily broken; and that its parts, brought near, united again. This

(*a*) Later experiments have ascertained, with greater precision, the degree of cold at which quicksilver congeals. In place of merely exposing a mercurial thermometer to cold, the mercury of which was both to congeal and indicate the degrees of its own contractions at one time, and thus to serve two offices at once, the mercury to be frozen was put into a small cylindrical vessel, to which the cold was next applied. The advantage of this change was, to afford an opportunity of measuring the cold of the surrounding fluid mercury, when a piece which had been frozen was dissolving by heat. In this situation the mercury continues a considerable time of the same temperature, and the surrounding fluid is very nearly equally cold with what is solid. When the experiment is conducted thus, the spirit-of-wine thermometer is found to stand at the 40th degree below 0 of Fahrenheit's scale; a degree of cold which is indeed excessively of intense, but far inferior to what it was formerly supposed to be, from the less accurate mode of making the trial.



This metal, then, is the most fusible of all those we are acquainted with: the greatest natural cold cannot render it solid. It is probable, that if, in the experiment of Petersburg, the cold which congealed the mercury had been conducted by insensible degrees, this metallic substance would have assumed a crystalline and regular form. The habitual fluidity of mercury has occasioned its being looked upon as a particular metallic water; and it has been called *Aqua non madefaciens manus*, Water which does not wet the hands. It is true, that mercury wets neither the hands, nor any of the other bodies which may be wet by water, oils, or other liquors: but that phenomenon depends on this only, that this metallic fluid has no affinity with those bodies; for when it is in contact with any of the substances to which it can unite, as gold, silver, tin, &c. then it applies itself intimately to these bodies, and wets them to that degree that they cannot be dried, except by evaporating the mercury which is mixed with them.

Mercury being a fused metal, it always assumes the form of perfect globules when it is divided; when it is contained in a bottle, its surface appears convex. This effect depends, both on the little affinity which mercury has with glass, and on the great attraction which endeavours to draw its parts together: for if we put this fluid into a metallic vessel with which it has affinity, then its surface appears concave, like every other fluid, because it combines with the sides of the vessel. Mercury has a taste which the nerves of the taste cannot perceive; but which, however, produces a very remarkable effect on the stomach and intestines, as well as on the surface of the skin. Insects and worms are infinitely more sensible, than other animals, of this taste; for that reason mercury very quickly kills them, and physicians employ it as a very excellent vermifuge. It is also on account of the property which it possesses of curing the diseases of the liver, and sundry other maladies of the skin, that learned men have thought that those diseases were produced



duced by the presence of certain insects which penetrated the texture of this organ. But this opinion has not been generally adopted, although several naturalists have described the worm of the gall.

Mercury rubbed for some time between the fingers emits a slight particular odour. When very pure, and when it is agitated, we sometimes observe, and particularly in the hot seasons, that it shines with a very sensible phosphoric light: this phenomenon has been observed in the mercury of the barometer by several natural philosophers. If we plunge the hand into this metallic fluid, we feel a cold, which would seem to show that it is of a colder temperature than the atmospheric air; at the same time, by plunging a thermometer into it, we are immediately convinced that it is of the same temperature with the atmosphere. This effect, which deceives us, and which entirely proceeds from our sensibility, should it depend on the enormous weight of this metallic substance? or rather on this, that it accelerates the evaporation of the fluid which continually issues through the pores of the skin?

Mercury, divided by means of a rapid and continual motion, as that of a mill wheel, gradually changes itself into a very fine black powder, called *æthiops per se* on account of its colour. In this experiment the mercury suffers no alteration; and by a slight heat, or trituration, it may be made to assume its ordinary fluidity and metallic brilliancy.

Mercury is not very abundant in nature: it is found in the earth, either in a pure state, possessed of all its properties; or combined with sulphur and some other metallic matters; then it is mineralized by these substances.

Flowing mercury is found in globules, or in considerable masses, in earths or in soft stones; and most frequently it is interposed in ores. It is generally with sulphur that mercury is combined: then it forms a compound known by the name of *cinnabar*. This mineral substance



substance is red, and has in no degree the metallic aspect; although the sulphur found in it is in small proportion to the mercury, because the combination of these two substances is very complete. Cinnabar is found in the duchy of Deux Ponts, in the Palatinate, Hungary, Frioul, in Spain at Almaden, and in South America, particularly at Guamanga in Peru. It is sometimes in a compact mass, whose colour varies from the pale red to the deep red and blackish, sometimes in transparent crystals of the colour of rubies. It is called *native vermilion*, or *cinnabar in flowers*, when it is in the form of a red powder, very brilliant. Lastly, we find it dispersed in different earths, in selenite, mixed with iron, pyrites, and silver. M. Cronstedt, in his Mineralogy, speaks of a mineral of mercury, in which this substance is united to arsenic and copper. This mineral is in crystals of a grey yellowish colour, very like the crystals of the grey mineral of silver, from which it differs but very little; it is exceedingly rare. The same mineralogist asserts, that some mercury, amalgamated with pure silver, was sometimes found in the mine of Sahlberg in Sweden.

M. Romé de Lisle had in his cabinet a bit, which he supposed to be of this kind. The different states in which mercury appears in the bowels of the earth, may be reduced to the following varieties.

State 1. *Native Mercury.*

Dispersed among earths and stones, and most often in its own mines.

State 2. *Mercury mineralized by Sulphur. Cinnabar.*  
Varieties.

1. Transparent cinnabar, red, and crystallized in triangular very short prisms, terminated by triangular pyramids.
2. Red transparent cinnabar, in octaëdral crystals, formed of two triangular pyramids, united by their bases, and truncated.

2

3. Solid



3. Solid cinnabar, compact, of a brown red, or of a clear red. It is sometimes formed of leaves.
4. Red cinnabar, disposed in striæ, upon a stony matrix, or upon solid cinnabar. It is sometimes needled like cobalt.
5. Cinnabar in flowers, native vermilion. This is a cinnabar of a red brilliancy, like fatten, which adheres to different matrixes in the form of a very fine powder: it is sometimes crystallized in needles, and then it much resembles the preceding.

State 3. *Saline Mercury.*

1. Horned mercury, or mild native mercury. This mineral was discovered at Muschel-Landberg in the duchy of Deux Ponts. It is generally deposited in an ore of iron mixed with earth, in the form of prismatic crystals, with four sides, terminated by three-sided pyramids. Its colour varies as well as its transparency; it is white, grey, or greenish. M. Sage looked upon it as a true combination of mercury with marine acid, analogous to sweet mercury, with which he found it to have much resemblance in form, insipidness, volatility, &c.
2. Dark horned mercury. This mineral is in irregular masses, heavy and solid; we do not well know its nature: the fire decomposes it without addition, and disengages from it running mercury.

State 4. *Mercury combined with the Metals.* Natural Amalgams.

There was found at Muschel-Landberg, an amalgam of silver which contained one-third of mercury. Hereafter, perhaps, this metallic fluid will be found in mines united with other metals.

To know when an ore contains mercury, it is pounded, and mixed with lime and the alkalis. It is laid on a hot brick, and covered quite over with a vessel; the mercury is reduced into vapours, and is condensed on the sides of the vessel. If we wish to know the quantity



tity of mercury contained in it, after having pulverized and washed it, we distill it with matters capable of seizing on the sulphur and separating the mercury. We take care to put some water into the recipient, in order to collect the mercury at the bottom of this fluid. By taking the exact weight of the mineral before assaying, and the mercury we obtain by distillation, we compute the quantity which it can furnish.

The pure mercury is easily separated, by grinding the stones with which it is mixed, and washing them in water; the mercury precipitates, and the water draws off the earth: it is in this way extracted from the mines of Idria in Frioul. We do not roast the cinnabar, because being volatile it would be dissipated by the fire; but as nature has almost always mixed it with a calcareous or martial substance, this substance becomes a proper intermedium for decomposing the cinnabar by means of fire.

In the Memoirs of the Academy in the year 1779, M. de Jussieu has described the work which was erected at Almaden in Spain for extracting mercury from cinnabar. This mineral contains some iron and a little calcareous stone: it is put into furnaces in the form of a reverberatory furnace; these furnaces are heated by putting combustible matter into the ash-pan. The furnace has no aperture, but eight holes made at its posterior part: to every one of these holes a line of aludels is adjusted; the last of which reaches to a small support sufficiently distant from the fire. Between the furnace and the support, where the aludels terminate, there is a small terrass level with the openings of the furnace and those of the support. This terrass forms two inclined planes, and supports the aludels: if any crevice, not well secured, allow the mercury to escape, it is collected in the junction of the inclined planes of the terrass. When the fire is applied to the cinnabar, the iron and calcareous stone absorb the sulphur, the mercury being reduced into vapours passes into the aludels,



and reaches the small support. After the distillation, all the aludels are carried into a square chamber to be emptied, and to reunite the mercury in a hollow made in the middle of this chamber, whose bottom is inclined, sloping towards this small hollow.

M. de Jussieu has observed, that the mines of cinnabar emitted no destructive exhalation to vegetables, and that the places around and above the mines of Almaden were very fertile. He has likewise observed the working of this mine was not hurtful to the workers, as had been supposed: that those who work in the inside of the mines, as the slaves, are alone subject to fatal diseases; because the fire, which they are forced to kindle, volatilizes a portion of the mercury, and they are continually immersed in a mercurial vapour. In the Memoirs of the Academy for the year 1776, M. Sage has described the process which is employed in the Palatinate for extracting the mercury from cinnabar. The furnace is a room containing 48 retorts of cast iron an inch thick, three feet nine inches long, and containing about 60 lib. of matter. These retorts are fixed to the furnace: we put into it, with iron spoons, a mixture of three parts of the mineral, well rubbed, with one of slacked lime: the heat is raised with peats, which are introduced into the two extremities of the furnace; the sides of which are pierced with several holes, which increase the currents of air, and make the fuel burn. The mercury is volatilized by means of the reaction of the lime on the sulphur; it is collected in earthen receivers, adapted to the retorts, and filled one-third with water. This operation continues 10 or 11 hours. The mercury extracted or revived from the cinnabar is very pure, and does not contain a heterogeneous particle. Very little is to be found of this purity in commerce; all that which is sold by the merchants is more or less mixed with lead or tin: it appears a little dull, in place of being divided into globules.



globules; when it flows it is flattened, and seems to consist of several points.

Mercury seems to suffer no alteration from the light. It is one of the fluid substances which is most quickly and regularly heated, that is, the degree of whose dilatation is the most constant, as M. Bucquet and Lavoisier have demonstrated, in their inquiries into the different degrees of heat in different fluids, read to the Academy of Sciences. This phenomenon shows that mercury is the most proper fluid to mark the degrees of heat exactly, and to form the most accurate thermometers.

This metallic fluid exposed to fire in close vessels boils like liquids. This property is not particular to it; silver, gold, and several other metals, have the same property. It is true, that as mercury is more fusible than any other, it boils sooner, and a long time before it is red. The ebullition is nothing else but its passage from fluidity to the state of vapour. This vapour, which is very evident in the form of a white fume, lessening the transparency of the vessels into which it is received, is condensed by cold into drops of mercury, which has suffered no loss nor any alteration, when it is distilled with care. Mercury, therefore, is a very volatile substance, which may be distilled like water, and hence approaches to the semi-metals.

Boerhaave distilled the same quantity of mercury 500 times successively: it was not altered in any degree, it only appeared to him a little more brilliant, heavy, and fluid, which surely depended only on a very complete purification. In this distillation he obtained a small quantity of a grey powder, which was just mercury very much divided, and only required trituration to become fluid and brilliant: it was a little *æthiops per se*.

Distillation is a means of purifying mercury and of separating the fixed metals, by which that in commerce is ordinarily adulterated: we find in the retort the foreign metal in a brilliant crust in some places, and in a blackish in others. By weighing this residuum,



we know the quantity of matter which adulterated the mercury.

The extreme weight of mercury has made chemists believe that it contained a great quantity of the pure earthy principle or vitrescible earth: but, on the other hand, this principle, when it predominates in bodies, gives them solidity; and mercury, on the contrary, is very fusible: the earthy principle is eminently fixed, and mercury is very volatile. These qualities, which appear contrary, induced Beccher to admit in this fluid a particular earth, which he called *mercurial earth*; to which he attributed its weight and volatility. According to this chemist, then, mercury was a compound of these three earths, the vitrescent, the inflammable, and mercurial earths. No person has yet demonstrated the existence of the last in any body; and we ought to consider this opinion only as an assertion destitute of proof. Mercury appears to us, like all the other metallic substances, a simple combustible body, which never has been separated into different principles. With respect to the vitrescent earth, whose properties have been examined in the beginning of this work, we think we cannot admit it in mercury more than in the other metals, since as yet no similar principle has been separated from it. What Beccher and Stahl gave this name to in mercury, and in the other metallic substances, is nothing but a simple earthy body, as we have already said in speaking of the metallic calces in general.

Mercury, reduced into vapour, has a considerable expansive force, and is capable of producing great explosions, when it is close shut up. M. Hellot related to the academy, that a particular person being desirous to fix mercury, put a certain quantity of it into an iron pan, very well soldered: he put this pan into the middle of a strong fire; but it was scarce red, when the mercury burst in pieces its covering with a considerable noise, and was entirely lost. M. Baumé, in his *Experimental Chemistry*, Vol. II. p. 393, relates a fact very  
nearly



nearly fimilar, of which M. Geoffroy the apothecary was a witnefs.

Mercury, heated with the contact of air, in a few months is changed into an earthy red brilliant powder, difpofed in fmall fcales. This powder, which has no longer the metallic afpect, is a true mercurial calx. The alchemifts, who believed that mercury is fixed in this experiment, improperly called it *mercurius precipitatus per fe*. As mercury is very volatile, and at the fame time requires the concurrence of air to be calcined, for this operation a very commodious inftrument has been conftituted Mr Boyle. It is a very large and flat cryftal vefel: the mercury is put into it, which forms a thin bed, and confequently presents a large furface. The ftopper, which accurately fits the neck of the vefel, is a cryftal cylinder, pierced with a capillary funnel: the vefel is placed on a fand-bath; the mercury is heated till it boil; the opening of the cylinder is fo made, that the air has accefs into the vefel without allowing the mercury to be diffipated. After it has digefted fome months, we feparate the calx, which is formed at the furface of the mercury. For this purpofe, we throw the whole upon finelinen; the mercury paffes through by preffure, and the red calx remains in the cloth. With as much fuccefs we may make ufe of a matrafs with a flat bottom, into which we put enough of mercury to form a fmall bed: we by means of a lamp draw the neck of the matrafs into a capillary tube, and break off the point. By this method, mentioned by M. Baumé, we make a vefel more proper for the calcination of mercury, becaufe it contains more air: it is alfo more eafily heated, lefs troublefome, and lefs fubject to be broken than the vefel of Boyle. In order that this experiment may fucceed, we muft keep the mercury in a boiling heat night and day: by putting feveral matrafles on the fame fand-bath, we obtain a great quantity of precipitate *per fe*; and we may even obtain a certain quantity in 15 or 20 hours.



Precipitate *per se* is a true calx of mercury, or a combination of it with air. When we heat it, it attracts the pure air contained in the atmosphere, and forms with it this red powder. What proves it in a convincing manner is this: 1. We can never reduce it into precipitate *per se* without the contact of the air: 2. This combination can only be formed with pure air, and never happens with the different gases, which are not the pure air: 3. Mercury in this experiment increases in weight: 4. By heating it in close vessels, it is entirely reduced to the state of flowing mercury, and at the same time it disengages a great quantity of air; in which combustible bodies burn four times more rapidly than in atmospheric air, and which M. Priestley called *dephlogisticated air*. In this reduction the mercury loses the weight it had acquired in calcination. This last fact, joined to the phenomena of the calcination relative to the necessity and the diminution of the air in this operation, is what has induced modern chemists to believe, from an analogy as well founded as any established in physics, that the metallic calxes are only combinations of the metals with air. As the precipitate *per se* may be very well annalized by heat, and as it separates into two principles, pure air and flowing mercury, we see how much light this elegant experiment throws on the pneumatic theory, and how greatly it favours it. The combination of air and of mercury is therefore not very strong, since it may be destroyed by the action of the fire. Precipitate *per se* is reduced by heating it in vessels accurately stoppt: if it is in contact with the air, it remains in the state of a calx, as it always finds in the atmosphere the body with which it can unite, and which alone is able to calcine it. For this reason Baumé maintained, that precipitate *per se* was irreducible; that, on the contrary, it sublimed in reddish crystals of a ruby colour: whilst M. Cadet pretended, that all the precipitates *per se* could equally be reduced into flowing mercury. M. Macquer has proved, by an in-



ingenious explanation, corresponding with facts, that both these chemists were in the right; and that if the calx of mercury was heated in contact with the air, it was entirely sublimed, and even could be fused into a glass of the finest colour, as has been said by Dr Keir, a learned Scotch chemist, in his translation of the Chemical Dictionary; whilst the same calx, capable of subliming when in contact with the air, is reduced into flowing mercury, and affords pure air, if strongly heated in close vessels \*.

F f 4

Mercury

\* It is known mercury may be distilled, like other simple fluids, without undergoing any change from the distillation. Neither does mercury suffer any alteration from a digestion of fifteen years continuance, as we learn from an experiment of Dr Boerhaave. We are not, however, to conclude from these facts, that pure mercury is totally incapable of change from the action of heat. It is true, that if the heat be too great, the mercury will rise in vapours; or if too gentle, it will remain unaltered: but if the heat be at an intermediate degree, at a degree just below what is sufficient to distill the mercury, we then perceive its effect. The surface of the mercury is first covered with a greyish powder, which then turns yellow, and afterwards red. The heat is some weeks of beginning to produce the grey powder, and must continue some months before any considerable quantity of mercury can be converted into the red one. This red powder, exposed suddenly to a strong heat, without addition, sublimes in the form of reddish crystals; but if the heat be somewhat lower, it will soon recover its phlogiston, and become running mercury. This phenomenon has puzzled the chemists to explain, in a satisfactory manner, and to point out clearly the way in which it is revived. M. Baron conjectures the mercury attracts saline particles from the air with which it unites, and forms this substance. The theory of M. Lavoisier and his followers so far corresponds with this, as to pretend this calx to be a combination of the pure air, which the atmosphere always contains, with the mercury; and that the action of the heat is to expel this air again, and leave the mercury uncombined. M. Baumé explained the revival of the calx, upon the supposition of the phlogiston passing from the coals through the bottom of the sand pot and retort. Mr Scheele says, that no pure phlogiston could pass in this manner; and therefore it must be derived from something which we know passes for certain: we know that heat passes; this heat, then, is decomposed by the attraction of the mercurial calx for the phlogiston, and the pure air escapes uncombined.



Mercury is not changed by the air; we only observe, that it is tarnished by the molecules of dust which the air carries along with it; and which, by being deposited on its surface, diminish its brilliancy. From this, mercury has also been called the magnet of dust: but it appears that all bodies have this property, and that it is only uncommonly perceptible in this metal from its brilliancy. In other respects it is nowise altered; and it is sufficient to filtrate it through shamoy to separate it from its impurities, and restore all its lustre.

Mercury does not appear to dissolve in water; however, physicians are in the practice of suspending a rag full of it in vermifuge ptisans during their ebullition. Experience has also evinced the good effects of this practice. Lemery says, that mercury does not lose any of its weight in this decoction. It is probable, that there issues from mercury a principle, without doubt, analogous to smell, so volatile and subtle that its weight cannot be known on account of its extreme tenuity: it is this principle which communicates to water the anthelmintic virtue. Mercury does not unite with the earths more than the other metallic substances do: perhaps its red calx or precipitate *per se* might be fixed in glasses, and colour them, as we have observed is done by the calx of arsenic. We do not know the action of magnesia, lime, and the alkalis upon it \*.

The vitriolic acid does not act on this substance, unless it is very concentrated. To make this solution, we put into a glass retort one part of mercury, and one and

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\* The fixed and volatile alkalis do not act, or but insensibly, on mercury, in its metallic state; but they dissolve pretty easily its precipitates. Thus when a solution of mercury, with more acid than is necessary to dissolve it, is poured into an alkaline solution, the precipitate, which is at first formed upon their admixture, will be presently redissolved, and will disappear. In this way a very large portion of mercury may be dissolved by the volatile alkali. Applied also to dry prepared precipitates, the alkalis take up a considerable quantity.



a half or two parts of oil of vitriol: we apply heat, when brisk effervescence is gradually excited; the surface of the mercury becomes white; a powder of the same colour is separated from it, which, on mixture, makes the acid turbid. A great quantity of sulphureous gas is disengaged, and may be collected above mercury. This is the process for obtaining this gas, as we have already observed in speaking of the vitriolic acid. There passes over also a portion of water impregnated with this gas, and in the state of volatile sulphureous acid. When we urge this distillation till there pass no more sulphureous acid, we find in the bottom of the retort a white, opaque, very caustic mass, which weighs a third more than the mercury employed, and attracts a little humidity from the air. The greatest part of this mass is a calx of mercury united with a small quantity of vitriolic acid. This matter is very fixed, according to Kunckel, Macquer, and Bucquet. In this operation the oil of vitriol has been decomposed. The mercury, which is a combustible substance, unites with the pure air contained in this acid, and disengages from it the sulphureous gas and water. It ought therefore to be in the state of a calx, and to have much more fixity than flowing mercury. A portion of this vitriolic mercurial mass is soluble in water: when we add a great quantity of this fluid, it dilutes the mass, and allows a white powder to be precipitated if the water is cold; if we employ boiling water, the powder assumes a fine brilliant yellow colour, the more lively as we pour on more water, and the water is more warm. The name of turbith mineral, or yellow precipitate, was very anciently given to this matter. We decant the water employed to wash it: we pour on the turbith a new portion of boiling water, and it becomes of a more brilliant yellow: it is again washed with a third water, in order to carry off all the vitriolic acid which it contains. In this state it has no more taste; it is a mercurial calx, which, urged with the fire in a retort, becomes of a red

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colour like precipitate *per se*, and is reduced into flowing mercury, giving over a great quantity of pure air. Kunckel publishes this experiment: it succeeded with M. Monnet, Bucquet, and Lavoisier, who have followed him in all his details. I have repeated it several times with success. It proves, as we have observed, that the vitriolic acid is formed of sulphureous gas, water and pure air; but it requires a very violent fire for its reduction. Perhaps Baumé did not heat it sufficiently so as to obtain mercury; and for that reason he announces, that it cannot resume its metallic form without the addition of phlogisticated or combustible matter. By continuing to heat the vitriolic mercurial mass in the same retort in which it was dissolved, without unluting it, and without wasting the mass to carry off the portion of acid, the calx is likewise decomposed: at first it acquires a red colour, and is then reduced into flowing mercury, in proportion as it returns the air which it had taken from the vitriolic acid.

The water which has been poured on the white vitriolic mercurial mass, is charged with the acid which was formerly contained in it. But as the calx of mercury is very soluble in the vitriolic acid, this saline substance always carries along with it some of the calx; so that the water keeps in solution a true vitriol of mercury. By evaporating it, the salt is deposited in small needles, whose form we cannot determine, because they are soft and very deliquescent. By putting boiling water on these crystals of vitriol of mercury, they become yellow, and in the state of turbith mineral; because the water separates the acid from it, which has little adhesion, and leaves the calx pure. The same thing happens after we have strongly evaporated the first ley of the mercurial mass: if we dilute it with much boiling water instead of crystallizing it, a yellow powder precipitates in the state of a true turbith. If cold water is used, the precipitate is white; but it suffices to pour again boiling water on this white precipitate,



to make it resume the yellow colour. Thus at pleasure we may render the solution of the calx of mercury liable or not liable to be decomposed by water: for this purpose it is sufficient to evaporate it strongly, or to impregnate the acid with all the calx it is able to dissolve; then the union of these two bodies is easily destroyed by water: if we add to it a little acid, it is not precipitated by the water. I am convinced of this truth by dissolving turpeth mineral well washed in the weak spirit of vitriol. This solution is not overcharged with mercury, and it is not precipitated by water. But if we make this acid dissolve all it can of the turbith, by means of heat, as in adding the turbith till it refuse to dissolve any more; then this solution poured into cold water, forms a white precipitate; or if into a warm, a yellow. If in this state we add to it a little spirit of vitriol, the precipitation ceases. The white calx which the vitriol of mercury, strongly impregnated, when poured into water, deposits, is very soluble, and may be made to disappear by adding a little spirit of vitriol. The combination of vitriolic acid and of mercury may be decomposed by magnesia and lime, which precipitate it yellow. The fixed alkalis separate a calx of mercury very nearly of the same colour: the volatile caustic alkali precipitates very slowly, and very little of the vitriol of mercury. We should observe, that these precipitates of mercury vary in colour according to the state of the solution, and according to the precipitating substance; for the same reason the quantity is very different. The precipitates are very copious when the solution is strong: on the contrary, if we decompose a solution which is not saturated with mercury, every tuft of calx which is thrown down by the precipitant, is redissolved by the superabundant acid; when this excess of acid is saturated, the precipitate is permanent. Hence it appears, that the alkalis act on the acid combined with the mercury, rather than on the acid uncombined. These different calxes of mercury precipitated by the alkalis may be reduced



duced in close vessels. In order to obtain them pure, we must wash them several times with distilled water.

The nitrous acid is decomposed by mercury with the greatest rapidity. The solution is made in the cold, and with more or less activity, according to the state of the acid. The ordinary aquafortis in commerce acts on mercury without emitting many red vapours: if we add a little fuming spirit of nitre, or heat the mixture, the action becomes very rapid; a great quantity of nitrous gas is disengaged; and the mercury reduced into a calx remains in solution. The liquor is greenish, but loses that colour after some time. By this process the nitrous acid may be charged with a quantity of mercury equal to its weight. M. Bergman, in his Dissertation on the Analysis of Waters, has observed, that the nitrous solutions of mercury differ from one another according to the manner in which they have been prepared: that which has been made in the cold, and without the disengagement of many red vapours, cannot be decomposed by distilled water. If we assist the solution by means of heat, and if it has produced a great quantity of nitrous gas, it will be precipitated by water, and cannot be employed again with certainty in the analysis of waters, as we shall observe in speaking of the mineral waters. I think that this phenomenon is owing to the same cause in the nitrous solution as in the vitriolic. The nitrous acid, by means of heat, may be overcharged with calx of mercury, and may keep it suspended. This kind of solution with excess of mercury, will be precipitated by distilled water, which changes the density of the liquor, and diminishes the adhesion of the calx to the mercurial nitre: likewise the precipitate is a true turbith, and which is very yellow, if we pour the overcharged solution into warm water; but is white, when poured into cold water. We can instantly give it colour by washing it with hot water. As the solution contains only mercurial nitre, without excess of calx, when it has been made in the cold, since it cannot be impregnated  
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with an excess of calx, except by means of heat, the distilled water occasions no precipitate. I am persuaded of this by a fact of which I have been assured a great number of times. We can at pleasure render the same nitrous solution of mercury liable or not liable to be decomposed by means of water, either by adding some mercury or some acid; and we can make it pass from the one state to the other. For this it is sufficient to dissolve in the cold some mercury in nitrous acid, and to allow the acid to take up as much as possible: this solution cannot be decomposed by water, although it may have allowed some nitrous gas to escape. By adding some mercury to it, and allowing it to dissolve as much as it can by means of heat, it becomes liable to be precipitated by water. From the same theory we easily understand why a nitrous solution of mercury, which is not precipitated by water, acquires this property if we heat it: the heat disengages some nitrous gas, which cannot happen without destroying a portion of the acid: hence the proportion of the mercurial calx being too strong with respect to the acid, is no longer united, but adhering to the mercurial nitre, is suspended in such a manner that water may precipitate it very easily. I am certain that water precipitates only a superabundant calx from the mercurial solutions, since they still retain a portion of true mercurial nitre, decomposable by the alkalis in the same way as the vitriolic mercurial mass when washed for the preparation of turbith mineral. The solution of mercury in the nitrous acid is very caustic: it corrodes and destroys our organs: when it falls on the skin, it stains it of a deep purple colour, which appears black; the stains do not go off before the separation of the epidermis, which falls away in scales or kinds of eschars. It is used in surgery as a powerful escharotic, and called *mercurial water*.

The solution of mercury in the nitrous acid is susceptible of forming crystals, which vary from one another



ther in their form according to the state of the solution, and according to the circumstances which accompany the crystallization. By carefully observing these varieties, I have marked four very distinct kinds, which I shall describe.

1. A solution made in the cold, gives, by a spontaneous evaporation of several months, very regular transparent crystals. M. Romé de Lisle has very well defined them: They are flat solids with four sides, formed by the union of two three-sided pyramids, cut very nearly at the base, and truncated in the four angles which result from the junction of the pyramids.

2. If we evaporate the same solution made in the cold, and allow it to cool, kinds of acute prisms, striated obliquely lengthwise, are deposited in twenty-four hours, formed by the successive application of small laminæ covering one another like tiles, which the botanists call *imbricatum*. Upon an examination of these shapeless prisms, near their beginning, I saw that the laminæ which constitute them are solids with four facets, resembling the crystals we obtain by spontaneous evaporation, but smaller and more irregular.

3. If we make a nitrous solution by means of a gentle and well conducted heat, it furnishes, by cooling, crystals in flat needles, very long and acute, striated lengthwise. These are got most frequently, and have been described by the most of chemists, especially Macquer, Rouelle, Baumé, &c.

4. Lastly, if we apply more heat to this solution, and it becomes liable to be decomposed by the addition of water, it generally turns into a white and shapeless mass, resembling the vitriolic. In this circumstance I have sometimes had a confused mass in needles, very small and long like satin, flexible, and which followed the motion of the liquor: they were exactly similar to the brilliant and argentine dendrites which I have several times seen on the sides of the bottles in which I have kept the *terra foliata tartari*.



It is essential to add, that this last solution, which furnishes only irregular and confused crystals or shapeless masses, because they contain a great deal of superabundant calx of mercury, may be made to crystallize more regularly by the addition of a little acid.

These different mercurial nitres present nearly the same phenomena: they are very caustic, and redden the skin like their solution; they detonate when we put them on burning coals. With regard to this property, we must observe, that it is much more sensible in very regular crystals with four sides, than in those which are in small needles; and that the white mass precipitated from the solution, strongly heated, wants it altogether. The detonation of mercurial nitre is but very imperceptible in newly formed crystals: in order to observe it well and render it very perceptible, we must allow them to filter some time through foul paper; then if we put them on a well kindled coal, they fuse, blacken, and extinguish the place where they are placed; but their sides, which are dry, emit small reddish sparks with a noise resembling a slight decrepitation. When they are dry, a whitish and more vivid flame appears, which very soon goes off.

Mercurial nitre fuses when we heat it in a crucible; very thick red vapours are exhaled: in proportion as it loses its water and nitrous gas, it assumes a deep yellow, which turns to an orange, and at last to a brilliant red; in this state it is called *red precipitate*. It ought to be done in a matrafs and with a gentle heat, if we design it for a caustic in surgery, that it may retain a portion of acid, to which is owing the corrosive property. But if we apply a strong heat, it is no more than a calx of mercury, formed by the metal united with the pure air of the nitrous acid. Mercurial nitre, distilled in a retort, gives an acidulous phlegm and some nitrous gas at first; it is then in the state of red precipitate: by heating it strongly, a great quantity of pure air is disengaged, and the mercury sublimes in the form of flowing mercury.

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This experiment having been made with the utmost precision by M. Lavoisier, it led him to demonstrate the composition of the nitrous acid, as we have said in the history of that acid.

Mercurial nitre becomes yellowish by the air, and is decomposed very slowly: it is very soluble in distilled water; more so in warm than in cold water, and crystallizes by cooling. When we dissolve this salt in water, a portion precipitates without dissolving, and is yellowish: M. Monnet calls this *nitrous turbith*; and he observes, that a great quantity of it may be obtained by washing a nitrous mercurial mass evaporated to dryness, such as that which is made into red precipitate. If we want to dissolve the mercurial nitre entirely, we must make use of distilled water, into which aquafortis should be put till the precipitate disappear. I have observed, that when boiling water is poured on very pure mercurial nitre, it turns yellow instantly, and gives nitrous turbeth of a deeper colour; and which exposed to the fire becomes red much more quickly than that which is made with the vitriolic acid. In general, nitrous turbeth is more calcined than the vitriolic; owing, as we have already observed of the other combustible substances, to the nitrous acid containing more air than the vitriolic, and the air appearing to have a much weaker adhesion to the nitrous gas in the nitrous acid, than it seems to have to the sulphur in the vitriolic: For this reason the nitrous acid is more easily decomposed than oil of vitriol.

Terra ponderosa, magnesia, lime, and the alkalis, decompose mercurial nitre, precipitating the metal in the form of a calx. The precipitates vary in colour, weight, and quantity, according to the state of the solution. The caustic fixed alkalis form a yellow precipitate, more or less brown, or of a brick colour, according to their causticity. The volatile alkali precipitates, in a grey stony colour, the nitrous mercurial solution when in a proper state, that is, in which it cannot be decomposed by



by water; whereas the same salt produces a white deposition from a saturated solution of mercury precipitable by water. These differences have been accurately observed by M. Bergman. These precipitates are only calces of mercury more or less calcined: they are all reducible without addition in close vessels, and give out pure air in their reduction. Those which have been precipitated by the aerated alkalis, furnish a great deal of aerial acid by the action of the heat. The precipitates of mercury, occasioned by the alkaline intermedia, present a property, discovered by M. Bayen, which we should not omit to mention: it is a detonation like gun-powder, when they are exposed in an iron spoon to a gradual fire, having been previously triturated with flowers of sulphur, in the proportion of half a gros of precipitate to six grains of the sulphur: after the detonation, a violet powder remains, which may be sublimed into cinnabar.

The vitriolic acid, and the salts into which it enters, can likewise decompose mercurial nitre; because the vitriolic acid has more affinity with the mercury than the nitrous acid has. If we pour some spirit of vitriol or a solution of Glauber's salt, vitriolated tartar, selenite, and of the vitriolic salts in general, into a nitrous solution of mercury, a white precipitate is formed, if the nitrous solution is not saturated; and so much the more yellow, as the mercurial nitre contains less acid and more metal: the precipitate is either vitriol of mercury or vitriolic turbith. M. Bayen observed, that it always retained a little nitrous acid.

The marine acid has no sensible action on mercury, though it has the strongest affinity of all its acids with it; but it has a very remarkable action on the calx, and forms with it a particular neutral salt. This combination takes place whenever the marine acid comes in contact with the calx very much divided. If we pour a little marine acid into a nitrous solution of mercury, it attracts the metal, and forms a salt which is precipitated



ted in the form of a white coagulum, called *white precipitate*. The marine salts, with alkaline or saline-earthly bases, absolutely produce the same effect; and besides form neutral salts, differing according to their base. But it is of importance to observe, upon the subject of this operation, that the precipitate may be found in two different states, according to the nature of the nitrous solution, and according to the quantity of marine salt employed: and indeed M. Monnet has observed, that if we take a weak solution of mercury, and mix it with a strong solution of marine salt, the salt which is precipitated contains only the quantity of mercury necessary for saturation; and that if we use a strong nitrous solution of this metal with an unsaturated solution of marine salt, the precipitate is formed of marine acid with the greatest possible quantity of mercury. Now, it will be presently observed, that these two combinations whose respective quantities of metal and acid vary, greatly differ from one another: the marine acid also has more affinity with mercury than the vitriolic acid has; and occasions, in the solutions of mercury in the vitriolic acid, the same precipitates as in the nitrous solutions of mercury. The compound of marine acid and mercury may be in two states, as we have said already, according to the quantity of metal it contains: the two states are, corrosive sublimate and sweet mercury.

Corrosive sublimate may be prepared by several processes: for the most part we mix equal parts of mercurial nitre dried, decrepitated marine salt, and martial vitriol calcined to whiteness; we put this mixture into a matrafs, two-thirds of the capacity of which ought to remain empty: this vessel is put into a sand bath, and gradually heated till its bottom be a dark red. The acid of the vitriol disengages that of the marine salt. This last decomposes the mercurial nitre, and sublimes with the mercury in the form of flat and pointed crystals, which line the upper part of the matrafs. The nitrous acid is dissipated; the residuum is  
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reddish or brown: it contains Glauber's salt, formed by the union of the vitriolic acid with the base of the marine salt and a calx of iron.

In Holland this salt is prepared in great, by triturating equal parts of mercury, marine salt, and vitriol, and by exposing this salt to a violent fire. It may be formed also by subliming mixtures of martial vitriol, marine salt, and mercurial precipitates by the fixed alkalis, or of turbith mineral. Boulduc likewise has given a very good process for preparing corrosive sublimate. M. Spielman remarks, that it was shown by Kunckel in his Chemical Laboratory. It consists in heating in a matrafs an equal quantity of vitriol, mercury, and decrepitated marine salt: the sublimate is volatilized, and the residuum is only some Glauber's salt. This method furnishes a very pure corrosive sublimate; whereas that in commerce, and even that prepared in small with martial vitriol, always contains a little iron; at the same time it is more easy and more economical. M. Monnet also asserts, that he obtained this salt by heating in a retort some very dry sea-salt, and mercury precipitated from its solution in the nitrous acid by the fixed alkalis. In all these preparations of corrosive sublimate, we should take care not to break the subliming vessel till it is quite cold, in order to shun the vapours of this salt.

Corrosive sublimate is a saline neutral substance, which merits all the attention of chemists and physicians. It possesses a great number of properties, which it is of importance to know well, and of which we are going to give the history. This salt has a very caustic taste. Laid in very small quantity on the tongue, it leaves for a long time a styptic and very disagreeable metallic impression: This impression is even communicated to the larynx, which it shuts spasmodically, and it frequently continues a long time, particularly in persons of sensibility. The action of this salt is still stronger on the coats of the stomach and intestines: when it re-



mains applied to them for any time, it corrodes them, and forms eschars: it is also one of the most violent poisons we know. This causticity of corrosive sublimate seems to depend on the state of the mercury in this salt, as M. Macquer has very ingeniously explained. It cannot be attributed to the marine acid, as some have thought, since this acid is not superabundant in the sublimate: the mercury is in more than triple the quantity of the marine acid. Moreover, this salt renders the syrup of violets green rather than red, according to the observation of M. Rouelle. Besides, the taste of corrosive sublimate is much stronger than that of the marine acid: for we can take a gros of spirit of salt, diluted in water, with impunity; whilst some grains of corrosive sublimate dissolved in the same quantity of water would undoubtedly be a poison. M. Baumé thought that this extreme taste depended entirely on the combination of the two substances of this compound: and hence he drew the great proofs of the law of affinity, which establishes, that compounds have new properties, and very different from those of the component parts.

Corrosive sublimate is not sensibly altered by the light. Heat volatilizes it, and makes it undergo a semi-vitrification. If it is heated strongly, and in the free air, it is dissipated in a white fume; the effects of which on the animal œconomy are very powerful and dangerous. Heated slowly, and by degrees, it sublimes in a crystalline and regular form. Its crystals are prisms, so compressed, that it is impossible to determine the number of sides. They are terminated by very acute tops: and they are justly compared to the laminæ of a dagger, scattered on one another. Fire cannot decompose this salt: it suffers no alteration from the air. It dissolves in nineteen parts of water, and crystallizes by evaporation into prisms flattened, and very acute at their extremities, like those obtained by sublimation. The spontaneous evaporation of its solution produced to M. Bucquet oblique angled parallelopipeds, whose extremities



mities were truncated crosswise. M. Thouvenel got crystals of this salt in six-sided prisms, a little compressed.

Terra ponderosa, magnesia, and lime, decompose corrosive sublimate, and precipitate the mercurial calx. The phagedenic water, which the surgeons use as a caustic, is prepared by throwing half a gros of corrosive sublimate in powder into a pound of lime-water; a yellow calx is formed, which renders the liquor turbid, and it is used without separating the precipitate. The fixed alkalis separate from the corrosive sublimate an orange calx, whose colour deepens by settling. The volatile alkali precipitates a white calx; but this precipitate in a little time becomes coloured like slate.

The acids and neutral alkaline salts do not alter it in any way. This salt contracts an intimate union with sal ammoniac, but without being decomposed. It forms, either by sublimation or crystallization, a very singular saline compound, which the alchemists esteemed very much, and called *sal alembroth*, *sal artis*, *sal sapientiæ*. Sal ammoniac renders sublimate very soluble; as, according to M. Baumé, three ounces of water, containing nine gros of sal ammoniac, dissolve five ounces of sublimate. This last solution occasions heat, and turns into a mass in cooling. With this salt is made a preparation, called *white mercury precipitate*. For this purpose we throw into a solution of a pound of sal ammoniac an equal quantity of corrosive sublimate in powder; when this salt is all dissolved, we pour in some oil of tartar, which forms a white precipitate: this precipitate is washed and dried in the air, after having been made into troches. In this operation the fixed alkali disengages the volatile alkali of the sal ammoniac, which in its turn precipitates the mercury in a white calx. This precipitate turns yellow when exposed to heat, or even to the light.

Corrosive sublimate is altered by inflammable gas. Sulphur does not alter it; but liver of sulphur decom-



poses it, like all the other solutions of mercury: there is instantly formed a black precipitate, which results from the combination of the sulphur with the mercury. The most part of the semimetals which we have examined, are capable of decomposing this salt; and each of these decompositions present particular phenomena, which merit an accurate examination.

If two parts of corrosive sublimate are distilled with a gentle heat with one part of regulus or calx of arsenic, matter passes over into the receiver of the consistence of oil, transparent, but which condenses very soon into a kind of white jelly, called *corrosive oil*, or *butter of arsenic*. If we continue the heat when the butter is over, we obtain flowing mercury; and by this process we can discover the exact principles of corrosive sublimate. The butter of arsenic is not capable of crystallizing; it fuses with a gentle heat; it has so caustic a taste, that it instantly destroys our organs. It dissolves in water, which in part decomposes it: we are ignorant of its other properties. The effects of cobalt, nickel, and manganese, on corrosive sublimate, have not been examined. As for bismuth, regulus of antimony, and zinc, these three semimetals decompose it very well. By distilling two parts of sublimate, and one of bismuth, we obtain a thick fluid substance that congeals into a mass as if greasy, which fuses with heat, and is precipitated by copious washing; in a word, a true butter of bismuth. Poli, who published this experiment in the History of the Academy for the year 1713, says, that by subliming this butter several times, there remains in the vessel a matter of the colour of oriental pearls, very soft to the touch, and as if gluey; he likewise proposes it for painting. If 12 ounces of regulus of antimony, and two pounds of corrosive sublimate, are mixed accurately, a heat is occasioned, which proves a violent action between these two bodies. If this mixture is distilled with a gentle fire, we obtain a thick liquor, which fixes in the receiver, often even in the neck of the retort, in a white mass,



mass, called *butter of antimony*. This butter is generally to the quantity of 16 ounces and a few gros.

The residuum is composed of mercury, and a grey powder of regulus of antimony which swims upon it. If we continue the distillation after the butter has passed, by adapting a new ball, we obtain some flowing mercury; but it is contaminated with a little butter of antimony, of which it is impossible entirely to free the neck of the retort. M. Baumé, who has fully described this operation, says, that by this process we may extract 22 ounces of flowing mercury, an ounce of regulus in powder, and 6 gros 24 grains of regulus fused in the retort. This in the retort is in part calcined. It exhibits red and argentine flowers. In this experiment the regulus, which has more affinity with the marine acid than the mercury has, decomposes the corrosive sublimate. This decomposition likewise happens with crude antimony. By distilling one part of this mineral reduced into powder with two parts of corrosive sublimate, we obtain butter of antimony; but the residuum, in place of containing flowing mercury, presents a combination of sulphur with this semimetal. This combination may be sublimed by a violent fire into red needles, called *cinnabar antimonii*.

The butter of antimony may be prepared in several other ways. We always obtain it when the regulus in vapour meets the marine acid in the state of a gas: but the decomposition of corrosive sublimate is the process which most easily furnishes it, and in the greatest quantity. This compound is in a solid form; it crystallizes in very thick parallelopipeds; it is a most violent caustic, so as to destroy the skin instantly, and to burn combustible vegetable matters, as wood: it is very alterable by the contact of the light; it fuses with the least heat, and fixes by cooling; it very easily loses its whiteness, and is easily coloured. It may be rectified by distillation. It attracts humidity from the air; it is resolved into a thick fluid, as if oily; in water it dissolves only



in part, and the greatest portion is decomposed by this fluid. When butter of antimony is thrown into distilled water, a very copious precipitate instantly falls down, which is called *emetic powder*, or *powder of Algaroth*, from the name of a physician who employed it as a medicine. It has also been improperly called *mercurius vitæ*. This precipitate is a calx of antimony, which is violently purgative and emetic; and even in a very small dose, as in that of three or four grains. To get it very pure, we must wash it several times in distilled water. By these properties it differs from the other calces of this semimetal, which have no very powerful action on the animal œconomy. A portion of this calx remains in solution in the water employed to wash the butter of antimony, by means of the acid which this fluid contains. We are certain of this fact, by pouring a little alkali into it. There is formed a very copious white precipitate, which is nothing but the excess of this calx with which the butter of antimony is charged, that gives it the property of being decomposed by water, as well as that of turning into a solid mass. The butter of antimony dissolves with heat and effervescence in the nitrous acid. In this solution a great quantity of nitrous gas is disengaged, which excites a considerable motion in the mixture. The butter of antimony disappears, and the liquor is of a reddish yellow. It is a solution of calx of antimony in aqua regia. It very soon deposites the calx of antimony in the form of a powder, and even of a black magma. If we evaporate to dryness the solution of butter of antimony in the nitrous acid, as soon as it is done we obtain a very white calx: it is again mixed with its own weight of the same acid, which we evaporate afresh: we mix a third time this powder with the same quantity of nitrous acid, which we evaporate to dryness; we calcine it in a crucible, which we keep red about half an hour, and then leave it to cool. The calx which we get is white above and red below; we mix these two portions together, which form a preparation

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tion called *bezoar mineral*. M. Macquer looks on this medicine to be a perfect calx of this semimetal, and he thinks it absolutely similar to diaphoretic antimony. However, Lemery, who has described this preparation with care, recommends calcining it only till it has but a very slight degree of acidity; he therefore wishes it to retain a certain portion of acid, which should necessarily change the properties of the calx of antimony.

Corrosive sublimate is decomposed by zinc, as Mr Pott has affirmed, and I myself have several times ascertained. If we distill in a glass retort a mixture of corrosive sublimate and one of zinc in filings or in a gross powder, a very white and solid butter mounts, which crystallizes into small united needles, like the bundles of which the stalactites are composed: the mercury remains pure in the retort, and passes over after the butter of zinc. This butter fumes slightly when it is taken out of the recipient: it fuses with a gentle heat; it is coloured by inflammable vapours; and lastly, it is in part decomposed by water like the butter of antimony. The most singular property of corrosive sublimate, with regard to its alteration by the metallic substances, and at the same time the most important, is its combination with flowing mercury. When it is saturated with the flowing mercury, it loses the most part of its properties, and particularly its taste and solubility. This combination was formerly made by triturating in a glass-mortar the corrosive sublimate with flowing mercury, which was gradually added till this last could be no more quenched. The quantity of this metallic fluid with which the sublimate can incorporate by this process, is about three-fourths of its weight, as Lemery and Baumé have observed. This mixture was put into vials, two thirds of which were left void, and it was sublimed three times successively: care was taken each time to separate a white powder, which was found above the sublimate, and is very corrosive. This production is called sweet sublimate, sweet mercury, or aquila alba. It differs from



from corrosive sublimate in its almost perfect insolubility, in its insipidity, and in its crystalline form. The crystals obtained by a slow sublimation are three-sided prisms, terminated by pyramids with four sides. Frequently two three-sided pyramids, very elongated, are united at their bases, and form very acute octagons. The process we have just now described, for the preparation of sweet mercury, has several inconveniences. The trituration of corrosive sublimate with flowing mercury, till the metal be extinguished, is very tedious and difficult: a very fine acrid powder rises, against which we are obliged to defend ourselves by covering the nose and the mouth with a napkin. Mercury is never exactly extinguished in a mortar: the sublimations are very slow. M. Baumé advised pouring a little water on the substances which we triturate. This fluid accelerates the trituration, and prevents the rising of the powder. He also made use of porphyzation, which greatly facilitates the extinction of the mercury. Lastly, in order to be sure of having a sweet mercury, entirely free of sublimate, Zwelfer, Cartheuzer, and Baumé, have proposed to pour on the sweet mercury, once sublimed, some hot water to dissolve the sublimate, and to dry the portion of mercury, which is then found very gentle. M. Cornette, to shun the volatilisation of the sublimate with the mercury, proposed using the precipitate of mercurial nitre by the volatile<sup>n</sup> alkali, which unites much better with the corrosive sublimate than flowing mercury: but this precipitate not being so pure as crude mercury, we cannot be so certain about the preparation, into which it enters. M. Bailleau, an apothecary at Paris, communicated to the Royal Society of Medicine, a process for the preparation of sweet mercury, without having any accidents to fear, which might render the preparation liable to danger. The process consists in forming a paste with the corrosive sublimate and water, and in triturating it with flowing mercury. Half an hour's trituration suffices to extinguish



tinguish the mercury, as the water promotes its division. We finish the combination by digesting the mixture on a bath of sand in a gentle heat: the matter, from being grey becomes white, and forms a very sweet mercury, requiring only a single sublimation to render it perfectly pure. Mr Baumé made several experiments on sweet mercury: he has demonstrated, that this compound cannot take up a greater quantity of mercury than that which it contains; that it cannot be in a middle state between that of corrosive sublimate and sweet mercury; and that by mixing with corrosive sublimate a less quantity of mercury than what is necessary to convert it into sweet mercury, a quantity of sweet mercury is formed only in proportion to the quantity of mercury added; and that the remainder of the sublimate is volatilized with all its properties, and without being rendered sweet. By means of hot water we may separate these two compounds. From the inquiries of the same chemist, we have also learned, that we can change sweet mercury into corrosive sublimate, by subliming it with marine salt decrepitated, and with martial vitriol calcined to whiteness. In this operation, the marine acid is disengaged by the oil of vitriol, and seizes on the mercury not saturated with the sweet mercury, and is thus converted into corrosive sublimate. M. Baumé says, that sweet mercury greatly differs from corrosive sublimate, in this, that it cannot contract an union with sal ammoniac, as the sublimate does in the preparation of the sal alembroth. In consequence of this property, he has advised to wash sweet mercury with water charged with a little sal ammoniac, to dissolve all the corrosive sublimate, which this salt renders very soluble. Lastly, he discovered, that in every sublimation the sweet mercury loses a portion of mercury; and that in consequence it gives a small quantity of corrosive sublimate; and that by repeated sublimations we may completely change sweet mercury into corrosive sublimate. It naturally follows from this last experiment, that the



medicine called *panacea of mercury*, and prepared by subliming sweet mercury nine times, so far from being sweetened by these operations, as the most part of chemists and physicians have thought, does not differ at all from sweet mercury. This last assertion is the more true, since in every sublimation it is necessary to separate a white powder, which is first raised, and is only some corrosive sublimate. In the preparation of sweet mercury, it is necessary to observe, that there remains in the vials a reddish powder: it is a calx of iron, arising from the vitriol of iron, which is used in commerce to sublime the corrosive: a portion of this calx is raised with this salt in the sublimation: frequently also there are found bits of glass which have been carried over by the corrosive sublimate in vapour. These are the most interesting properties of this neutral salt: let us resume the examination of those of mercury, which are as yet not known to us \*.

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\* As sweet mercury is a medicine much employed in practice, and troublesome to prepare in the common way, it may be agreeable to insert a process, which has lately been recommended by Mr Scheele of Sweden, as it is easier and more expeditious. The process is to mix a solution of mercury in nitrous acid with a solution of common salt in water. Equal parts of quicksilver and pure aquafortis are mixed together in a long-necked matrass, which is to be placed in a sand bath: the heat is raised till it nearly boil, and kept so three or four hours, and then it is made to boil for about twenty minutes. In this state it is poured into the solution of salt, which is also at a boiling heat, care being taken to keep the mixture in constant motion till the whole addition be made. After the precipitate settles, the clear liquor is to be decanted off, and the precipitate washed with hot water till the water comes off tasteless. The proportion of the ingredients is,

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|-----------------------------|---|---|--------------------------|
| Aquafortis, and             | } | { | Common salt, three parts |
| Mercury, of each four parts |   |   | Water forty parts.       |

The precipitate, prepared according to this process, possesses all the properties of the best sweet mercury. It is perfectly insipid. When sublimed, the sublimate which arises first shows no marks of a corrosive quality. When the precipitate is mixed with some fresh quicksilver, there is none of the quicksilver taken up, which would be the case if any corrosive sublimate were contained in the precipitate. It  
also



Sedative salt does not immediately dissolve mercury, but it acts in a very remarkable manner upon it in the state of a calx. By means of the double affinities these two substances are made to combine. By pouring a solution of borax into one of mercurial nitre, a very copious yellow precipitate falls, which M. Monnet first made known. In this operation, the fixed mineral alkali of the borax unites with the nitrous acid, and forms cubic nitre; whilst the sedative salt combined with the calx of mercury, in the state of a neutral salt not very soluble, is precipitated. The liquor, when filtrated, affords, by evaporation, fine and brilliant pellicles of mercurial sedative salt. This salt, exposed to the air, becomes perceptibly green: sal ammoniac renders it very soluble, and forms with it a compound analogous to sal alembroth. Lime-water precipitates it yellow, which becomes of a deep red; and the fixed alkali, white. According to Messieurs the Academicians of Dijon, corrosive sublimate is likewise decomposed by borax, which in its solution produces a precipitate of the colour of bricks. Water made to boil on this precipitate becomes milky by the addition of the fixed alkali; which shows that it contains some mercurial sedative salt.

We do not know what action the sparry acid has on mercury. That of the aërial acid is likewise very little known. It is only known that the acid spirit of chalk does not affect this semimetal, although the solutions of mercury decomposed by lime and the aërated alkalis afford

also gives a black colour with caustic alkali and lime-water, like common sweet mercury: so that this precipitate appears equal in all respects to best prepared sweet mercury, and is made with less trouble, at less expence, and without employing corrosive sublimate. There is no danger of its being corrosive if it be sufficiently washed with water. The operator is not exposed to the noxious dust which rises from the triture of the corrosive sublimate with the quick-silver; and the powder is finer than any which can be made from the common sublimed calomel by any trituration whatever.



ford precipitates very different from those produced by the same salts when pure and caustic \*.

Mercury does not seem capable of altering sal ammoniac by distillation. M. Bucquet, who made this experiment, observed that two parts of mercury were not properly extinguished in one of sal ammoniac; and that this mixture did not give over any volatile alkali by distillation. M. le Comte de Garaye, however, had prepared with these two substances a medicine, which he called *tincture of mercury*. M. Maquer, who has examined his process, Academy of Sciences, An. 1755, p. 28. found it entirely conformable to what he had advanced. The process consists in triturating in a marble mortar one ounce of flowing mercury with four of sal ammoniac; in moistening the mixture with a little water, till the mercury be properly extinguished; in leaving it exposed to the air for five or six weeks, taking care to agitate it from time to time: after that, it is triturated afresh, put into a matrafs, and laid on a sand bath, with some good spirit of wine, which should swim above the powder to about the height of two fingers: the spirit of wine is made to boil gently. The spirit of wine is coloured yellow, and contains some mercury, as it whitens a plate of copper. It seems, that in this experiment, the volatile alkali is gradually disengaged by the mercury; that some sal alembroth is formed, a part of which is dissolved by the spirit of wine; and that the dif-

\* The vegetable acids have no power to dissolve mercury in its crude state, from the small disposition they show to attack phlogiston. But when the mercury has been calcined by long exposure to heat, they will then act upon it; and still more so if the mercury has been previously dissolved in nitrous acid, and precipitated by means of an alkali. A solution may also be made by the intervention of a double elective attraction: if some diuretic salt and mercurial nitre, both dissolved in water, be mixed together, the alkali unites with the nitrous acid, and leaves the vegetable acid to unite with the mercury. This new compound is not very soluble in water. It was once much employed in medicine under the name of *Keyser's pill*; but the preparation is not so much valued now, and is rather falling into disuse.



different quantity of mercury, and the slow action during maceration, are the causes which make this experiment differ from that of M. Bucquet.

Mercury combines very well with sulphur. When one part of this metallic fluid is triturated with three parts of flowers of sulphur, the mercury is gradually extinguished, and a black powder results, called *æthiops mineral*, whose colour deepens by standing. The combination is effected with more rapidity when the mercury is mixed with the sulphur fused: by agitating this mixture, it becomes black, and takes fire very easily. When we intend to make *æthiops* of it, we should withdraw it from the fire, and extinguish the flame as soon as it appears, and stir it until it be solid and in clots. It is then powdered and put through a silk sieve. *Æthiops* is not the most intimate combination which sulphur and mercury are capable of forming. When this compound is exposed to a great degree of heat, it takes fire, the greatest part of the sulphur is consumed, and after this combustion a substance remains that puts on a violet colour when pulverized. The powder is put into matrasses, which are heated till the bottom be red: in this state they are kept for several hours until the matter to be sublimed is perceived. In the top of the matrass is found some artificial cinnabar crystallized in needles of a brown red. This cinnabar is of a colour not so deep, but more vivid, when we sublime it in retorts. The Dutch prepare in great the cinnabar which is employed in the arts. This compound has but little volatility, and requires a strong fire for sublimation. When it is very much divided in the porphyry, it assumes a brilliant red colour. It is then called *vermilion*. If we heat it in open vessels, the sulphur, which is not the fourth of the whole cinnabar, is consumed gradually, and the mercury is volatilized. Many substances are capable of decomposing cinnabar, on account of the affinity, they have with sulphur: lime and the alkalis have this property,  
When



When they are heated with this substance in a retort, in the proportion of two parts of cinnabar to one of these salts, we obtain flowing mercury, and the residuum is some liver of sulphur. M. Baumé knew also that this decomposition took place in the moist way, by boiling some cinnabar, ground, in the solution of fixed vegetable alkalis. It should be remarked, that he used only the mild alkali. Several femimetals, such as cobalt, bismuth, regulus of antimony, likewise have the property of detaching the sulphur from the mercury. It has been asserted, that almost all the metals, lead, tin, iron, copper, and silver, too, have more affinity with sulphur than mercury has, and decompose cinnabar: they may then be employed indiscriminately to separate the mercury of this compound. The metallic fluid obtained by this process is perfectly pure: it gets the name of mercury revived from cinnabar.

Mercury instantly decomposes the livers of sulphur; but it produces different phenomena, according to the nature of these compounds. It forms an æthiops with the alkaline liver of sulphur. This æthiops becomes red in a few years. With the volatile liver of sulphur, or fuming liquor of Boyle, it very readily changes to an æthiops; and in a few hours, or at most a in few days, this æthiops puts on a shining red colour, and produces a pretty cinnabar. Turbith mineral, precipitate *per se*, red precipitate, and all the calces precipitated from mercurial solutions by the alkalis, more or less readily exhibit the same phenomenon with the fuming liquor of Boyle. This phenomenon is also occasioned by pouring this liquor into the mercurial solutions, and by exposing the black precipitate resulting from these mixtures to a new quantity of volatile liver of sulphur.

We do not know the action of mercury on the regulus of arsenic. Cobalt does not unite with it. Mercury very easily dissolves bismuth, which combines with it in all proportions. There arises from this combina-

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tion a matter brilliant, friable, and more or less solid according to the quantity of bismuth. This amalgam may be crystallized into a pyramid with four sides, which sometimes unite into octagons. For the most part we find it crystallized in small laminæ, which have no regular form. This crystallization is effected by fusing the amalgam, and leaving it to cool slowly. When it is heated in a retort, it does not part without great difficulty with the mercury which dissolved it. Mercury does not unite with nickel nor with regulus of antimony. With zinc it combines by fusion. The amalgam which it forms with this semimetal is solid: it becomes fluid by trituration. When it is heated and left to cool slowly, it crystallizes into laminæ, which seem to be square and rounded at the sides.

Mercury is of very extensive use in the arts; such as gilding, tinning of glass plate, the construction of meteorological instruments, metallurgy, &c. In medicine this semimetal is used in all sorts of forms.

1. Crude mercury was formerly employed in the volvulus. It is boiled in water, to which it communicates the property of being a vermifuge. It is likewise mixed with fats, to be used in the form of ointment in venereal complaints.

2. For the same complaints turbith mineral, too, in the dose of a few grains, has been recommended. This medicine is emetic and purgative.

3. The mercurial water is used by the surgeons as a powerful escharotic. Red precipitate is used in the same indication. With hog's-lard and the nitrous solution of mercury, we prepare the unguentum citrinum, which cures the itch very well.

4. Corrosive sublimate has been recommended by Baron Van Swieten in venereal complaints. A few grains are dissolved in proof-spirit, and the solution taken in spoonfuls, and diluted in a large quantity of emollient drinks. We should be very careful about the state of the stomach in the use of this remedy, which re-



quires great prudence to manage. Sweet mercury has been given in the dose of twelve or fifteen grains as a purgative, and in that of three or four as an alterant. The aqua phagedænica is used in surgery for eating down proud flesh, &c.

5. Sedative mercurial salt has been successfully employed in venereal complaints by M. Chauffier, junior of the academy of Dijon. *Journal de Physic*, tom. vi. page 361. and tom. ix. page 348.

6. M. Nicolas, physician at Grenoble, has announced to the Royal Society of Medicine, the good effects of mercury dissolved by fixed air, in the same complaints; but has not described the process for the preparation of this medicine.

7. Cinnabar is looked upon as an antispasmodic and anodyne: it makes a part of the pulvis temperans of Stahl, which is prepared, according to the Paris Pharmacopœia, by accurately mixing three gros of vitriolated tartar and nitre with two scruples of artificial cinnabar. The sick are likewise exposed to the vapour of cinnabar; and hence a method of treating venereal complaints by fumigation.

All the mercurial preparations that are given inwardly, answer many other cases besides venereal ones; such as almost all the cutaneous diseases, the scrophula, lymphatic obstructions, &c. We cannot, however, but observe, that these medicines, and particularly the saline preparations of mercury, should be employed by skilled and wary physicians; and it endangers the health, and even the life of mankind, that the mercurial remedies are in the hands of so great a number of persons who are destitute of the greatest part of the knowledge, necessary to their administration, not only with success, but even without danger. We have been more than once witnesses of the unhappy effects of these preparations, occasioned by the unskilfulness of those who had employed them, with the assurance which generally



nerally accompanies ignorance. We also think that this object is so important as to merit the attention of government.

## L E C T U R E XXXIV.

*Species 9. TIN.*

**T**IN, or Jupiter of the alchemists, is an imperfect metal of a white colour, more brilliant than lead, but less so than silver. It is very flexible; and in this flexion it makes a small noise, called *crackling of tin*: a phenomenon which, as we have already observed, is produced, though not so notably, by zinc; and hence M. Malouin thought this semimetal approximated in its nature to tin. This noise seems to depend upon the separation or sudden division of parts; and to indicate a fracture, although tin makes very little resistance when we endeavour to bend it. Tin is the lightest of metals. It is soft enough to be scratched by the nail. It loses in water about a seventh of its weight. It has a very sensible smell: when friction or heat is employed, this property becomes more remarkable. It has also a disagreeable taste peculiar to itself; so very strong, that several physicians have ascribed to it a very perceptible action upon the animal œconomy; and have therefore recommended it in several diseases. On account of its excessive softness, it is but inconsiderably sonorous. Tin is the second of the metals in the order of their ductility: it may be made into plates thinner than the leaves of paper, which are of great use in several arts. Its tenacity is so great, that a tin wire a tenth of an inch in diameter, is able to support a weight of forty-nine pounds and a half without breaking. M. l'Abbé Mongez could not effect the crystallization of tin: but M. de la Chenaye, one his of scholars, succeeded by fusing tin several times. By this means he obtained a rhomboidal



assemblage of prisms or needles adhering longitudinally.

Most mineralogists are still doubtful of the existence of native tin. However, some authors assure us, that it has been found in Saxony, Bohemia, and at Malacca. It is strongly asserted also, that it is found in the mines of Cornwall: and M. Sage has described a specimen of this tin which was given him by M. Wolfe a London chemist. This piece is grey and brilliant in its fracture; when beat on the anvil, it forms brilliant and flexible plates of tin. It is more common to find tin in the state of a white calx, heavy, opaque, and crystallized in octagons, or pyramids with four sides. Its texture is laminated and sparry. M. Bucquet considered it as a true spar of tin. M. Sage is of opinion, that these crystals are minerallized by the marine acid: perhaps they are, like the sparry iron, a combination of the calx of tin with fixed air. This white tin has been ranked among the number of iron ores by M. Cronstedt. The name of *tin ores* has been given especially to the matters of a very deep red, violet, or black colour, and of a more considerable weight than that of all the other mineral substances. These ores in their colour and form greatly resemble shirl, but differ from it in their weight and opacity. They are sometimes crystallized in irregular cubes, and form groups, dispersed in a matrix of quartz or of fusible spar. They are frequently in masses without any crystallization. Almost all the naturalists are agreed in considering the coloured ores of tin as combinations with arsenic; and they ascribe their enormous weight to the absence of sulphur. M. Sage thinks that they contain no arsenic at all; and says, that they have no need of being roasted, unless they contain arsenical pyrites, which is very common. No tin ores are found in France. However, M. Baumé alleges that they might be found about Alençon, and in some villages of Bretagne; because rock crystals are found there, which seem to be coloured by this metal. The countries  
where



where they are found in abundance, and where they are smelted, are the counties of Cornwall and Devonshire in England; Germany, Bohemia, Saxony, Isle of Banca, and the peninsula of Malacca in the East Indies. Several naturalists have considered the grenates as ores of tin, no doubt from their colour. They differ, however, from them in their transparency and greater lightness; and besides, Mess. Bucquet and Sage found no tin in them.

The ores of tin, then, are few in number, and may be reduced to the four following.

Varieties.

1. White sparry ores of tin, in eight-sided crystals.
2. Tin ore of a yellowish white, often coloured and semitransparent, like topazes.
3. Red ore of tin, in more or less regular cubic crystals.
4. Black ore of tin, of the same form as the preceding.

In order to essay an ore of tin, it must be divided into different pieces, reduced into a gross powder, washed, and roasted in a covered earthen vessel, taking care to uncover it from time to time, that the arsenic, when volatilized, may carry off as little tin as possible; for if it is roasted in an open fire, it parts with a great deal of tin along with this semimetal, as Cramer has remarked. It must also be roasted quickly, that the tin may not be too much calcined. M. Baumé, in order to remedy these two inconveniences, proposes mixing it with pitch, which reduces a portion of the calx, and facilitates the volatilization of the arsenic. The ore of tin, when once roasted, readily fuses in a crucible with three parts of black flux and a little decrepitated marine salt. By comparing the weights of the ore when washed and roasted, and of the metallic button obtained, we estimate the quantity of arsenic, and how much tin it should afford in the quintal. Cramer proposes making this essay in a more expeditious way, and perhaps with less



loss, by using two large pieces of charred linden or hazel wood. One of them has a cavity serving for a crucible, into which the ore of tin is put along with the pitch; the other is pierced with a small hole, in order to give issue to the vapours, and is laid upon the other for a cover; they are kept together with an iron-wire, care being taken to lute the joinings. A fire is applied to them before the chimney of a forge, and coals applied round them. As soon as a pretty strong fire has been raised, that the tin might have been fused, the coals are extinguished with water, and the tin is found in a button.

The great works of tin resemble the preceding operation. There is frequently a necessity of kindling wood fires in the mine, in order to calcine and soften the matrix, which is very hard: these fires disengage very dangerous vapours. This process is employed in the mountains of Geyer. At other times the ores of tin are found in sand, at a small depth, as at Eibenstein. The pounded ore is washed in vessels with small linen partitions, destined to retain the metallic parts. It is roasted in reverberating furnaces, to which a horizontal chimney is joined to collect the sulphur and arsenic. It is then fused in the air-furnace, and run into moulds, in order to be reduced into pigs. In Germany and England the ores of tin are treated in nearly the same way. In this last country this metal is alloyed with lead and copper, according to Geoffroy, and none of it is exported pure. From England, likewise, a tin comes, like stalactites, called *tears of tin*, which are supposed to be very pure; but Messrs Bayen and Charlard assert that they sometimes contain copper. The purest of all is that which comes from Malacca and Banca. The first has been run into moulds, which have given it the form of a truncated quadrangular pyramid, with a small border at its base; it is called *tin in bats* or *standishes*. Every ingot weighs about a pound. The second is in oblong ingots, from 45 to 50 pounds. These two kinds  
of



of tin are covered with a grey rust or dross more or less thick.

The tin which comes from England, and which is much more employed than the pure tin of the Indies, on account of its less value, is in large pigs of about 300 pounds. It is alloyed with copper, either artificially according to Geoffroy, or naturally according to the Baron de Dietrich. To promote the sale, the pewterers run them into small ingots or rods, from nine to ten lines in circumference, and about a foot and a half long.

Tin exposed to the fire in close vessels fuses very easily. It is the most fusible of the metals. It remains fixed so long as the fire is not augmented; but this fixity appears to be only relative; for upon the application of a considerable heat, it is volatilized, as we shall presently take notice. If it is heated with the contact of the air, its surface, as soon as it is fused, is covered with a dull grey pellicle, wrinkled. This pellicle being removed, the tin below, with all its brilliancy, is found not adhering to it; but it very soon changes, by the formation of a new pellicle. All the tin may then be reduced into pellicles, which are just the calx of the metal, or a combination of this metal with the air. The tin, in its calcination, acquires an addition of a tenth of its weight. If this metal is heated to redness, Geoffroy has observed, that its calx is carried off gradually by a very vivid white flame, which he compares to that of zinc. This is a true inflammation or rapid combustion of this metal; at the same time, a slight smoke of volatilized tin is raised, which condenses upon cold bodies like a whitish needled calx, or like flowers of tin. The grey calx of tin becomes white; if it is exposed anew to the action of the fire, it unites with a fresh portion of air, and is more completely calcined. In this state it is called *putty of tin*. If it is made to undergo an extremely violent heat, as that of a porcelain furnace, it is susceptible of fusing into a glass. Messieurs Macquer and Baumé have observed, upon treating tin in a cru-



cible in this way, that a part was changed into a white and needled calx, or flowers of tin; that another, placed below the first, was a hard calx, adhering, reddish, and half fused; that a third part formed a glass of the colour of the ruby or hyacinth; and lastly, that there was at the bottom a button of metallic tin. The calx of tin requires a fire of the most extreme violence for its conversion into a glass: it is one of the most refractory glasses. The calx or putty of tin may be decomposed by means of animal or vegetable combustible matters which attract the air, which this calx contains, and reproduce the metal with all its properties. The putty of tin, however, seems to retain, when well calcined, the air which is in it, as it is reduced with great difficulty, requiring a great deal of combustible matter. On this account M. Baumé and several other chemists are of opinion, that when the tin ores have suffered too great a heat in roasting, there is a portion irreducible into a metal. Tin is not altered much by the air: it is difficultly tarnished even when it is very pure. That of commerce is covered all over with a grey powder; but which, according to M. Macquer, is always very slight at the surface, and never penetrates inwards, as in copper and iron.

Water does not dissolve tin; it tarnishes and calcines its surface in length of time. The earthy matters contract no union with this metal. Its calx, which is very unfusible, forms neither a transparent nor coloured glass with vitrescent substances; but as it is very white, it may be interposed between the molecules of the glass, and render it of a dull very opaque white. This kind of vitreous frit is called *enamel*. Putty of tin, on account of its infusibility, takes the transparency away from all glasses, and makes them coloured enamels.

The action of lime, magnesia, and the alkalis, upon tin, is not understood; however, it cannot be doubted that these last bodies alter it, for in a very short time they put on the colours of the rainbow.



The concentrated vitriolic acid, or oil of vitriol, dissolves, according to Kunckel, the half of its weight of tin: this solution is the better of heat. Without any sensible motion or effervescence, some very pungent sulphureous gas is disengaged. In this experiment the tin attracts the air of the acid; on this account it is readily calcined, and the oil of vitriol contains enough of it, so as to suffer precipitation by water. Oil of vitriol, diluted with a little water, likewise acts upon tin; but this solution is more permanent, and less apt to be precipitated by water. Spirit of vitriol, or weak vitriolic acid, does not dissolve it. In this combination the tin takes so much air from the acid, that sulphur is very readily produced. This substance occasions a brown colour in the solution when it is hot, but it falls down when the liquor cools. Messieurs Macquer and Baumé were convinced of its presence in this combination. By applying a stronger heat to this solution, we get the tin precipitated in a white calx. The same phenomenon takes place through time, and without the aid of heat. This solution is very caustic. M. Monnet obtained crystals like selenite by cooling, or like fine needles interwoven with one another. The calx of tin precipitated from this solution by repose and heat, is soluble in the vitriolic acid. If we evaporate to dryness the vitriolic solution of tin, the calx then obtained is grey, very irreducible, and no longer soluble in this acid. The alkalis precipitate the tin of the purest whiteness.

The nitrous acid is decomposed with a singular rapidity, even in the cold, by tin. It is one of the most rapid and astonishing solutions in chemistry. It appears that tin has a very strong tendency to unite with pure air; and as the nitrous gas has not by far so firm an adhesion to the pure air in the nitrous acid, as the sulphur has to the same air in the vitriolic, it is no wonder that the decomposition of the nitrous acid by tin is much more quick and brisk than that of the vitriolic acid by the same metal. A very great quantity of very  
red



red nitrous gas is disengaged with a prodigious vivacity. I have also observed that this combination was one of the most advantageous means of obtaining instantly a great deal of this gas. The tin is reduced into a white powder, or into a calx; which M. Macquer in vain endeavoured to reduce: it seems from this, that the metal is overcharged with air. The nitrous acid retains only very little in solution; and when the solution is evaporated to obtain the crystals of nitre of tin, that which was dissolved is very soon precipitated, and the acid remains almost pure. M. Bucquet, in his Introduction to the Study of the Mineral Kingdom, says, that from this solution a nitre of tin may be obtained very deliquescent, the form of which he has not determined. He likewise assures us, that in washing the calx of tin produced by the decomposition of the nitrous acid, the water dissolves a little nitre of tin, which we may obtain by evaporation. The nitrous acid, when very much diluted with water, keeps more of the tin dissolved; but it allows this calx to precipitate, either by standing or by heat. M. Bayen and M. Charlard, in their excellent researches on tin, have discovered, that when the nitrous acid is charged with all the tin it can calcine, to that degree that the acid is thick and incapable of acting on a new addition, we obtain, by washing this mass with a great quantity of distilled water, and evaporating this ley to dryness, a salt, stanno-nitrosus, which detonates alone in a well-heated pot, and which burns with a thick white flame like that of phosphorus. The calx of tin well washed, gives, by exsiccation, a semi-transparent mass resembling shells. This sal stanno-nitrosus, distilled in a retort, bubbles up, and at once fills the receiver with a thick and white vapour with a nitrous odour.

The fuming marine acid acts well upon tin: the tin dissolves by a gentle heat, and even in the cold: it instantly loses its colour and property of fuming. The very slight effervescence which takes place on this combination



bination disengages from the mixture a fetid gas, but which does not resemble the smell of arsenic, as some chemists have announced. By this process the marine acid can take up more than the half of its weight of tin. The solution is yellowish; it has a very fetid smell. There is no precipitate of calx of tin from it, as is the case with the two preceding acids. This solution, evaporated, furnishes brilliant and very regular needles, which attract a small humidity from the air. M. Monnet says, that these needles, after having disappeared by deliquescence, crystallize, and remain dry in the air. M. Baumé, who prepared the salt of tin in great, as in the dose of 150 pounds of acid upon 25 of tin, for the manufactures of printed cloths, has given us an accurate detail of several properties. From 12 pounds of tin, dissolved in 48 of marine acid, he got two ounces six gros of a grey powder, which he could not dissolve in a pound of marine acid, which he digested along with it several days. M. Margraaf believes that it is some arsenic; M. Baumé did not examine it. He compares the smell of this concentrated solution to the black earths extracted from privies; and he remarks, that when it falls upon the fingers, nothing can carry off the metallic smell particular to tin, which it communicates to them, and that it is scarcely dissipated in 24 hours. He observes, that, according to the state of the acid, the crystals of the salt of tin are different. Frequently they form small white needles: the same solution afforded white ones, and of a rose-colour. This last, purified by solution and evaporation, gave, after cooling, thick crystals, very nearly resembling those of Glauber's salt. At other times, by employing the ordinary marine acid, he could obtain this salt only in small scales of a pearly white, resembling those of sedative salt. He has not made mention of the action of the fire on this salt. M. Monnet, who distilled the marine solution of tin, declares that he obtained a greasy matter, very fusible and gelatinous; in short, a true butter of tin,



tin, and a fuming liquor similar to that of Libavius; of which we shall speak afterwards. This fact agrees with what M. Macquer observed of a solution of tin in the marine acid, which almost wholly crystallized during the winter, and again became fluid in the summer: a property which is likewise found in the butter of tin, as shall be taken notice of. This illustrious chemist has also observed, that in a few years this solution afforded a white deposition. The combination of the marine acid and tin gives a much more copious precipitate than the other solutions do with the alkalis and lime: the alkalis re-dissolve a part of the precipitated calx, and become of a yellow brown colour. M. Bayen and Charlard, by dissolving the English tin in large pigs, and all the impure tin in general in the marine acid, have discovered some regulus of arsenic in this semimetal. When it contains any of it, in proportion as the acid acts on the tin, the metal assumes a black colour; and when it is entirely dissolved, there remains a blackish powder, which is some arsenic, either pure, or united with a little copper. Therefore, this acid may be employed to detect the presence and the quantity of regulus of arsenic which tin contains.

Aqua regia, made with two parts of nitrous, and one of marine acid, combines with tin with effervescence. A brisk heat is excited, which it is necessary to diminish, by putting the mixture into cold water. In order to make a durable solution of tin in aqua regia, we must be cautious to add the metal only by degrees, and wait till the first addition be entirely dissolved: if we put it in all at once, a great part of it will be calcined. In this manner aqua regia may be impregnated with half its weight of tin. This solution is of a reddish brown: it has only a small taste; it forms often in a few minutes a gelly, moveable and viscous like a resin. In a few days this substance becomes more solid, and may be cut like a solid animal gelly. It is transparent, of a clear colour; sometimes the colour is more deep. Some portions exhibit



exhibit the semitransparency and whiteness of the opal; it emits a pungent odour of marine acid, but which has not the fœtor of the marine solution. I have kept some of it for more than two years in a bottle carelessly shut: it lost nothing of its solidity and transparency. The solution of tin in aqua regia must be impregnated with a very great deal of metal to form a jelly. Sometimes by adding to it half its weight of water, it concretes, though it was by no means so before: but then this jelly, made by means of water, is the colour of the opal: because, according to the remark of M. Macquer, this solution being susceptible of decomposition by water, a portion of the calx of tin which is precipitated destroys the transparency of the jelly. This learned chemist has also observed, that if we heat a solution of tin in aqua regia, an effervescence ensues, in consequence of the re-action of the aqua regia on the metal, upon which it has not exhausted all its action. This solution then loses all its colour, and grows fixed when it cools. The jelly, which it forms in this case, is most beautifully transparent. Frequently, by allowing a liquid solution of tin to stand for a time, crystals in small needles are deposited. They have not yet been examined, nor the gas disengaged during the action of aqua regia upon tin. Mess. Bayen and Charlard have found that this solvent may also answer as a test to discover the presence of reguline arsenic in tin; but as it has a very sensible action on this semimetal, it did not determine the quantity with so much precision as the marine acid did. The action of the other acids on tin is not known \*.

The

\* M. Margraaf made a very accurate set of experiments to ascertain the solubility of tin in the vegetable acid. After repeated trials with the purest tin, tin free from the admixture of any other metallic substance, he found that both common vinegar and distilled vinegar dissolved tin in considerable quantity. It was not even necessary to apply the acid in a strong state, as common vinegar, diluted with wa-



The detonation of this metal with nitre is very rapid. To do this we fuse and redden it obscurely in a crucible: and upon it we project some very dry nitre in powder. A white and brilliant flame is produced. When by a farther addition there is no detonation, the tin is entirely calcined. The white powder remaining contains some alkali, rendered caustic by the action of the calx of tin, which is even combined with a certain quantity of it. After it is washed, the tin may be precipitated by an acid. If the grey calx of tin fuses with the nitre, as Geoffroy has observed, it is because it still contains some tin, which is only much divided: for by taking a perfect calx of this metal, as, for instance, that which has been for a long time heated, and which is very white, or rather that formed by the acids, we do not observe the same phenomenon.

Tin very readily decomposes sal ammoniac: some volatile very caustic alkali is disengaged in the state of a gas. M. Bucquet, who made experiments respecting the decomposition of sal ammoniac by means of the metallic substances and their calxes, observes, that much inflammable gas is extricated by the reaction of the tin on the marine acid. According to the experiments of this learned chemist, the metals decompose this salt in consequence of the action which the marine acid has upon them. As we have seen that the marine acid has a great affinity with tin, we may hence conclude, that the theory given by M. Bucquet is very satisfactory, and quite agreeable to facts. Glauber had announced, that his secret ammoniacal salt was decomposed by tin; but this decomposition is not completed, according to M. Pott, who repeated Glauber's experiments; undoubtedly because the vitriolic acid has less affinity with tin than the marine acid has. M. Bucquet  
also

water, was found sufficiently strong to answer the purpose. M. Margraaf, being satisfied of the fact, did not trouble himself with studying the properties of this solution; so that it remains as yet unknown to us.



also observed, that the tin, as it is very fusible, is collected in a button at the bottom of the retort; and that, consequently, the sal ammoniac is not so completely decomposed as it might be by this metal. On which account tin does not decompose this salt so perfectly as the metals do which are not so fusible. The residuum of this decomposition is a stannum corneum, or butter of tin, susceptible of decomposition by water, and similar to that which is formed with corrosive sublimate and this metal; of which we shall take more notice afterwards.

Tin easily combines with sulphur, by throwing one or two parts of this combustible substance in powder upon five or six of tin, fused in an iron laddle: the mixture, agitated with an iron spatula, turns black and inflames. If it is fused in a crucible, a brittle mass is formed, disposed in flat needles united in bundles. This combination is much more difficult to be fused than the tin, as is the case with all the soft and fusible metals combined with sulphur \*. But what is of most importance to remark

\* Besides the mixture of tin and sulphur mentioned by M. Fourcroy, this metal may be combined with a much larger quantity of sulphur, by means of mercury, which promotes a more minute division of parts, and more intimate union with the sulphur. For this purpose, tin is amalgamated with half its weight of mercury, and the amalgam, when cold, mixed with half its weight of sal ammoniac and half its weight of sulphur. The whole ingredients are well rubbed together, and then put into a retort to sublime. Some sal ammoniac and cinnabar rise first, and then some gold coloured flakes, which are the tin united with a large portion of sulphur. One hundred parts of tin contain about forty of sulphur. This preparation is extremely beautiful, and is employed by artists to bronze statues, and to imitate the shining spangles of lapis lazuli. Mr Bergman lately received the specimen of a mineral substance from Siberia, which proved to be a native combination of tin and sulphur. It consisted of a nucleus about the size of a walnut, covered over with shining yellow spangles. The nucleus was composed of tin and sulphur united in one proportion, and the crusts of the same ingredients differently proportioned. As yet this is the only instance known of tin mineralised with sulphur: and from the  
great



mark is, that though tin is easily alloyed with sulphur by fusion, nature never presents it in this state. It is quite the inverse of zinc, which is frequently found in its ores combined with sulphur, and cannot be united with it in our laboratories. Nature in its operations often differs widely from art: but if it sometimes forms combinations which art cannot imitate, art likewise forms compounds, of which nature does not furnish an example.

Arsenic unites with tin by fusion only in a small degree, because it is in a great measure dissipated. The arsenical neutral salt combines better with it; and M. Baumé has observed, that, from this combination, in which the arsenic leaves the alkali to unite with the tin, there results a brittle button, which is very brilliant, and disposed in facets like the regulus of antimony. From the experiments which M. Margraaf has made on the union of tin with arsenic by distillation, we learn that a part of the arsenic is reduced to its reguline state, whilst a portion of the tin is calcined: that the tin united with the arsenic cannot be separated from it by the action of the most violent fire: and that as the ores of tin contain a good deal of this semimetal, it is probable that the tin always contains a part of it, which renders the use of it dangerous in kitchen utensils. In distilling the calx of tin charged with arsenic, M. Margraaf obtained a small quantity of a liquor which had the smell of phosphorus. Since the experiments of the Berlin chemist, Mess. Bayen and Charlard have examined the combination of arsenic and tin. They observed, that the calx of arsenic, simply called *arsenic*, cannot combine with tin, except so much of it as passes to the metallic state; and that the combination of arsenic and tin succeeds much better by using the regulus of arsenic. If we put into a retort three ounces six gros of tin with two gros of regulus of arsenic in gross powder;

great abundance of both in nature, it is singular that this combination should be so rare.



powder ; and if, after adapting a recipient, we heat the retort till it is reddened, scarce two grains of arsenic are raised into the neck of the vessel ; and we find in the bottom of the retort a metallic button weighing four ounces. This alloy, which contains a sixteenth of regulus of arsenic, is crystallised in large facets like bismuth : it is more brittle than zinc, and more difficult to fuse than tin ; it afterwards softens ; and if we touch it in this state with an iron rod, we hear a noise, produced by the friction of its laminæ on one another. When in fusion it is clammy, and it fumes, gradually losing the regulus of arsenic which is combined with it.

Cobalt unites by fusion with tin, and forms an alloy in small fine grains of a slightly violet colour. Tin and bismuth, according to M. Gellert, give a brittle alloy in cubic facets. The pewterers sometimes add this metal to tin to give it whiteness and hardness. As it communicates to it a considerable inflexibility, and as it is dearer than zinc, which produces the same effects upon tin, the workmen cannot employ more than a pound or a pound and a half in the hundred weight, and we have nothing to fear from its effects on the animal œconomy ; effects which, the remarkable analogy of bismuth with lead in all its properties, leads us to suspect are similar to those of this dangerous semi-metal. We may separate the bismuth from the tin by means of the marine acid, which dissolves the tin, and leaves the bismuth in the form of a black powder, provided it is employed weak. Aqua regia produces the same effect when it is diluted. The regulus of antimony united to this metal, according to M. Gellert, forms a very brittle white metal, whose specific weight is less than that of these two metallic substances weighed separately. Zinc alloys very well with tin, and forms a hard metal in small fine grains, possessing the greater ductility proportionally to the quantity of tin. M. Cronstedt asserts, that nickel combined with tin forms a white and brilliant mass ; which being calcined under a muffle, rises in the form of vegetation.



Mercury dissolves tin with great facility, and in all proportions. To make this combination, we pour the mercury upon fused tin. The amalgam resulting differs in solidity according to the proportions of these two metallic substances. There was formerly made, with four parts of tin and one of mercury, an amalgam which was run into balls, and which became solid by cooling. These balls were suspended in water to purify it. As the water was likewise made to boil, it was upon the ebullition only that the precipitation of the foreign matters which altered it, depended. The amalgam of tin is susceptible of crystallising. It forms small square crystals, as M. Daubenton observed upon the amalgam of tin which he employed to shut up some glass-vessels in the king's garden.

M. Sage says, that these crystals are grey, brilliant, in leafy laminæ, made thin towards their sides, and leaving between them polygonal cavities. Tin has more affinity with the marine acid than mercury has, and decomposes corrosive sublimate. To effect this decomposition, we divide the tin by means of a small portion of mercury: we triturate three equal parts of this amalgam and corrosive sublimate, and distil this mixture in a glass retort with a gentle heat. At first there passes over a colourless liquor, and then with a kind of explosion a white thick vapour rises, which lines the sides of the receiver with a very slender crust. This vapour condenses into a transparent liquor, which emits a thick, white, and very copious fume, and which has received the name of *fuming liquor of Libavius*. It is a combination of the marine acid with tin, in which the acid seems to be more abundant than the calx of tin. This liquor, contained in a vial, discovers no vapours. A certain quantity, however, is disengaged, which deposits the calx of tin in needle-like crystals upon the upper part of the vial, and the extremity of the neck is found to be completely shut up in a few minutes. There is also precipitated a little calx at the bottom of the liquor in the form of irregular leaves. It has a very penetrating



netrating smell, which excites coughing. It cannot be decomposed by water, because, as M. Bucquet has remarked, it is not overcharged with the calx of tin. We should likewise observe, that the vapours which it emits are invisible, unless they come in contact with the air. It seems that they are formed of a gas of a particular nature, which is decomposed by the air, and which, by its contact, leaves the calx of tin to be precipitated, as the sparry acid gas leaves the quartz earth to be precipitated by the contact of water, and as the hepatic gas of Mr Bergman deposites some sulphur on exposure to air. Might this be a combination of marine acid gas and of the calx of tin? When we pour the fuming liquor of Libavius, recently prepared, into distilled water, it occasions a small noise, like that produced by oil of vitriol when it unites with water. Small, irregular, transparent molecules are disengaged, which appear to have no adherence to the water. By examining closely what passes in the mixture, we observe a bubble escape from these molecules, which bursts at the surface of the water, and expands into vapour, which grows white by contact of the air. By agitating the water, these molecules very soon dissolve, and the solution no longer emits vapours. M. Macquer says, that by diluting this fuming liquor with a great quantity of water, a calx of tin is precipitated in small white and light tufts. The gas of the fuming liquor possesses but a small degree of elasticity; it never raises the stopper of the phial in which it is kept, as happens to the nitrous and marine acids, volatile alkali, &c. The residuum, after distillation, presents as many interesting phenomena as the liquor itself. The roof and the neck of the retort are covered with a slender white and grey layer, which, according to the experiments of M. Rouelle junior, contains a little fuming liquor, some stannum corneum, sweet mercury, and likewise some flowing mercury. In the bottom of the vessel is an amalgam of mercury and tin, above which is found a stannum corneum of a greyish white colour, solid and compact, which may be volatilized by



a more intense heat. If we put this substance into a retort, it fuses and separates into two layers; the one black, laid under the other, which is white, and resembles the former *stannum corneum*. Perhaps the name of *butter of tin* might more properly, than that of *stannum corneum*, be given to these combinations. M. Rouelle seems to suspect, that these two substances, which differ from one another, and do not mix, are owing to the alloy contained in the tin. The more this metal is alloyed, according to this able chemist, the less fuming liquor is obtained. *Stannum corneum* attracts humidity from the air, and dissolves very well in water: which property distinguishes it from *plumbum corneum*. Upon the combination of tin with the marine acid, M. Baumé has given us a theory, which quite resembles that of Messrs Scheele and Bergman, (*Experimental Chemistry*, Vol. II. p. 506—512.) He thinks that the marine acid loses its phlogiston in this operation, as these chemists suppose this acid to be deprived of it by being distilled over from the calx of manganese. He suspects that this acid might be obtained perfectly pure by distilling the fuming liquor of Libavius; by which it appears, that he looks upon the marine acid as overcharged with phlogiston. M. Baumé, then, from this observation, anticipates M. Scheele in the discovery of the two states of the marine acid. The uses of tin are very various. It is used in a great number of arts; it serves as the lining of many vessels, the pipes of organs, &c.

Its amalgam is used to tin over glasses. The braziers use it, alloyed with lead, to tin their copper. It is alloyed with copper to compose the metal for bells and statues. The pewterers combine it with bismuth, regulus of antimony, lead, and copper, for the preparation of all kinds of utensils, which are easily altered by the air. The putty of tin is used to polish many hard bodies. It is fused with the calx of lead and with sand, to make enamel, as well as the covering of earthen ware. The marine salt of tin, crystallized, is useful in the



the business of painting cloths : its solution in aqua regia exalts the tincture of cochineal, of gum lac, &c. turning its colour to that of the strongest fire. The dyers use this solution, which they call *composition*, to make scarlet. When it is mixed with these tinctures in the tub, a precipitate is formed, which carries along the colouring matter, and deposits it upon the stuff which we are dyeing. This observation is owing to M. Macquer, whose labours have rendered great services to this art.

The use of tin in kitchen utensils, has been looked upon by some chemists to be very dangerous. M. Navier, in his work upon the counter poisons, says, that the ragouts in which tin spoons have been left, and likewise sugar contained in a vessel of this metal, have poisoned several persons : these fatal effects have been almost universally ascribed to the arsenic which M. Geoffroy, 1738, had announced to be contained in tin, and which M. Margraaf supposed he found in the most pure tins, and even in a very considerable quantity.

But the works of Messrs Bayen and Charlard, already cited, dissipated all apprehensions excited on this point. By the most decisive experiments, they have proved, 1. That the quantity of arsenic extracted by M. Margraaf from the tin of Morlaix, which exceeded half a drachm in the half ounce, would be much more than sufficient to deprive the metal of its peculiar softness and flexibility, and to render it as brittle as zinc. 2. That the tins of Banca and Malacca do not contain an atom of this dangerous semimetal. 3. That the English tin in large pigs affords, by the action of the marine acid, a small quantity of a blackish powder, frequently mixed with copper and arsenic ; in which powder this last semimetal never exceeded three quarters of a grain in the ounce of tin, and often not so much. 4. That the mixture which the pewterers make of the thick English pigs with the pure tins of Malacca or Banca, still diminishes this dose. 5. That the regulus of arsenic, combined with the tin, loses a part of



its properties, and of its corrosive action. Lastly, that the small quantity of tin alloyed, which can enter the aliments by the daily use of utensils of this metal, cannot influence the animal œconomy; since, according to calculation what a plate of tin had lost in two years, there had not been altogether wasted more than three grains per month; and consequently the 5760th part of a grain of regulus of arsenic in the day; upon the supposition that the wrought tin of Paris contained as much of this poisonous semimetal as the plate of London tin used in the experiment contained.

Let us observe, that if the Parisian chemists do not altogether agree with M. Margraaf, it may be owing to the difference which subsists between the tin of Saxony, which M. Margraaf used in his experiments, and between the tin employed in France, which is imported from the Indies and from England.

Several physicians, who have made a study of the metallic substances considered as medicines, have already owned the innocence of this metal, and even advised the use of it in filings in diseases of the liver, of the womb, and in the case of worms. Schulz, in his dissertation on the use of vessels made of this metal in the preparation of our food and of medicines, looked upon pure tin as very salutary. M. Lapoterie has converted the calx of tin into a medicine, which he says is *antibœtic*; and which is nothing else but a ley of a calx of the regulus of antimony and of tin, formed by the detonation of nitre. The alkali which the water dissolves always retains a portion of metallic calx.

Tin has been recommended as a vermifuge. I have been assured that it was employed in large doses, and with great success, at Edinburgh. Some families in the country are in the practice of infusing in the cold, for twenty-four hours, some sweet wine in a tin vessel; a glass of which liquor they give their children which have been troubled with worms. M. Navier saw a girl of fifteen or sixteen years of age, void thirty worms, with copious stools, a few hours after she had taken a  
similar



similar drink. This medicine then acts as a violent purgative.

## LECTURE XXXV.

*Species 10. LEAD.*

**L** EAD is an imperfect metal, of a dull white, a little inclining to blue. The alchemists gave it the name of *Saturn*. It is the least ductile, the least elastic, and the least sonorous of all the metals. It may be reduced into thin laminæ by the hammer. No metallic substance has less tenacity than it. A thread of lead of one-tenth of an inch in diameter supports only  $29\frac{1}{4}$  lbs. weight without breaking. It is the third heaviest of the metals. A cubic foot of lead weighs 828 pounds. In water it loses between one-eleventh and one-twelfth of its weight: it is very soft, and is very easily cut with a knife; it has a very remarkable particular smell, which becomes much more so by friction: its taste is but very weak on the palate, but discovers its qualities in the stomach and intestines, irritating their nerves, and producing at first pains, convulsions, and then stupor and palsy. It is susceptible of a regular form. M. l'Abbé Mongez has obtained it in quadrangular pyramids lying on the side; so that of the four surfaces there was always one of a great extent, whose base widened as the pyramid lengthened. Each pyramid is composed of layers or zones of other small pyramids, ending generally with a single one pointed. Lead is found rarely native. Messieurs Waller and Linnæus admit of its being to be found in this state. Its existence is denied by M. Cronstedt, Justi, and others. It is found for the most part in an earthy state, or in the state of an ore united with sulphur, and forming galena. The mines of lead are commonly at very great depths in the earth; they are situated in the mountains or in the plains. Naturalists have distinguished a great number of kinds of ores of lead. The most essential to be known are the following.



1. Ochre of lead. It is a kind of clay, of a leaden colour, mixed with a small quantity of ochre of iron.

2. Natural cerufs. It seems to take its rise from an ore of lead, reduced by water to the state of a white earth.

3. White sparry lead. This is a calx of lead, slowly deposited by the waters, and crystallized. This lead sometimes has a semi-transparency like spar. Its crystals are generally truncated hexaëdral prisms, or cylindrical columns striated, and which seem to be composed of a great number of filaments, or they are small very fine needles. Some of it is found which is of a brilliant white, like the soft gypsum. There are other specimens of a yellowish white. Some of its prisms are frequently fistulous. White sparry lead is to be found in great plenty in Basse-Bretagne, in the mines of Huelgoat, and of Poullaouen. M. Sage had announced that the white lead was lead mineralized by the marine acid. M. Laborie has asserted that it was only a pure earth of lead, united to fixed air or the chalky acid, and crystallized by water. The Academy of Sciences of Paris having repeated the experiments of these two chemists, has adopted the opinion of Laborie; and M. Macquer has taken notice of it in his Dictionary, in the article *Ores of Lead*. Sparry lead is always found in the same places with the galena; and it appears that it is only a decomposition of this ore which has parted with its sulphur, and whose lead has been calcined; for it is not rare to find galenas which are beginning to pass to the state of white lead, as M. Romé de Lisle has very well observed. Some chemists have admitted a black ore of lead; this is white lead altered by some hepatic vapours, which metallize it: it may be regarded as an intermediate species between white lead and galena.

4. Green sparry lead. This mineral is of a green, more or less transparent, for the most part yellowish, always mixed with ochre and bog-iron. It has frequently no regular form, and represents a kind of moss. Of this kind generally are the specimens of the ores of  
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Hoffgrund, near Fribourg in Bresgaw. Green lead is generally crystallized in hexaëdral truncated prisms, or in prisms terminated by six-sided pyramids, either entire or cut near to their base. A great quantity of it is found at Sainte-Marie-aux mines, at Tschoppau in Saxony. It is probable that this lead owes its green colour to the admixture with iron, it being always found in the mines of this metal. Mr Spielman is of opinion that it is copper which colours it.

5. Red sparry lead. This lead is very rare. M. Lehman, anno 1776, discovered a species of it crystallized in four-sided rhomboidal pyramids, short and truncated obliquely. It was found in a mine of Siberia. Some of it has been since found in several other mines. It is generally of a very lively red, and assumes very rarely a crystalline form. Some of it, however, is found at Sainte-Marie-aux-Mines, which is crystallized in prisms like white sparry lead. M. Lehman attributes the red colour of this lead to iron.

6. Galena. This is the true ore of lead, or the combination of this metal with sulphur. These ores are all very heavy. They have very nearly the colour and appearance of lead, but are more brilliant and very brittle. A great number of varieties are distinguished in the galena; namely,

1. Cubic galena. Its cubes, which are more or less thick, are found either isolated or adhering. Some of it is found often whose angles are truncated: it is common at Freyberg.
2. Massy galena. This is what is in a mass without any regular figure. This kind is very frequent at Sainte-Marie.
3. Galena with great facets. It seems not to form regular crystals, but is all composed of great laminæ.
4. Galena in small facets. This galena appears formed, like the mica, of small, white, and very brilliant scales. It is called *white ore of silver*, because it contains a great quantity of this metal.



tal. Such is that of the mines of Pompéan in Bretagne.

5. Galena in small grains; so called, because it presents a very compact grain: it is very rich in silver, and is found along with the preceding. In general, all the galenas contain silver. There are few, except that of Carinthia, which are found not to contain some of it. But it has been observed, that the galena, whose facets or grains were smallest, yielded the greatest quantity of it. It seems that the silver being in some measure a body foreign to the combination of the galena, deranges the regular crystallization of this ore.
6. Galena, striated, or like antimony: it seems massy externally; but its fracture exhibits flat and brilliant needles like those of antimony.
7. Galena crystallized like sparry lead, in hexagonal prisms or cylindrical columns. Like the preceding, it is found in the mines of Huelgoat in Low Bretagne. It is not rich in silver; and seems to be only some sparry lead, which has been mineralized without having suffered any alteration of form. And indeed there are sometimes observed upon the same piece crystals of pure sparry lead, entirely covered with a very fine galena; others which are absolutely changed into galena, even in the inner part of their prisms. M. Romé de Lisle possesses several of this kind. In my cabinet I have a specimen of a white ore of lead, whose base of the prisms is absolutely in the state of galena, and demonstrates the change which I mention.

Galena is found frequently placed between two borders of black ochry quartz, which contains a great deal of silver, though this metal is not apparent in it. M. le Chevalier de Dolomieu, who has the merit of this observation, presumes, that the lead was at first mixed with the silver; but that water having carried along this imperfect metal, left the fine metal in the matrix.

M.



M. Monnet says, that he discovered that the galena is vitriolized like a pyrites; and that he extracted a true vitriol of lead from the washing of this ore, the surface of which was whitened, and as if covered with flowers \*.

As almost all the ores of lead contain a very great quantity of silver, it becomes important to essay them with accuracy. To this end, after having pounded and washed a certain quantity of ore, parcelled out, it is roasted with care in a covered head, lest it should jump about. Galena loses little by the roasting. The weight of it is found after it has undergone this operation; and it is fused with three times its weight of black flux and a little decrepitated sea-salt. The fixed alkali of the black flux absorbs the sulphur which was combined with the lead: the charcoal of the tartar, which makes a part of the same flux, serves to reduce the portion of the metal which is in the state of a calx; and the sea-salt prevents the evaporation of the contents of the crucible. After fusion there is found a button of lead, which is carefully weighed; after that, the lead is calcined and vitrified upon a cupel, to separate the silver which it contains. We cannot depend greatly upon the fidelity of this essay; because the alkali, which is employed as a flux, forms, with the sulphur of the galena, a liver of sulphur, which dissolves a portion of the lead. Besides, so expensive a reducing flux as the black flux cannot be used in the great works. It is then necessary to set about fusing the ore across coals in a reverberatory furnace, either alone, or by the addition of some unexpensive materials, as a little iron and glass-gall, to absorb the sulphur.

At Pompéan, in order to smelt an ore of lead containing

\* Lead is found also mineralized with the phosphoric acid. This is of a greenish colour, from the mixture of iron, and does not effervesce with acids. The essay is made by dissolving the metallic salt in the nitrous acid, and precipitating the lead by the vitriolic. A hundred and thirty-seven grains of this precipitate are equivalent to a hundred of lead; and the liquors, evaporated to dryness, give the phosphoric acid.



taining silver, it is pounded at the stamping-mill; it is washed with great care upon tables, and carried to an air-furnace; or it is roasted at first by means of a gentle heat, and then is fused by augmenting the fire. The fused lead is got out of the furnace by a hole, which corresponds with one of the sides of its cavity, and which has been shut up with clay. The lead is moulded in pigs, and called *enriched lead*. It contains some silver. To free it from this metal, the enriched lead is carried into another furnace, the bottom of which is covered with well-washed, sifted, and beat cinders. At one of the sides of the cavity of this furnace two large bellows are placed, in opposite directions, to which there are two furrows, for the descent of the litharge. When the furnace is heated, the lead is calcined; a part evaporates, and sublimes into the small chimneys, which are above the ways of the litharge: another part is absorbed by the floor of the furnace; a third portion, and it is the most considerable, is calcined, and even vitrified, in part: it gets the name of *litharge*: it is driven out of the furnace by means of the bellows, which likewise facilitate the vitrification of the lead by the quantity of air which they pour upon this metal in fusion. When the litharge has been calcined by a moderate fire, it is in a red scaly powder: it is called *vendible lead*, because it is sold in this state; or *litharge of gold*, on account of its colour. If the litharge has undergone a stronger heat, it is more advanced towards vitrification, and of a pale colour: it is then called *litharge of silver*. At last, when the furnace is heated strongly, the litharge rises most completely, and flows in the form of irregular stalactites: this is what is called *pure litharge*. When the operation is ended, in the furnace there remains some silver, which was contained in the lead. This silver requires to be refined, but in small masses, in order that it may be deprived of the lead which it retains.

The lead which has been calcined by the refining is then fused across coals; and it contains but a few atoms of silver. It is run down in pigs, and may afterwards be



be exposed to sale. The sparry lead is fused among the coals in the same manner as the calx of lead.

Lead exposed to the fire fuses long before it is red. It requires, in order to be kept in fusion, even so slight a heat that the hand may be immersed into it, when it fuses, without suffering any pain; in this state it does not burn vegetable substances. It possesses but a small degree of volatility: however, it is volatile in a very strong fire, and it fumes and is reduced into vapours, like the most fixed metals. If, when it has been fused, we leave it to cool very slowly, and pour off the fused portion from that which has become solid, it is found crystallized in quadrangular pyramids, which we have already described.

Lead fused with the contact of the air is covered with a grey and dull pellicle. This pellicle is carefully taken off; and it is reduced by agitation into a calx of a greenish grey, inclining a little to yellow. This calx, separated by the sieve from the little grains of lead, which are found mixed with it, and after that exposed to a more violent fire capable of reddening it, becomes of a deep yellow: in this state it is called *masticot*. This heated slowly with a gentle fire, assumes a fine red, and bears the name of *minium*. If we heat the masticot very strongly, it fuses into a glass, and does not afford minium.

Lead in its calcination increases in weight near 10 pounds in the hundred. It is this augmentation of weight, as much as the necessity of air for this operation, which led Jean Rey, a physician of Perigourdin, to suspect that the air fixed in this metal during its calcination. Dr Priestley has confirmed the opinion of Jean Rey, by extracting pure air from minium. The calx of lead, though very much coloured, loses this colour entirely: if the minium be heated a little too strongly it grows pale: if we urge it alone with the fire, it fuses into a transparent glass, so fusible that it penetrates all the crucibles, and escapes, without being able to be retained; but by adding one part of sand to three parts



of calx of lead, the sand is fused by means of this calx into a beautiful glass of the colour of amber. The hue of this glass is less deep, and imitates the colour of the topaz, when two parts of calx of lead and one of sand or powdered flint are fused together. A less quantity of calx of lead added to common glass, does not alter its transparency, but increases its weight, and gives it a sort of unctuousity, which renders it susceptible of being cut and polished more easily without calking. This glass is very proper to make achromatic glasses: but it is very subject to have striæ and a gelatinous aspect. The English call it *flint-glass*. Our merchants have a good deal of difficulty in finding not very large pieces exempt from these striæ in that which they import from England. It seems that this inconvenience, which is very great, depends, as M. Macquer supposes, upon this, that the principles of this glass are not uniformly combined. For this purpose it would require to be a long time kept in fusion: but as the lead then dissipates, the flint-glass loses a part of its density and of this unctuousity, which give it its reputation.

Although all the phenomena of the calcination and of the vitrification of lead, announce that this metal unites with very great facility and readiness with pure air, it is, however, one of the metallic substances which has the smallest adhesion with this principle, since it separates by the action of the fire alone, as Dr Priestley has demonstrated. If some minium is strongly heated in a retort, some pure air comes over, and a portion of minium is observed to be reduced to its metallic state. All the calces, and even the glasses of lead, are very easily decomposed by the combustible substances: it is sufficient to mix them with some charcoal, fuel, grease, oil, resin, or in short any inflammable substances and to heat them some time, and a button of lead is obtained. This metal, therefore, has less affinity with pure air than most other metallic substances have: and tho' it has some properties similar to those of tin, in its calcination and reduction it is absolutely the inverse.

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These phenomena prove more and more, what we have advanced as one of the laws of the affinity of composition; namely, that we must not judge of the degree of affinity between two bodies by the facility with which they combine, but much rather by the difficulty which we feel in disuniting them.

Lead exposed to the air tarnishes so much the more easily as the air is more humid. It contracts a white rust, which the water gradually carries off: it is not certain if this white powder with which it is covered is a pure calx of lead, or if it is not combined with the aerial acid contained in the atmosphere. The silver which is extracted from old leads that have remained for a long time exposed to the air, is owing to the lead, which has not been refined at the proper time, being in part calcined by the action of the atmospheric acid; so that the silver which has not been separated remains without alteration, and its proportion augments according to the quantity of destroyed metal.

Water alters lead, particularly that which is charged with saline matters: the sides of the vessels for carrying water are covered with a whitish crust, whose nature has not been examined.

Lead unites with the earthy substances only in its state of a calx.

We are not certain of the action of lime and the caustic alkalis upon lead \*.

Lime is soluble in all the acids. Oil of vitriol attacks it only when boiling, and when the lead is in small laminæ: some gas and volatile sulphureous spirit arise. When the acid is entirely evaporated, the mixture is white and dry; by washing with distilled water, it separates into two portions. The most considerable portion is insoluble in water: it is a calx of lead formed by

\* Caustic alkaline lixivia, boiled on plates of lead, dissolve a small portion, and corrode a considerable quantity. The solution stains hair black. Lead fused with fixed alkaline salts is in part corroded into a dark-coloured scoria, which is partially soluble in water.



by the air, of which the metal deprived the oil of vitriol, disengaging it under the form of sulphureous gas. This calx may be fused or reduced like that which has been made by the combined action of fire and air. The small portion which the water dissolved is a combination of vitriolic acid and calx of lead: this solution evaporated gives small needles of vitriol of lead. Mess. Baumé and Bucquet designed this salt only under this form. M. Monnet has obtained it sometimes in prismatic and short columns. The opinions of M. Sage and of this chemist nearly coincide, since M. Sage says that the vitriol of lead gives crystals in four-sided prisms.

This salt is very caustic and very deliquescent.

It is decomposed by fire, lime, and the alkalis.

The nitrous acid seems to act very strongly upon lead.

When this acid is very concentrated, the lead is very readily reduced to a white calx by means of the air which is separated from the acid, at the same time that the nitrous gas is dissipated: but if the acid is more weak, it is less decomposed, and there remains enough of it to dissolve the calx of lead. A grey powder is precipitated during this solution, which M. Grosse looked upon as mercurial: but M. Baumé asserts, that this matter is only a portion of calx of lead; and I have several times in vain endeavoured to obtain mercury from it by sublimation, and by using a fire strong enough to reduce the mercury if there had been any in the state of a calx. This solution is not precipitated by water; by cooling it gives crystals of a coarse white, in form of flattened triangles, whose angles are all truncated. The same solution set to evaporate slowly for several months, gave crystals, the thickest of which were more than inch broad, and hexaëdral pyramids, and whose three surfaces were alternately great and small, and the point was truncated; so that each crystal is a solid with eight sides. M. Rouelle has very accurately described this salt. Nitrum saturni decrepitates on the fire, and fuses with a yellowish flame when it is put



put upon a burning coal: the calx of lead, which is at first yellow, is very quickly reduced into globules of lead.

What this salt gives upon distillation has not been examined

It is decomposed by lime and the alkalis. The vitriolic acid, although it has only a weak action upon lead, has however more affinity with this metal than the nitrous acid has. If we pour some pure vitriolic acid, in form of an earthy or alkaline neutral salt, into a nitrous solution of lead, a white precipitate in a few instants is formed. The occasion of this precipitation is, the vitriolic acid takes the calx of lead from the nitrous, and forms with it some vitriolum plumbi, resembling that resulting from the immediate combination of the oil of vitriol with this metal.

The pure marine acid, with the aid of heat, readily enough calcines lead and dissolves a part of its calx; but it is difficult to saturate it completely. This solution has always an excess of acid: it may, however, furnish, by a strong evaporation, crystals in fine and brilliant needles, as M. Monnet has observed.

Lime and the alkalis decompose it like vitriolum plumbi. This metal combines with the marine acid more readily and intimately by pouring this acid, either uncombined or united with an earthy or alkaline base, into a solution of nitrum saturni; a white precipitate is instantly formed, much more copious than that produced by the addition of the vitriolic acid, and resembling a coagulum. It is the combination of the marine acid with the calx of lead, which separates from the nitrous acid upon the addition of the marine. This salt falls down on account of its too considerable insolubility in water. If it is exposed to the fire, vapours are disengaged of a saccharine taste, and it fuses into a brown mass, called *plumbum corneum*, because it has some resemblance with the silver which goes by a similar name. The solution of this salt evaporated, crystallizes in small, fine, and brilliant needles, which form bundles, or



which unite by one of their extremities at an obtuse angle. M. Sage says, that this solution crystallizes by insensible evaporation into striated hexaëdral prisms. The solution of plumbum corneum is decomposed by the vitriolic acid, which occasions a white precipitate in it as in the nitrous solution. This discovery, which is due to M. Grosse, has been acknowledged by M. Baumé, and may be repeated by all the chemists. It falsifies the eighth column of Geoffroy's Table of Affinities, which exhibits the lead, as having more affinity with the marine than with all the other mineral acids.

All the solutions of lead are precipitated black or brown by the liver of sulphur, and then a sort of galena forms by the deposition of the sulphur upon the calx of lead; which seems to indicate, that the lead is in the state of a calx in this ore.

All the calces of lead dissolve in the acids as easily as lead itself, and often more easily than this metal. Minium loses its colour in these solutions. The calces of lead approach to the metallic state by the contact of hepatic gas.

Lead does not produce an evident detonation with nitre. If we project the powder of this salt upon this metal in fusion and a little red, but very little motion and no apparent flame is raised. However, the lead is calcined and vitrified by the alkali of the nitre, and is found in small yellowish leaves resembling litharge.

Lead easily decomposes sal ammoniac by means of heat. This property is common to it with most of the metals. Its calces, triturated with this salt, disengage from it alkaline gas in the cold: but if the mixture is heated in a retort, the decomposition is very rapid. There comes over a caustic penetrating volatile alkali. Some chemists have advanced, that the volatile alkali, separated by minium, effervesced with acids: and hence they have concluded, that this calx of lead contained some of the chalky acid. But M. Bucquet has observed, that this effervescence is owing only to a portion of alkaline gas, volatilized by the heat occasioned by the com-



combination of the alkali and acid; and that it happens only when the concentrated acids are used. To clear up this point, he made a very ingenious and decisive experiment. Having introduced some volatile alkali, obtained by means of minium, into a vessel above mercury, he put into the same vessel some weak vitriolic acid sufficient to saturate the alkali: in a moment an ebullition arose, and a disengagement of a gas, which was readily absorbed, and was only some alkaline gas. The mass which remains in the retort after the decomposition of sal ammoniac by the minium, is a marine salt of lead, which with a gentle heat fuses into a *plumbum corneum*, and may be totally dissolved in water. It was this substance which M. Margraaf employed for the preparation of the phosphorus of urine.

Inflammable gas alters lead in a very sensible manner. It colours its surface, gives it the changing varieties of the rainbow, and seems to revive its calces \*.

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\* The calces of lead are much affected by sulphureous vapours of all kinds. Even metallic salts, which have lead for their base, especially *saccharum saturni*, change colour by the vicinity of such vapours. The common way of showing the experiment is, to wet a bit of paper with a solution of *saccharum saturni*, and, after it is dry, to place it in the neighbourhood of a solution of sulphur in lime-water. The imperceptible vapours which arise from the sulphur, will in a short time blacken the *saccharum saturni*; and this will happen though two hundred or three hundred leaves of a book be interposed between the paper wetted with the one solution and that wetted with the other. In this way *saccharum saturni* may be employed as an invisible ink, which the correspondents can render visible by means of sulphureous vapours.

This experiment has been frequently used to detect the presence of lead in any fluid, and is then called *liquor probatorius*. The chief use of the test is to discover the adulation of wines and of other fermented liquors with *saccharum saturni*, which fraudulent dealers add to correct any sharpness which the wine has acquired, as *saccharum saturni* communicates a sweetness and astringency very similar to the product of native fermentation. Frauds of this kind are pernicious, on account of a very violent and dangerous colic which the drinkers of adulterated wines are subjected to, from the poisonous qualities of lead, which, when taken internally, occasions pains and spasms of the bowels, which often terminate in a paralytic affection.



Sulphur easily unites with this metal. By the fusion of these two substances there results a sort of brittle mineral in facets of a deep and brilliant grey. This matter, very nearly like galena, is of much more difficult fusion than lead: it is a phenomenon which is particular to the combinations of the metals with sulphur. Those which are very fusible, are after this union difficultly fused; whilst those which fuse with difficulty, acquire a great fusibility in this combination \*.

Nothing is known of the alloy of lead and arsenic. Nickel, manganese, cobalt, and zinc, do not by fusion combine with lead. Regulus of antimony forms with it a brittle alloy in small brilliant facets, which imitate the texture and the colour of iron or steel, according to the proportion of the mixture, which is specifically heavier than the two metallic substances which compose it taken separately.

Lead combines with bismuth, and forms a fine and compact grain unmalleable and brittle.

Mercury dissolves lead with great facility. This amalgam is made by pouring some hot mercury into fused lead; it is white and brilliant; it becomes solid after it has been made some time: when it is rubbed with the amalgam of bismuth, it equals the fluidity of flowing mercury. It may be proper to take notice, that

tion. This practice was once so frequent, as to require the authority of the different legislatures in Europe to stop the abuse. By the operation of these salutary laws, and by the discovery of certain and easy tests, the frequency of the fraud is much diminished. The best way of trying any suspected drink, is to drop a small quantity of the solution of sulphur in lime-water. If there be any lead present, this addition will instantly occasion the precipitation of a dark-coloured cloud. From the convenience and facility of the method, it should be practised by all who drink much cyder or other liquor whose chief merit consists in the agreeable mixture of a sweet and acid taste, as these small wines are the most frequent subjects of adulterations.

\* Lead is acted on by all the inflammable bodies. The gross oils dissolve the calces of lead very copiously by the assistance of heat. This preparation has the consistence of a tenacious paste, and constitutes the base of many plasters which are used in surgery.



that this singular phenomenon is occasioned by the union of three very fusible and heavy metals, possessing more or less volatility.

Lead alloys very well with tin by fusion. Two parts of lead and one of tin form an alloy, which is more fusible than these two metals separately, and constitute the solder of the plumbers. Eight parts of bismuth, five of lead, and three of tin, give so fusible an alloy, that the heat of boiling water is sufficient to fuse it, according to the observation of M. d'Arcet †.

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† Lead unites by fusion to most of the other metals. A small addition of it makes gold and silver brittle, though a proportional addition of either of these metallic substances to lead has the contrary effect, and makes it more ductile. Copper does not unite with lead, unless the lead be red hot and boiling: and after this union it may again be separated by using a gentle heat, which melts the lead without melting the copper. This mode of separating the metals by means of their different degrees of fusibility, cannot be used in any other mixture which is hitherto known, as in all other cases the compound fuses as one homogeneous mass.

Lead does not unite with iron: but if lead and iron be exposed to the fire in one vessel, the lead is first converted into litharge, which attacks and scorifies the iron by taking away the phlogiston, and afterwards reduces the martial calx into a dark-coloured glass.

This property which lead possesses of reducing all the imperfect metals into a glassy slag, is the means used to purify gold and silver; neither of which lead can deprive of their metallic character, and which remain untouched at the bottom of the vessel. This process is the more complete, from the power of glass of lead to dissolve all earthy bodies, seeing it is so powerful a flux, that no vessel can confine it when fused, of whatever materials the vessel be made. A mixture of raw and burned clay stands the action of lead for the longest time, but at last it has its sides corroded. Litharge is employed in the composition of all the finer glasses called *pastes*, which imitate the precious stones. The addition of the litharge makes them more solid and brilliant, as it enables them to disperse the different coloured rays in a greater degree. The purest flint, purified alkali, borax, and litharge, are the chief and essential ingredients. The other additions are made for the sake of tinging them of various colours. Flint-glass also contains a large proportion of lead, which communicates a greater degree of ductility, and enables it to retain this in a greater degree of cold. It must, however, be observed, that all glass made with lead has the defect of being unequal in den-



The alloy of lead with tin being employed frequently for æconomical purposes, and as the first of these metals may render dangerous the use of utensils made of the second, which is made use of in cooking and pharmaceutical vessels, it becomes of importance to know the means of ascertaining the proportion of lead, which often greatly exceeds that which is prescribed by law. Messrs Bayen and Charlard have given a very good process for determining the quantity of this vile and dangerous metal when contained in tin. It consists in dissolving two ounces of a suspected tin in five ounces of good nitrous acid, in washing the calx of tin thus produced with four pounds of distilled water, and in evaporating this water in a sand bath. Some nitrum plumbi is obtained by this evaporation, which is calcined; and the residuum, after having been weighed, is considered as the quantity of this metal contained in the tin, making an allowance of some grains for the increase of weight, which it must acquire in the calcination, as well as for the presence of other metals, such as zinc and copper, which the tin may contain. These chemists have assured themselves, by this means, that the fine wrought tin contains about ten pounds of lead in the hundred; and that the tin sold under the name of *common*, contains often twenty-five pounds in the same quantity. The quantity is enormous, and it exposes those to the greatest dangers who make use of utensils of common tin. It is found almost constantly in the vessels of which great use is made; such as those for measuring out liquids, and particularly wine. It is evident how a liquor which fours easily may unite with lead, and convey into the viscera of the unfortunate persons condemned to drink it through necessity the feed

density, from want of a perfect mixture of all its parts. Many attempts have been made to remedy this inconvenience, though hitherto without success, although a very considerable premium has been offered to the discoverer of a glass which would serve all the purposes of optical instruments.



feed of diseases ; which are so much the more grievous, as their cause is often unknown.

The pewterers have several methods of distinguishing the quality of tin, and of ascertaining the quantity of lead contained. The simple inspection often suffices them ; the weight and the sound confirms their opinion. They have two kinds of essay ; the one, called *essay with the stone*, is made by running tin fused into an hemispherical cavity made in a thunder-stone, and terminated by a furrow. The phenomena which the tin presents upon cooling, the colour, the roundness, the depression of its middle part, the noise which the extremity of the essay makes when bent different ways, are so many signs which an intelligent workman knows, and which, by a long observation, lead him to comprehend very exactly the quantity of the metal. Be this as it may, this essay employed by the masters of Paris, does not appear to be so exact as that made use of by the masters of Provence, although rejected with disdain by the first. This second essay is called *essay by the ball or medal* ; because it consists in running the tin to be essayed into a mould, which gives it the form of a ball or of a flattened mass resembling a medal. The weight of this specimen, after it is moulded, is then compared with an equal volume of fine tin run into the same mould. The more the specimen weighs than the standard, the more lead it contains. Messrs Bayen and Charlard prefer this last essay ; of which the principles are surer and less subject to error than the circumstances which direct the workmen who determine the quality of the metal by the essay with the stone.

Lead is of very extensive use. It is used in many alloys : it is used to make pipes for the conveyance of water. Its calx is used in the making of glass and enamels : it also serves to imitate the yellow precious stones, and to add fusibility to the coverings of earthen ware. The metal itself is employed to make utensils for æconomical purposes, but not without danger to health. A noxious quality is often communicated to the water, which



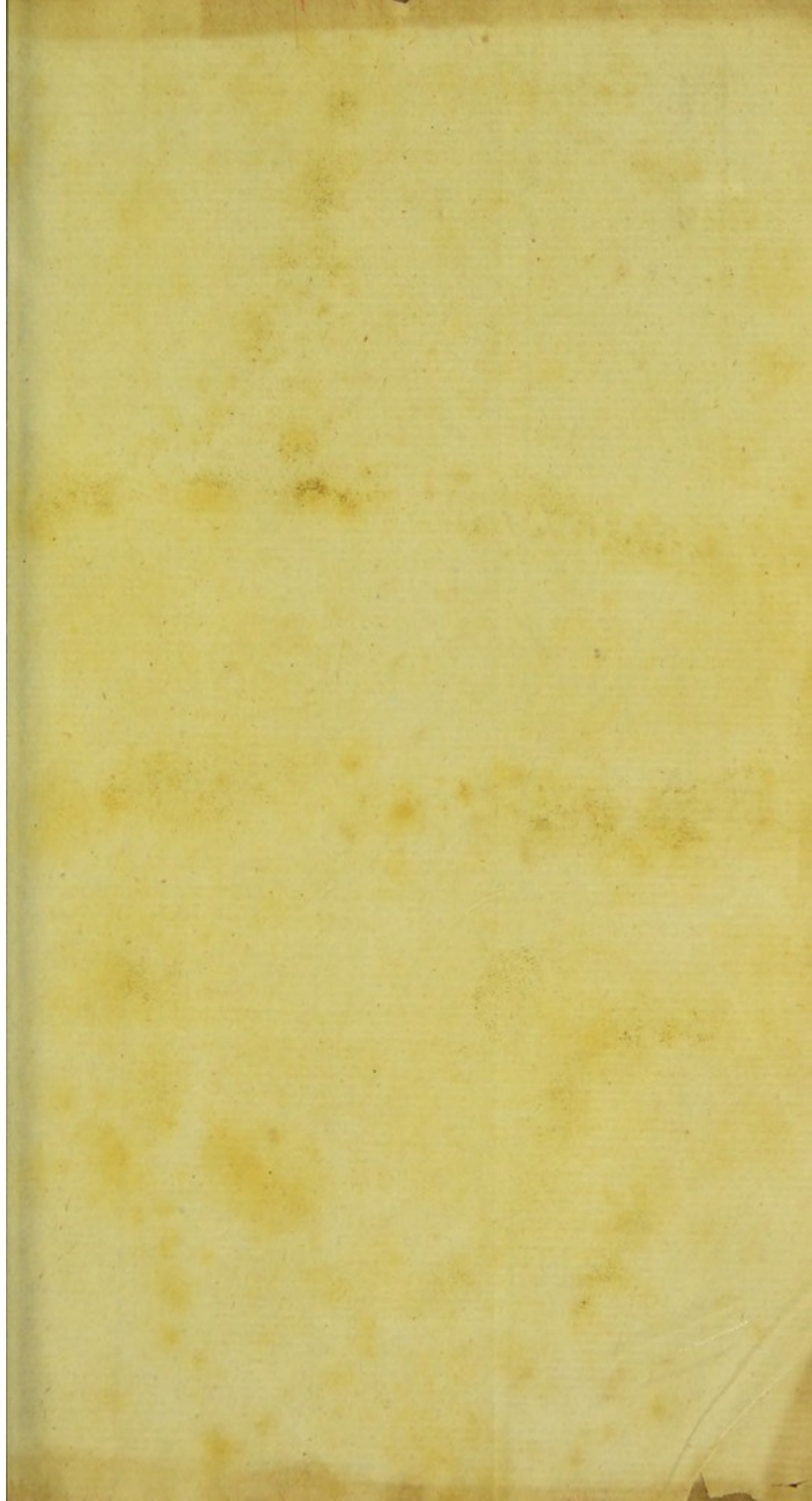
which is allowed to remain in leaden cisterns or basons. Its vapour is dangerous to the workmen who fuse it, and its powder is still more dangerous to those who file or rub it. This metal, when received into the stomach and intestines, occasions violent colics, frequently accompanied with a vomiting of very green bile, and remarked for the flattening of the belly and depression of the navel. In this case it has been observed, that antimonial emetics and purgatives are used with great success. M. Navier recommends the different livers of sulphur, in cases of persons poisoned with lead, as well as with arsenic and corrosive sublimate. It is particularly in the palsy and tremors, which generally attend those who have laboured under the colica Pictonum that this physician boasts of the good effects of the liver of sulphur and hepatic waters. From these facts, then, we ought to lay aside the use of all the preparations of lead internally, and to make use of it only as an external remedy; and even externally, we ought to use it with all the precaution requisite in the application of a violent discutient\*.

\* Lead, in passing from a state of fluidity to a state of solidity, passes through a certain state of aggregation, which is called the *granulation of lead*. In this state it coheres like particles of wet sand, and may be divided by continuing to stir it with a stick during the time of cooling. But this is not the way it is formed into shot. To make shot, the melted lead is poured into an iron box, which is perforated with small holes in the bottom, through which it runs into a vessel of water. As it touches the surface of the water, it begins to congeal, forming into drops which resemble the shape of pears. This irregular form is corrected by adding a small quantity of orpiment or white arsenic to the water, which disposes the lead to form into more perfect spheres. Those which are not sufficiently so, are separated from the rest, by making the whole run down an inclined plane, when the little spheres run straight down to the bottom, and those which are irregular tumble off at the sides. After this the shot is sorted, by passing through sieves of different sizes.

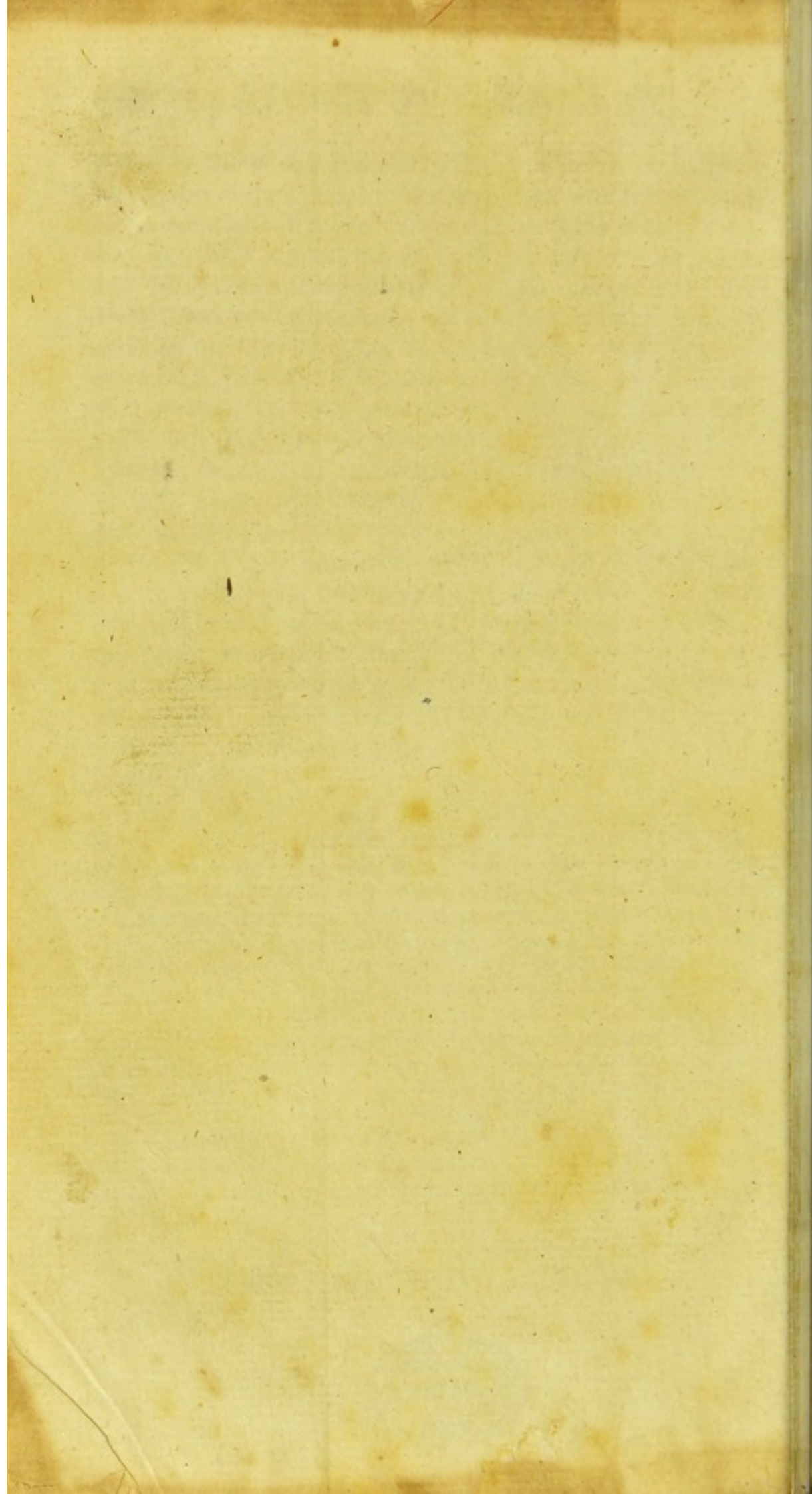
END OF THE FIRST VOLUME.













178



