hence the Galvanic battery is formed. this last consideration is of great consequence, for it is always to be remembered that in every Galvanic circle, or combination, the electric fluid circulates in one way only. In each simple arrangement, the tendency of the electric fluid is in the same way, and probably the one accelerates the other. If a battery consist of 40 simple combinations and 12 be placed in a direction contrary to the others; then these 12 will counteract 12 others, and the whole battery will have no more force than if it consisted of but 16 simple combinations. There are different ways of constructing batteries. Two different metals and a fluid must be used in the following manner; 1st. Silver, 2nd. Zinc, and 3rd. cloth or pieces of card soaked in water, or other proper fluid. The pieces of cloth or card must be gently squeezed in order that the fluid may not run down the outside of the pile. Other metals besides zinc and silver may be used, but will not answer so well. Water answers better when mixed with a certain portion of nitric muriatic acid. The forms of batteries are various. Charged batteries of sufficient extent will melt wire in their discharge. If two wires be connected with the different ends of a battery and brought in contact, the spark will be perceived. Fifty or sixty combinations give a spark. It is most useful in dropsies and rheumatic complaints. The most extraordinary phenomena of a Galvanic battery are its chemical effects. The first is the decomposition of water by wires coming from the upper and lower sides of a battery. Both hydrogen and oxygen are obtained. The negative gives hydrogen.

Additional Observations.

The best definition of Galvanism seems to be, that it is the effect which small quantities of electricity produce, of convulsing the muscles and nerves of animals. Galvanism, it is true, embraces a variety of facts besides the above, but this definition should be adopted for the sake of distinctness.

The effect was first supposed to be owing to a property of the animal. Some have supposed it to be the effect of the nervous fluid in motion. It has also been supposed that the nerve and the muscle are in different states of electricity the one being positive and the other negative; and that when a communication is formed between them by means of a wire or other conductor, the equilibrium is suddenly restored, which causes the convulsion. But it is now ascertained that electricity is the agent in these phenomena.

The facts which were known previous to the discovery of Galvanism are as follows. It was observed that any liquor when drank out of a pewter or tin vessel, had a taste different from that which it had when drank out of a glass one. Mercury retains its brilliancy when alone; but amalgamated with another metal, it is soon tarnished or oxydated. It was also observed that in coppered vessels and the sheeting of ships, the metals soon became oxydated at the places where they were fastened on by iron nails. Some ancient Tuscan medals made of one metal are still entire, whereas those of different metals have soon become oxydated. — These facts must be owing to the chemical agency of the metals.

In forming the combination the effect appears to increase, sometimes with the quantity of surface, and at others, only with the number of combinations.

The most powerful batteries are generally formed by troughs

Lecture XVIII.

Pneumatics.

That part of philosophy which treats of the properties of our atmosphere, is called pneumatics. The term pneumatics is derived from the Greek word pneuma which signifies wind or breath. The inodorous, colourless, and extremely subtile fluid that surrounds our earth, is called the atmosphere. It is highly important to become acquainted with its properties, because in it we may be said to live, breathe, and move; and it is absolutely necessary to our life, and for all that has been demonstrated to the contrary, to the life also of every living thing. It is, in short, one of the most constant and interesting agents in nature. The principal properties of this fluid are rarity, transparency, and elasticity. That it is a fluid, is proved from observing that it yields to an impulse, and when yielding, has its parts easily moveable amongst each other. The particulars in which it differs from other fluids are commonly reckoned to be the four following. 1st. It is compressible. 2nd. It cannot be congealed. 3rd. It is of different densities at different distances from the surface of the earth. 4th. It is of an elastic or springy nature. These differences should properly be reduced to two, viz. that it is highly elastic, and insusceptible of congelation. If it be elastic, it must necessarily be capable of compression, and ought to differ in density at different distances from the surface of the earth. Some of the ancients have considered the atmosphere to be an element: but they probably did not understand the term element in the sense that we do. However that may be, modern experiments have incontestibly proved the atmosphere to be a compound substance. We distinguish it into common and elementary air. Common or heterogeneous air is that which we live in. The elementary is a settled material homogeneous substance, and is the base or chief ingredient of atmospheric air. This in its purest state is a mixture of two kinds, Oxygen and Hydrogen, and even these two themselves are mixtures, each having its base dissolved in caloric. These mixtures can only be dissevered by decomposition. Experiments show that all bodies contain air; in one case it exists in their pores and is dissipated by caloric; in the other, it is combined, fixed & immoveable, and is not destroyed except by decomposition. Many have regarded this air as the gluten or cause of the union of the particles of these bodies. Air is considered as to its chemical properties, such as are understood with respect to combustion and other processes. — and also as to its other properties such as gravity, elasticity, compressibility &c and these are called its mechanical properties. The latter will be spoken of here. The most evident proof of its existence as a real body may be shown by blowing a thread, dust, or any light substance placed at a short distance from the mouth; these bodies are immediately driven from their places. It is the current of air that being expelled from the lungs through the mouth, drives the light bodies in its way.

Take a wine glass, turn it upside down, and holding it in a perpendicular situation, immerse it in water; it will be found that the water does not enter the glass. If the glass be inclined a little, a certain quantity of air goes out and an equal bulk of water takes its place. The quantity of air which thus escapes from the cavity of the glass being pressed on every side by the water, is forced to assume a globular form, in which shape it is called a bubble; which being lighter than an equal bulk of water, ascends to the surface of the latter, where it mixes with the common mass of atmospherical air. But frequently when the bubble is small, it remains for a certain time on the surface inclosed in a film or shell of water, which is owing to the viscidity of the water, or the mutual attraction between its particles. Whatever increases that viscidity, such as a solution of soap or any glutinous matter, increases the durability of the bubbles; and in that case by blowing into the solution, the bubbles may be made very large. Hence it appears, that a bubble of air, is not according to the vulgar idea, an empty space, but that it consists of a fluid which tho' invisible, has weight & other qualities and is as much a substance as any which we feel or taste. The invisibility of air is what suggests the vulgar idea of its being nothing. But it must be considered that transparent bodies, viz. such as let the rays of light pass freely thro' them, cannot be seen. Thus water, glass, air, &c. cannot be perceived by an eye which is entirely surrounded by any one of them. And even when that is not the case, we can only perceive those substances by the heterogeneous bodies which they may happen to contain, or by the inflection, refraction &c. of the rays of light at their surface: hence when such bodies are pure and their surfaces removed from our sight so that we cannot observe the bending of the rays of light at them, then it is impossible to discern the bodies themselves. If a glass bottle entirely filled with pure water be situated entirely against a dark place so that no objects may be seen thro' it, a person who looks directly at it, will not be able to say whether the bottle be full of water or not. A fish, or a man in water, may feel it, but cannot see it.

The particles which are seen moving about when light passes thro' a hole in a room, otherwise dark, are not the particles of air, but they are particles of dust &c. which float in it.

The air is justly reckoned among the number of fluids, because it has all the properties by which a fluid is distinguished. For it yields to the least force impressed, its parts are easily moved among one another, it presses according to its perpendicular height, and its pressure is every way equal.

That the air is a fluid, consisting of such particles as have no adhesion between them, but easily glide over one another, and yield to the slightest impression, appears from that ease and freedom with which animals breathe in it, and move thro' it without any sensible resistance.

As air is a body, it must have gravity or weight; and that it is weighty is demonstrated by its pressure on the surfaces of bodies; and by experiment, a bottle that holds a quart, is found to be about 15 grains heavier than when the air is exhausted from it, which shews that a quart of air weighs 15 grains. But a quart of water weighs 14,621 grains this divided by 15 quotes 908 in round numbers which shews that water is 908 times as heavy as air near the surface of the earth.

The most interesting and important experiments in pneumatics are performed by the air pump. For its description see Ferguson's lectures. It was invented by Otto Guericke a German. the first was made in the year 1654, and is constructed the same way as the water pump. It was considerably improved by Hooke and next by Mr. Hawkslee, next by Mr. Gravesend, and then by Smeaton, that which is now in use.

The Torricellian experiment is as follows. Take a glass tube about 3 feet long, and open at one end; fill it with quicksilver, and putting the finger on the open end, immerse it into a small vessel of quicksilver, without letting in any air. The quicksilver will remain suspended in the tube 29½ inches above its surface in the vessel, sometimes more, and at other times less, as the weight of the air is varied by winds and other causes. That the quicksilver is kept up by the pressure of the atmosphere upon that in the basin, is evident; for if the basin and tube be put under a glass, and the air be taken out of the glass, all the quicksilver in the tube will fall down into the basin, and if the air be let in again, the quicksilver will rise to the same height as before. Therefore the air's pressure on the surface of the earth, is equal to the weight of 29½ inches depth of quicksilver all over the earth's surface at a mean rate.

It is the preponderance of the external air, that attaches the hand to the top of an exhausted receiver, and the receiver to the pump. A square column of quicksilver 29½ inches high, and one inch thick, weighs just 16 pounds, which is equal to the pressure of air upon every square inch of the earth's surface, and 144 times as much upon every square foot. At this rate a middle sized man, whose surface may be 14 square feet, sustains a pressure of 30240 pounds when the air is of a mean gravity. This pressure, it is well known, is counterbalanced by the spring of the air within us, which is diffused thro' the whole body, and reacts with an equal force against the outward pressure. These two forces are thus in equilibrio, and many useful mechanical purposes are effected by the destruction of it, as pumps, fire engines &c. When the end of a pipe is immersed in water, and the air is taken out of the pipe, the water will rise in it to the height of 33 feet, above the surface of the water in which it is immersed, but will go no higher; for a common pump will draw water no higher than 33 feet above the surface of the well. As it is the pressure of the air on the surface of the water in the well, that causes the water to ascend in the pump, it is evident that a column of water 33 feet high, is equal in weight to a column of quicksilver of the same diameter 29½ inches high; and to as thick a column of air reaching from the earth's surface to the top of the atmosphere.

The Barometer is an instrument to measure the weight & pressure of the air. The suspension of the quicksilver in the barometer or inverted glass tube, not beyond a certain altitude, and the variations of that altitude, were first observed by the celebrated Italian philosopher Torricelli; hence the barometer is often called the torricellian tube, and the vacuum in the upper part of it, the torricellian vacuum, the most perfect of all others. The barometer denotes the rise or fall of mercury to the 100th part of an inch. It never rises higher than 31, and never falls below 27, having a range of four inches.

The rising and falling of the mercury in the barometer must not be considered as sure indications of the weather that is to follow, yet generally, they will enable us to form a good guess of the change of weather that may be expected. Numerous observations relative to this subject have been made in various parts of the world, from a collection of which, the learned Dr. Halley deduced a set of rules, published in an early volume of the Philos. Trans., and to which not much subsequent addition has been made.–

1st. The first is, that in calm weather, when the air is inclined to rain, the mercury is commonly low.

2nd That in serene, good, settled weather, the mercury is generally high.–

3rd. That upon very great winds the mercury sinks lowest of all, with relation to the point of the compass the wind blows upon.–

4th. That, ceteris paribus, the greatest heights of the mercury are found upon easterly and north-easterly winds.–

5th. That in calm frosty weather the mercury generally stands high

6th. That after very great storms of wind when the quicksilver has been low, it rises again very fast.–

7th. That the more northerly places have greater alterations of the barometer, than the more southerly.–

8th. That within the tropics and near them, the range of the barometer diminishes, and is almost uniform at the equator.–

The principal cause of the rise and fall of the mercury according to Dr. Halley, is the variable winds which are almost every where found in the temperate zones. A second cause is the uncertain exhalation and precipitation of the vapours lodged in the air, whereby it comes to be at one time much more crowded than at another, and consequently heavier. But this latter in a great measure depends upon the former.

1st The mercury's being low, inclines it to rain because the air being light, the vapours are no longer supported thereby, being become specifically heavier than the medium whereby they floated, so that they descend towards the earth; and in their fall, meeting with other aqueous particles, they incorporate and form little drops of rain. But the mercury's being at one time lower than at another, is the effect of two contrary winds, blowing from the place where the barometer stands, whereby the air of that place is carried both ways from it, and consequently the incumbent cylinder of air is diminished, and consequently the mercury sinks.

2d. The greater height of the barometer is occasioned by two contrary winds blowing towards the place of observation, whereby the air of other places is brought thither and accumulated, so that the incumbent cylinder of air being increased both in height and weight, the mercury pressed thereby will rise and stand high as long as the winds continue so to blow.

3d. The mercury sinks the lowest of all by the very rapid motion of the air in storms of wind; for the tract or region of the earth's surface wherein these winds rage, not extending all round the globe, that stagnant air which is left behind, as likewise that on the sides, cannot come in so fast as to supply the evacuation made by so swift a current, so that the air must be attenuated when and where these winds continue to blow, and that more or less, according to their violence.

4th. The mercury stands highest upon an easterly or north-easterly wind, because in the great atlantic ocean, on this side the 35° of north latitude, the westerly and south westerly winds blow almost always trade; the air by these two opposite currents is heaped over us (in Gt. Britain) and the mercury must needs rise and stand high, so long as these winds continue to blow.

5th. In calm frosty weather the mercury stands high, because it seldom freezes, but when the winds come from the eastern or N. eastern quarters.

6th. After great storms of wind, when the mercury has been very low, it generally rises again very fast. Dr. Halley observed 1½ inch fall in less than 6 hours, after a long continued storm of S West wind. The reason is, the air being very much rarified by the great evacuations, which such continued storms make thereof, the neighbouring air runs in more swiftly to bring it to an equilibrium, as we see water runs the faster for having a great declivity.

7th. The variations are greater in the more northerly places, because those parts have usually greater storms of wind than the more southerly, whereby the mercury should sink lower in that extreme; and then the northerly winds bringing the condensed and ponderous air from near the pole, and that being checked by a southerly wind at no great distance, and so heaped, must of necessity in such case make the mercury stand higher in the other extreme.

8th. This remark, that there is little or no variation near the equinoctial; does above all others confirm the hypothesis of the variable winds being the cause of these variations in the height of the mercury: for at the equator there is always an easy gale of wind blowing nearly upon the same point, so that there being no contrary currents of air to exhaust or accumulate it, the atmosphere continues much in the same state.

The greatest alterations of the barometer generally take place during clear weather with a northerly wind. The small changes generally take place during cloudy, rainy, or windy weather with a S wind. The barometer is generally lower at noon and at midnight, than at any other period of the 24 hours. The mercury falls low at the approach of an earthquake; which may arise from the changes of weather at that time. During the time of the aurora borealis also, the mercury falls, but rises soon after.

Lecture XIX.

Of the Properties of Air.

Air is a compressible fluid, and is always more dense in a low than an elevated place. If a glass vessel be immersed in water with its aperture downwards, the water immediately under it will gradually rise in the vessel in proportion as the vessel is immerged deeper into the water; the air in it being compressed and condensed by the perpendicular altitude of the superincumbent water. On drawing the vessel upwards, the air in it will expand again.

If mercury be poured into a cylindrical glass tube bent in the form L or U, 6 inches long and having one end closed, the air in the closed end will contract in its dimensions, in proportion as the quantity of mercury by which it is compressed is greater. If 14 inches of mercury be poured in the mercury will rise to a certain height in the closed end, viz. 2 inches; and if 14 inches more be added it will rise to 3 inches, and the air will be double as dense, being confined in half its former place, and by its elastic spring will balance the 28 inches of mercury in the other end of the tube. Add 56 inches and the condensing force will be tripled, and the air always is condensed in the direct ratio of the force compressing it. The spaces will be inversely as the compressing force. It is estimated that air may be compressed into the 128th part of its usual volume.–

Next, the air is strongly elastic. The absence of the pressure of the atmosphere, or the total abstraction of the circumambient air from beneath the receiver of an air pump, causes a bladder to burst therein by the spring of the included air, which then acts without opposition. Mr Boyle dilated air 13,677 times. This expansion is in proportion to the diminution of the pressure, and will be unlimited where the pressure is proportionably small. Ferguson says it may be proved by calculation, that a cubic inch of such air as we breathe would be so much rarified at the altitude of 500 miles, that it would fill a hollow spere whose diameter was equal to that of Saturn's orbit. On the other hand by increasing the pressure proportionally, a quantity of air may be condensed into any given space however small, the density of the compressed air increasing as its bulk diminishes. Nor has this condensation any known limits, tho' it seems natural to suppose that a limit it must undoubtedly have.

The elasticity of the air, is perfect. Air has been left for several years very much compressed in proper vessels wherein there was nothing that could have a chemical action upon it; and afterwards on removing the unusual pressure, and replacing it in the same temperature, the air has been found to recover its original bulk, which shows that the continuance of the pressure had not diminished the elasticity of it in the least perceptible degree. Experiments on the air gun have shewn that the air retained its elasticity after a confinement of 16 years. Water also, has been taken from Herculaneum, which was inclosed in proper vessels, and found to be perfectly pure, after a confinement of seventeen hundred years. This could never have been the case, had not the air contained in the water retained its elastic properties in a perfect degree: for water becomes vapid and tasteless only, when the air has escaped from it, as may be observed by exposing it to the atmosphere, when the air will escape and settle in bubbles on the inside of the vessel, or unite with the general mass. —

Heat increases considerably the bulk of air, and by means of it the air becomes highly elastic, and in endeavouring to expand, will raise water to a great height. Cold destroys this elasticity and condenses it. But this expansion and contraction are not regular; viz. they are not exactly proportioned to the degrees of heat. A volume of air reduced to the coldness of ice, and then heated up to boiling water will have its bulk at these different times as two to three.

Air considered as a fluid, must press according to its perpendicular height. Hence the column of mercury supported by air is longer at the surface of the earth, than at the top of a mountain, the column of air pressing on it being longer in the former case. The air surrounds our earth as a circular covering; and its superficies, like that of water and other fluids, will remain level and plain.

Experience shows that this atmosphere is of different densities at different distances from the earth, or according as it is pressed by a greater or less weight of superincumbent air. But the compression arising from the weight of the superincumbent air, tho' by far the principal, is not the only cause upon which the various density of the atmosphere depends. Other causes seem to concur towards the production of that effect. 1st. The various quantity of superincumbent air at different altitudes; 2nd. The decreasing attraction of the earth or the decreasing weight of the bodies, in proportion to the squares of the distances from the centre of the earth. 3rd. The influence of heat and cold. 4th. The mixture of vapours and other fluids, and 5th. the attraction of the moon and other celestial bodies.

Imagine that ABCD is a pillar or vessel full of air, reaching from the surface of the earth, to the top of the atmosphere. Also that this pillar is divided by partitions parallel to the horizon into a vast number of equal spaces ABef, efgh, ghik, ikmn, &c. As the density of the air decreases from the earth upwards, therefore strictly speaking, that density must be various even in different parts of those spaces; yet as those spaces may be conceived to be infinitely small,

we may without any sensible error suppose the density of the air uniform, throughout all the parts of any one of them. The density of the air of ABef, is to the density of the air in efgh, as efCD is to ghCD. So that the difference between the pressure on gh and on ik, (or between the quantities of air in efgh and ghik), is equal to the quantity of air ghik; and the same of any other two spaces. Therefore the quantities of air in those spaces are proportional to the quantities of which they themselves are the differences. But when there is a series of quantities whose terms are proportional to their own differences, then both those quantities and their differences are in geometrical progression. Let A B C D &c be a series of quantities, and if those quantities are proportional to their differences, we have $A : A - B :: B : B - C : C - D$ &c hence conversely (Eucl. cor. to prop. 19. B. 5) $A : B :: B : C :: C : D$* &c. Therefore the densities or quantities of air in the equal spaces are in geometrical progression. The height of those equal spaces above the surface AB of the earth, are in arethmetical progression, the first space being one inch, or any other quantity from the surface, the second will be two, the third three, and so on — From all which we derive a very remarkable conclusion; namely, that if the altitudes above the surface of the earth be taken in arithmetical progression, the densities of the air at those altitudes will be in geometrical progression decreasing.

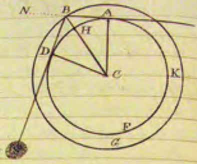
Thus for instance, if at a certain altitude the air be half as dense as it is immediately on the surface of the earth; then at twice that altitude the air will be four times less dense, at three times that altitude, it will be eight times less dense &c. Experience assisted by calculation shews, that at the distance of seven miles from the surface of the earth, the air is about four times less dense than it is close to that surface. The knowledge of this will enable us to construct a table of densities of the atmosphere at all altitudes from the surface of the earth.

In order to find the densities correspondent to the intermediate altitudes of the heights found by the tables, take an arithmetical mean proportional between those two heights. Also take a geometrical mean proportional between the densities of the air at those two heights.— An arithmetical mean proportional between two numbers is found by taking the half of the sum of two numbers. A geometrical mean proportional between two numbers is found by extracting the square root of the product of those numbers. (See Cavallo).—

If the air were of an equal density throughout, the height of the atmosphere might be determined; for by experiments we find that a column of air 72 feet high is equal in weight to one inch of water of the same base: hence the density of air is to that of water as 1 to 864. It is also found by experiment, that the weight of a column of air the height of the atmosphere will be equal to the weight of a column of water of the same base, and 32 feet or 384 inches high. Wherefore 864×384=331,776 or a little above five miles for the height of the atmosphere, were the density every where the same as at the earth.

But since the density of the air decreases with the pressure, it will be more rarified and expanded the higher we go; and by this means the altitude of the atmosphere becomes indefinite and terminates in pure ether. But tho' we cannot assign its real altitude, yet it is plain from observations and experiments that 45 or 50 miles is the utmost height where the density is sufficient to refract a ray of light. To discover this altitude we have the following method.

Let A D F be the surface of the earth, B K G the atmosphere S the sun below the horizon, S B a ray of light touching the earth, which is reflected by a particle of air in the highest part at B, in a horizontal line B A to a spectator at A. The angle S B N is the depression of



the sun below the horizon in this case, which because it is at the moment twilight ends, is known from observation to be about 18 degrees. But because B A is a tangent also, the angle A C D = S B N = 18°. And the angle A C B = one half A C D = 9° which would be true, did the ray S B pass thro' the atmosphere without refraction; but because it is refracted or bent toward H the angle A C B must be diminished by the horizontal refraction which is about half a degree, whence the angle A C B = 8° 30'. Therefore in the right angled triangle A B C we have all the angles given, and one side (to wit A C = 4000 miles or the semidiameter of the earth) to find the side B C. Thus,

As the sine of	A B C = 81° 30	9.995203
Is to the side	A C = 4000	3.602060
So is radius	90°	10.000000
To the side	B C 4044½	3.606857

Wherefore B C − H C = H B = 44½ miles, the height of the atmosphere.

269. * If a : a − b :: b : b − c then these terms are in geometrical proportion; for by Eucl. 6. 16. ab − ac = ab − bb and by cancelling ab, ac = bb. wherefore a : b :: b : c which is a geometrical series —

Lecture XX.

Of Air as necessary to combustion, vegetation and animal life.—

On inquiring into the character of air, we find two which are peculiar to it, and well adapted to distinguish it from other elastic fluids. The one is the property of promoting the combustion or inflammation of bodies susceptible of that process; and the other is that of maintaining the life of animals and vegetables that respire it.— It is difficult to give a good definition of combustion. It is a collection of phenomena which certain bodies exhibit when heated with access of air; the principal of which are, the continuance or augmentation of heat, agitation or intestine motion, the emission of light flame, redness, and a total change of the matter burned. It is here used to signify the active state of fire. Its power of burning or consuming bodies.—

A candle will burn but a short time in rarified air, and not all under an exhausted receiver, or in vacuo. The atmosphere consists of two kinds of air, one of which is necessary to combustion, and when this is consumed ignition ceases. Simple collision is sufficient to produce heat, (as when flint is struck by steel) and by this action the steel may be melted and consumed. Heat may be produced in the vacuum of an air pump by attrition, but no combustion can be effected. Mr Boyle contrived a machine which served to illustrate the fact.

Air is not only requisite for combustion, but it must have a free circulation, otherwise this action ceases. It is always vitiated by combustion, and as will be shewn in the next lecture, that in which an inflammable body has ceased to burn, will no longer serve the ordinary uses of air.

It is certain that it is essentially, indeed, indispensibly necessary, for vegetation, and the germination of all seeds, as those seeds which are placed deep in the earth never come up. One of the greatest objects of agriculture is to loosen the earth and let in air to the vegetable.—

All plants both inhale and exhale air; and their leaves may be justly regarded as their lungs. The air in passing thro' them undergoes a chemical process: one part of it goes to the formation and nutriment of their oil and other constituent parts; and the other is transpired by their leaves. Plants confined to a given quantity of air soon die, and always diminish this quantity in proportion to the time they live in it.

Another property of air, and its most essential one, is its being fit for breathing. It is in consequence of its weight and elasticity, that animals respire with freedom, and that the operations of pumping &c are performed. It is not only requisite that we have air to breathe, but it is also necessary that this air should be pure, all animals even microscopic insects perish under an exhausted receiver. Some live longer than others, the aquatic longer than the amphibious, and these longer than the terrestrial, and generally the young longer than the old.

A gallon of air is corrupted in 3/4 of an hour by respiration. A man usually performs about twelve inspirations, and as many expirations in a minute: but respiration may be quickened by various causes, as by agitation of body or mind, by heat, by a rarified or vitiated atmosphere, and by diseases.. Infants breathe quicker. In general a full grown person takes in 32 cubic inches of air at every inspiration, but a great deal of air does always remain in the lungs. In a forced or violent inspiration or expiration, a double quantity of air may be taken in or expelled, and even then a considerable quantity of air remains in the lungs, besides what is contained in the mouth, wind pipe &c for the capacity of the lungs of a man may at a mean be reckoned equal to two cubic feet.

All the operations of suction consist in removing the pressure of the atmosphere from a certain part of the surface of a fluid, whilst that pressure is at liberty to act on some other part of the surface of the same fluid, in consequence of which it ascends where the pressure has been removed.

145 English prisoners confined in a close prison at Calcutta, all died except three in the course of one night. A man can live in 60 gallons of air one hour only. In a room then containing

3000 gallons of air, with which the rest of the atmosphere has no communication, ten men could exist no longer than five hours. these facts should induce us to be cautious as to the confinement of rooms whose fresh air cannot easily circulate. Air is more vitiated by respiration than by combustion; for air that has ceased to burn will keep an animal alive some time.

Of all the authors who have written concerning respiration, the ancients are those who have had the most accurate ideas of it. They admitted in the air a principle proper to support life, denoted by the name of "pabulum vitæ", a kind of vivifying spirit or quality which is necessary to continue the lives of animals.

Considering atmospheric air as it exhists at different places, it is more rarified at the top of a mountain than at the surface, and more rarified there, than in pits and hollows. the lower it is, the more fit for respiration and combustion. These two leading phenomena, to wit, combustion and respiration, tend continually to vitiate and decompose the air which surrounds our globe. this fluid would be soon rendered unfit for the maintenance of the natural processes, if there were not other phenomena capable of restoring vital air to the atmosphere, in the place of that which is continually absorbed and lost. The atmospheric air is also subject to more causes of corruption, as rarefaction, condensation, and the rise of noxious effluvia. this contaminated air tho' removed by the wind, is not purified by this motion, for by changing its situation it is still no less vitiated than before. How then is our atmosphere, which is liable to so many causes of corruption and is more and more contaminated every day cleansed of these noxious particles and again rendered wholesome and fit for maintaining human life? The causes which have been supplied by nature for the purification of the air, are two 1st The growth of vegetables; 2nd The mixture of water with air. All plants inhale the impure and emit the vital air. that thrown out by the leaves is pure, and that emitted by the flowers of plants is noxious. Hence the impropriety of keeping flowing plants in an house, growing where the air is much more confined than a part of the general atmosphere.

Tho' the action of the wind by altering the situation of the corrupted parts of the air, by that motion, does not cleanse it.

yet by drawing the atmosphere with violence against the ocean it is purged of its impurity. The rains when descending also, carry down the impure particles of the atmosphere by combining with them, and may literally be said to wash the air. The ancients being ignorant of these two sources of purification, imagined that the reason why the antediluvians lived to an age so superior to ours, was the increased contamination of the air, which had been corrupted by the successive breathing of all the animals that lived since their time.

The air in subterraneous places is impure from confinement. In marshes where there is not a free circulation, the circumambient air is vitiated by the putrefaction of vegetables. Air that has lost its vivifying spirit, is called damp, not only because it is filled with humid or moist vapours, but because it deadens fire, extinguishes flame, and destroys life. The dreadful effects of damps are sufficiently known to such as work in mines. They are of two kinds, choke and fire damps. The former are those just described. Fire damps are those explosions which sometimes happen in mines, and are occasioned by nitrous, and sulphureous or oleaginous particles rising from the mine and mixing with the air, when they will take fire by lights which the workmen are obliged to make use of. When thus set on fire they will explode with a greater or less degree of force according to the density of the combustible vapours. It is sometimes so strong as to blow up the mine; and at others so weak, that when it has taken fire from a flame, it may be easily blown out. The noxious air contained in pits and hollows of the earth is often fatal to man. In descending into all such places a lighted candle should be carried before us.

Children and young people are the most susceptible of the ill effects of a close air, and shew it by turning sick and complaining of the headach; and they who by practice feel less present inconvenience, are slowly losing their complexions and destroying their constitutions.

Many people imagine that fire will purify contaminated air, by destroying the noxious particles that are mixed with it and thus render it fitter for respiration: this however is not tine; for fire or combustion in general is so far from purifying air, that it actually contaminates a prodigious quantity, so that even a lighted candle kept in a close room to which the external air has not free access, renders the air of that room extremely noxious. —

Gun powder may be fused but cannot be inflamed under an exhausted receiver; which shews the necessity of air in every operation of combustion. Air vitiated by combustion will not administer to that process again. A candle in a long bottle is soon extinguished and afterwards will not burn at all. Immerse the bottle in water and it will rise and shew how much of the air was consumed. Why a low place in the lower country, is generally more healthy than the top of the hill which surrounds it? — We only get one draught of the putrid effluvia in the one case, as it rises by us; whereas by the laws of specific gravity, it floats at the top of the hill where it must be breathed more abundantly —

Lecture XXI.
Of Heat.

It is supposed, that there exists a very subtile and elastic fluid, dispersed throughout all the bodies of the universe, and capable of passing with more or less facility thro' them all. This fluid has been called elementary heat; it is one of the principal agents the chemists employ in every process of decomposition, and in every enquiry by analysis.

In fire, two things are to be considered, heat and light. The term heat is used as being generally understood; but its signification is not so definite as the accuracy of philosophy requires; it is sometimes employed to express the sensation which fire produces upon the human body, and sometimes it is used to express the cause by which that sensation is produced. Philosophers call it caloric, to denote it as a cause only.

By fire, is understood such an accumulation of caloric as to produce ignition. It is a real body. The rays of light are refracted in going thro' diaphanous bodies. But it has been clearly proved by Dr. Herschel, that the rays of heat are refracted differently from the rays of light; so that tho' they are often emitted together, as from the sun or a common fire, yet they seem to be distinct powers. Whether or not heat and light are the same, is not to be known: one may be a cause and the other an effect, but which we cannot determine. Some bodies that possess the principle of heat, part with it sooner than others. If a body be heated and put into a cooler medium, it acquires the temperature of that medium: and if a cool body be put in a warm medium, it acquires in like manner the same temperature.

All bodies are continually radiating caloric in order to preserve an equilibrium between the particles of bodies by filling up the spaces between them. The cold body will communicate caloric to hot ones; but it is returned in greater quantities. nor need we be surprised at this, for a candle may send forth light to the sun, and a pebble will attract the earth.

The following experiments will shew in a most convincing manner the reflection of heat. Let AB and CD represent two concave metallic mirrors or reflectors, about 10 inches in diameter and 15 feet apart facing each other.

Place a piece of iron almost red hot at E. viz. in the focus of the speculum AB: then that part of the heat which proceeding from the mirror, falls upon the surface AB, is reflected by it in a parallel direction, to CD, from which it is reflected again, convergingly, to the focus F. and would raise the temperature of a thermometer placed there: if either of the speculums be screened, the thermometer will descend to its usual temperature.—

Gun powder put upon any convenient stand at the focus F will be fired by the heat reflected from a charcoal placed in the other focus, and rendered vividly red hot by blowing it with a pair of bellows.

If instead of the charcoal and gun powder you situate a thermometer at F, and a piece of ice at E, the temperature of the thermometer will be lowered. Cover the surface of either reflector and it will rise: uncover the reflector and the thermometer will fall again.—

Some have imagined that the cold proceeding from the ice is reflected by the speculums to the thermometer, and that, of course, cold is something positive. The true cause of the phenomenon, in Cavallo's opinion, is, that the heat of the thermometer is reflected upon the ice, in the same way as the heat of the charcoal is reflected on the gun powder. The thermometer thus radiating heat to the ice, falls in proportion to the quantity of caloric disengaged from it.

The most obvious instance of a body parting with caloric is this. When an heated body is cooling in the air, the air surrounding it will exhibit an undulatory motion, resembling the appearance produced by the mixture of two liquids (water and brandy for example) of unequal densities. This undulatory motion clearly results from the passage of some substance from the heated body to the air.

The method in which caloric is disengaged from bodies in which it is fixed, is first by means of affinity; and it is detained in all bodies a long or short time, according to the degree of affinity existing between them, and those substances to which it may be communicated. If a body has a greater affinity for another, than for caloric, then the heat is disengaged or precipitated. While the caloric is disengaging, the volume of the mixing bodies will not increase in proportion to their respective bulks, which proves that they actually usurp the place of the precipitated caloric. Water mixed with the vitriolic acid, has a stronger attraction for it than for caloric: it is therefore disengaged. Spirit of terpentine and the sulphuric acid mixed, will produce a great degree of heat and frequently burst out in flames. Wherever heat is produced in the mixture of bodies, condensation is also produced.

The methods of disengaging caloric, are by friction, squeezing, hammering &c in all which cases heat is produced. Chaptal thinks that much of the heat produced by these operations, arises from the caloric extracted from the surrounding air. Count Rumford, in his experiment of boring a cannon under water, found that the same degree of heat was produced as in open air: hence he inferred, that no caloric was collected from the air by friction, nor was it extracted from the surrounding water; for that being composed of two parts, caloric, and air, had the caloric been taken from it, the water would necessarily have been decomposed. No such effect, however, took place; therefore no such cause, no absorption of its caloric operated.

Fermentation, and in general every operation which tends to change the nature of bodies, disengages caloric; because the new compound may demand and receive a greater or less quantity. When compounds absorb caloric, cold is produced in the surrounding bodies, whence it is extracted for absorption; when they give it out, heat is produced in the surrounding bodies, to which it flies as for an asylum. The power of affinity which ever tends to keep bodies united, and the caloric which ever tends to disunite them, are in perpetual warfare with each other. Hence caloric not only surrounds the particles of bodies on every side, but fills up every interval which the particles leave between each other. We may form an idea of this by supposing a vessel filled with small spherical leaden bullets, among which a quantity of fine sand is poured; this insinuating itself into the intervals between them, will fill up every void. The balls here are supposed to touch each other, whereas the particles of bodies are not in contact, being retained at a very small distance from each other by the caloric.

If instead of spherical balls, we substitute bodies of a hexahedral, octohedral, or any other regular figure, the capacity of the intervals between them will be lessened and consequently will no longer contain the same quantity of sand. Fluids have a greater capacity of retaining caloric than solids: hence the particles of the former are supposed to be round, those of the other flat. Immerse pieces of different kinds of wood into water, some will absorb more of it than others; the softer and more porous, more than the harder and more solid. The same takes place with bodies that are immersed in caloric; taking into consideration, however, that water is an incompressible fluid, whereas caloric on the contrary is endowed with great elasticity.

In this manner we may understand the expression, "Capacity of bodies for containing the matter of heat," introduced by the English philosophers who have given us the first precise ideas upon the subject.

Caloric is considered in three states; free, combined and specific. Free caloric is that which is not combined in any manner with any other body. But as we live in a system, to the matter of which caloric has a very strong adhesion, we are never able to obtain it in a state of absolute freedom. Combined caloric is that which is fixed in bodies by affinity or elective attraction, so as to form part of the substance of the body, even part of its solidity. The expression specific caloric, denotes the relative quantity of caloric, which bodies of the same weight and temperature are capable of receiving. This proportional quantity of caloric depends on the distance between the constituent particles of bodies, and their greater or less degree of cohesion; and this distance, or rather the space or void resulting from it, is, as above mentioned, called the capacity of bodies for receiving caloric.

The more dense a body, the less is its capacity for heat, universally. Passing from the solid to the fluid, and from the fluid to the aeriform state, the capacity for receiving caloric increases; and vice versa, it decreases. Free caloric always endeavours to preserve an equilibrium, owing to its affinity for all other substances, and to their capacity to receive it. With the aid of this principle, many phenomena are explicable, and among them, the sensation of heat. Sensible heat is only the effect produced upon our sentient organs, by the motion or passage of caloric, disengaged from the surrounding bodies. In general we receive impressions only in consequence of motion, and it might be established as an axiom, that, without motion, there is no sensation. When we touch a cold body, the caloric which always tends to become in equilibrio with all bodies, passes from our hand into the body we touch, which gives us the feeling or sensation of cold. The direct contrary happens when we touch a warm body: the caloric then in passing from the body into our hand produces the sensation of heat. If the hand and the body touched be of the same temperature or very nearly so, we receive no impression either of heat or cold, because there is no motion, or passage of caloric; and thus no sensation can take place without some correspondent motion to occasion it.—

Some bodies are better conductors of caloric than others, as metals and marble better than wood; and in general, the conductors of heat are the same as those of electricity— The capacity of bodies to conduct caloric, is inversely as their tendency to unite with heat: generally the most dense bodies are the best conductors.—

Do fluids conduct heat? Rumford says they do, but not in the same way as metals, by transmitting it from one particle to another; but by the intestine motion of their parts.

Hence it may be known, why the deeper the water is, the more difficult it is to freeze: if it began to freeze at bottom, the largest bodies of water would become solid ice: but it there keeps the natural warmth of the earth, and by its intestine motion, which in large quantities of water is almost perpetual, transmits a part of this warmth to all the particles above, except the surface which freezes a little way.

Ice is a bad conductor of heat, for water possesses the property only in consequence of its intestine motion, and when that motion is fixed, its conducting power ceases in a measure. The reason why some clothes are cooler than others, is, that they have a greater capacity of conducting caloric; furs and linnens are themselves nonconductors of heat, hence their warmth. Some bodies give less resistance to caloric than others. It readily penetrates metals they transmit it with great facility. Wood and animal substances receive it to a degree of combustion; liquids, till they become vapour. The temperature of vegetables, fossils, and dead substances, is the same as that of the atmosphere which surrounds them; that of insects, a little above this; that of fish is the same as the water they swim in, except of the cetaceous kind which have the same temperature as a man.

The most general effect of caloric is that of the dilatation of all bodies into which it enters. It enters into the interstices of matter and separates its particles. When it departs, those particles come together, and the bulk of the body they constitute is contracted. There is hardly an exception to this law in nature: among the fluids there is none; air, mercury, oil of turpentine, water, expand more or less in longer or shorter times, according to the order mentioned. The greatest expansions of which liquids are susceptible, is when they are boiling. Water after this ceases to be heated, and it begins to expand as soon as it passes the 40°. The denser a body is, the more it may be expanded. As to the time in which different substances are made to the greatest expansion, there is no certain rule by which we can be governed. If we say, the denser they are, the sooner they reach this state, water is more dense than spirit of wine, yet acquires this state later than it. If we say, the less dense they are, the sooner arrive at the degree of greatest expansion; mercury is more dense than water, yet it acquires this state sooner than water; and water is more dense than linseed oil, yet acquires this state sooner than it. The greatest expansion generated by heat is when glass or a diamond, is made by it to assume an aeriform state. Some chemists lay it down as a general law, that all bodies are dilated by caloric, and say there is no exception in nature. Lavoisier contends, that the exceptions generally remarked are apparent and delusive. It is certain that when water becomes ice, its bulk is considerably increased. (Ice is about 1/9 lighter than water) It is no less certain, that in passing from water to ice, it emits caloric; why then does its bulk increase? He answers that the bubbles of air formed in the ice increase its bulk more than the loss of caloric diminishes it. The bulk of ice is decreased when it becomes water, yet in becoming so it absorbs caloric. How can it decrease? The caloric which it absorbs does not increase its bulk, as much as the air it emits diminishes it. The increase of the bulk of water from freezing, and the diminution of ice from thawing, cases in one of which caloric is emitted, in the other absorbed, do not militate against the general law, that caloric dilates bodies. Iron after being heated, expands while cooling. Pure clay contracts upon the presence of caloric; but there is no uniformity in this contraction. These facts may perhaps be reconciled to the general law above mentioned, by supposing that something is always expelled by caloric from those bodies; and that this expulsion diminishes their bulk, more than the absorption of caloric augments it. Water increases from the temperature of freezing to that of boiling 1/25 part of its volume, mercury to. —

It is this free caloric of which we have spoken, that affects our senses and the thermometer; hence it has been called manifested and thermometrical heat. Thermometers are instruments to measure the degrees of heat. Pyrometers are used to determine how much metal expands by being heated. The thermometer is founded upon the expansion and contraction of bodies by the accumulation and absence of caloric. It was invented by Drebbel and first used by Sanitorius. Spirit of wine was first employed instead of mercury in the thermometer now in use; and proposed by Dr Halley.— The mercury is confined in a glass tube having a bulb at the end, and sealed hermetically at the top, so as to produce as near as possible, a complete vacuum, in order that in expanding it may rise freely. Plunge the tube in water begining to freeze (which is the same degree all over the world) and call the point at which the mercury stands 32. Put it then in boiling water (also every where the same degree of heat) and call the point to which it rises 212; and between these points make any number of equal divisions; this will complete the graduated scale and the thermometer is formed.

The thermometers now in use, are Fahrenheit's Reaumur's and Celcius's. In Fahrenheit's scale, between the freezing and boiling points are 180 divisions, the freezing point being at 32°, and the boiling at 212°.— Both the numbers are above 0, or the point from which the degrees are numbered both ways. In Reaumer's scale, the number of degrees between these two points, is 80, and the freezing point is called 0°. In Celcius's thermometer, the interval is divided into 100, and the freezing point is 0° as in Reaumer's. To reduce these scales to one another you must observe that one degree of Fahrenheit's is equal to $\frac{4}{9}$ of a degree of Reaumer's, and to $\frac{5}{9}$ of a degree of Celcius's & therefore if you multiply the number of degrees below and above the freezing point of Fahrenheit's by 4 and divide the product by 9, the quotient will be the corresponding number on Reaumer's scale. If the multiplier 5 and divisor 9 be used, the quotient will give the degree on Celcius's scale. And on the contrary if any number of degrees be multiplied by 9 and divided by 4 if of Reaumer's, by 5 if of Celcius's, the quotient will give the degree on Fahrenheit's scale, either above or below the freezing point according to the case.

Mercury is preferred to any other fluid for the thermometer, from its unchangeableness the regularity of its—

expansion, and because it does not soil the tube.—

To all these thermometers there are these objections—1st They do not determine the actual quantities of caloric accumulated in bodies. Nor can they be made to do so. When the thermometer is rising, it shews that free caloric is entering into the surrounding bodies; the thermometer, which is one of these, receives its share in proportion to its mass, and the capacity which it possesses for containing caloric. The change therefore, which takes place upon the thermometer, only announces a change of place of the caloric of those bodies, of which the thermometer forms one part; it only indicates the portion of caloric received, without being a measure of the whole quantity, disengaged, displaced, or absorbed. The most simple and exact method of determining this latter point, is that of Lavoisier and De la Place, mentioned in the memoirs of the academy for 1780. A globe of ice is so contrived, that a heated body may be introduced into a cavity inside, and there confined so as not to touch the sides. Let it remain till the temperature of the heated body is reduced to that of the ice: a part of the ice will thaw; collect the water carefully, and it will be an exact measure of the quantity of caloric absorbed by the ice and emitted from the heated body.—

2nd These thermometers cannot indicate higher degrees of heat than is necessary to melt glass. Their real utility is the indication they afford of the relative degrees of heat which bodies contain at different times and in different situations. To ascertain higher degrees of heat, many methods have been devised. From a knowledge that water evaporates quicker from the surface of a body moderately warm, than if it were very hot, this principle for the construction of thermometers has been proposed. A drop of water in an iron spoon heated to the degree of boiling water, evaporates in one second: a similar drop poured on melted lead, is dissipated in six or seven seconds, and upon red hot iron in thirty.—

Wedgwood's clay pyrometer is constructed upon the principle, that pure clay contracts upon the application of caloric; and for this purpose it is immaterial whether that contraction is the mediate or immediate result of that application! By this contrivance we may measure degrees of heat as high as 2107°, computed by Fahrenheit's scale.

Hitherto caloric has been considered in a state of freedom! It must be spoken of also in a state of combination.—

Chaptal says that if caloric be applied to water, they will unite and dissipate in vapour. But in this state it exists only in a state of simple mixture, not combination; and the caloric will desert the water as soon as any substance for which it has an affinity is presented to it. Caloric however, becomes united to bodies from true chemical combinations, insomuch that it becomes imperceptible and neutralized in the substance with which it is combined. In this state it has been improperly called latent heat (calor latens). The two following cases exist in which heat when entering into a combination ceases to be felt or becomes insensible.—

1st. Every body that passes from the solid to the liquid state, absorbs a portion of heat, which is no longer sensible to the thermometer, but exists in a true state of combination. To prove this, plunge a thermometer into a vessel filled with pounded ice, it will descend to 0° of Reaumur's scale: immerse the vessel into boiling water, the thermometer will not rise during the liquifaction of the ice: the ice therefore in liquifying absorbs heat. Pour a pound of water heat to 60° of Reaumur, upon a pound of ice; the melted mixture will possess the temperature of 0°. 60°. of caloric will therefore have been absorbed. So great cold is generated, i.e. so much caloric is absorbed from the surrounding bodies by melting ice with strong nitrous acid as to sink the thermometer to 40°. below 0 (Fahrenheit) Take 11 parts of sal amoniac, 10 of common nitre, and 16 of glauber salts; dissolve them in 32 parts of water by weight: this mixture in dissolving will produce cold sufficient to freeze mercury.

2nd. All bodies in passing from the solid or fluid to the aeriform state, absorb caloric, which becomes latent: and it is by virtue of this caloric that they are maintained and placed in that state. Before a solid assumes the aeriform state, it must become a liquid, and in so doing heat is absorbed from the surrounding mass. But when a liquid passes from that state to the aeriform, cold is produced in the surrounding mass i.e. heat is absorbed from it; and this heat can only be absorbed in the process going on. It is upon this account, that evaporation, perspiration &c. produce cold. A warm current of air is best adapted to cool the human body, because it can absorb the moisture; moist air is more nearly saturated with it. The cold produced by perspiration is so great, that an animal which perspires freely, will live in a temperature equal to boiling water. 212°. In the dissipation of all chrystalized salts, cold is produced or caloric disengaged.

Lavoisier lays down the following general proposition respecting the appearances and disappearances of caloric.

In every combination in which caloric has been absorbed, when the substances absorbing it are restored to their former state, that caloric is emitted.

And whenever in changing their nature, bodies emit caloric, the absorb it when restored to their former situation.

An experiment was made by Picktet of Geneva to prove that caloric or heat possessed no absolute gravity. He placed an equally delicate thermometer at each end of an uniform metallic rod; on the centre of which, precisely between the thermometers, he threw the focus of a burning mirror; all under an exhausted receiver. The upper thermometer, in this experiment, showed the first and greatest sign of heat; which seemed to indicate the positive levity of caloric. But modern philosophers have with great propriety, objected to the conclusion drawn from this experiment, on account of the unavoidable difficulty to which it is subject. 1st The slightest difference in the delicacy of the thermometers would lead to a wrong conclusion. 2nd There is great difficulty in procuring a metallic rod, not only uniform but of equal density throughout. The smallest variation in either respect, would produce an inaccuracy. 3rd But what cannot fail to overthrow the truth of the experiment, is, that no receiver can be completely exhausted;

the last spring of the pump being caused by the expansion of the air within it, and so long as the smallest quantity remains, it will aid the caloric in ascending.—

Lecture XXII.

Introductory to Airs.

In this lecture we shall speak of the formation of aeriform fluids, and of the effects of the pressure of the atmosphere.—

Bodies, when heated, are subject to the general law of expansion: this law, according to Lavoisier, and some other philosophers, as we observed in the preceding lecture, is universal: certain it is that there are but very few exceptions to it.

If we compare this law, and the principles contained,—developed, and established in the preceding lecture, with those which are exhibited in lecture 3rd—, we shall thereby be enabled to explain many phenomena, otherwise not easily accounted for. If a person, who has not bestowed a thought upon the subject, be asked why a body is solid, he will no doubt think the question extremely simple, yet he will not be able to answer it. Two principles pervade the material world: attraction, ever upon an exertion to draw the particles of bodies into closer contact: and caloric, a subtile fluid which insinuates itself between the particles of bodies, overpowers the bond of their union, and forces them afar from each other. Now upon the proportion these two forces bear to each other, depends the varieties of consistence which the material world presents. If the attractive force preponderates, the body remains solid; and it is harder or softer, according as the quantity of caloric it contains is greater or less.—If the caloric preponderates, the body becomes fluid; and the fluid is denser or thinner, as the caloric preponderates more or less. If the quantity of caloric be greatly increased, the body assumes the aeriform state. Although this theory may not boast the unimpeachable truth and certainty of mathematics; yet it has this merit, that it concords with every fact, and satisfactorily explains every phenomenon, to which it may be applied.—

Water presents a singular phenomenon, which strongly corroborates the explanation just given of the various consistence of bodies. If water be reduced below the temperature of 32° (Fahrenheit), it will become solid: if it be raised above that temperature, it will become liquid: if above 212°, aeriform.— Bodies are therefore considered in these three states; because they are really reducible to them, by an application of caloric. But since the caloric produces this powerful repulsion in the particles of bodies, as soon as it has overcome the attractive force; it is clear that, were there not some third cause in operation, a solid would pass instantaneously from a fluid to an aeriform, as soon as it was become no longer a solid; and that we should have no such thing as a permanent liquid in nature. This third cause is the pressure of the atmosphere. When the solid has been exposed to such a degree of heat, as to become fluid, its caloric must be so much increased, that its elasticity proceeding from that increase, should be sufficient to overcome the pressure of the atmosphere, before it can assume the aeriform state. To prove that the pressure of the atmosphere performs this office, the following experiment has been made. Put Ether, or any other evaporable body, moderately heated, under the receiver of an air pump: take off the pressure of the air: the ether will evaporate. In this experiment, no alteration was produced other than the taking off, or the diminution of, the pressure of the atmosphere; it is therefore conclusively in favor of the idea above stated, that the existence of permanent liquids is owing to the pressure of the atmosphere. From what has been said, it is manifest, that the aeriform state of bodies is thus effected: caloric combines with every body, to which it has access; makes it so elastic as to overcome the pressure of the atmosphere; and the body then assumes the aeriform state.— When it has assumed that state, it takes the generic name gas. The body, with which the caloric combined to produce a gas, is called the base of the gas produced: the caloric acts as a solvent.

The science of chemistry was, for a long time, retarded by a certain confusion, and inaccuracy of chemical terms. The French philosophers have introduced a new nomenclature. It leaves nothing more to be desired. The principles, upon which it is formed, are conformable to the severest precepts of logic. We proceed to give a summary of them. 1st. Of the denomination of simple substances. 2. Of that of compounds. For the denominations of simples, those which, tho' they are arbitrary, yet, from long use, convey determinate ideas, are preserved unchanged; such as sulphur, phosphorus. &c. But if the old demonstration be vicious, the new nomenclature assigns another, deduced from the principal characteristic property of the substance. Thus many paraphrastic expressions are avoided.– Vital air is now called oxygen; because it is the basis of all acids; and the term is deduced from two Greek words, one of which signifies "acid", and the other to "make".– So also inflammable air is now called hydrogen; because its characteristic property is that it is the constituent principle of water; from two Greek words, one of which signifies "water," the other to "make".–

In the denominations of compounds, the new nomenclature endeavours to express the constituent principles. We make use of the terms sulphates, nitrates, muriates, or muriatic acids. To denote the substance with which the acid is combined, we add the name of the substance to the generic word; as sulphate of potash, and the like. The modifications of acids depend upon the proportion of their constituent principles: to express these, the terminations of the generic words are varied: if there be a great abundance of oxygen, it is called an oxygenated acid; if a less, an oxigenous acid.

The elasticity of the gases arises from this circumstance: they are combined with caloric in order to become such: now the caloric is extremely elastic: the gas, therefore, it has produced, must be so too.– Here, indeed, the question returns upon us, why is the caloric elastic? We know not. The fact is that it is so; and that being supposed, we can readily account for the elasticity of bodies, into whose combination caloric has entered. It may frequently be difficult to distinguish vapour from gas. We have, however, a good criterion of distinction. When a liquor or any substance is in a state of vapour, a change of temperature, the smallest idensfe will reduce it to its original state: thus a single drop of water will reduce the vapour of hot water into water. But a gas is permanently aeriform: a change in its temperature does not render it less so.

The following principles are essential to the philosophy of the gases. (They are extracted from Chaptal.) — 1st Calorie in its combinations with bodies, volatalises them, and reduces some of them to an aeriform state; so that, to reduce a body to a state of gas, consists in dissolving it in calorie. 2. Calorie combines with various bodies with greater or less facility: some are constantly in a state of gas: others require higher degrees of heat to reduce them to that state. 3. Supposing that two bodies have an equal facility of acquiring calorie, the one may acquire a greater quantity than the other, to become gaseous; and caloric may be applied to them in different ways, besides there are other methods of reducing bodies to a gas; such as that of double affinity, &c. 4. Solids are capable of being reduced to a state of gas; but the quantity of calorie requisite for their solution varies, according 1st to the force of aggregation with which their particles adhere. 2dly to the weight of those particles, by which they are rendered more capable of resisting the elasticity of the calorie: 3rdly to the strength of the attraction

Lecture XXIII.

Of some of the gasses.

Part 1st Of Hydrogene gas.

The existence of this gas has been long known to philosophers. It was first called inflammable air, from the extreme avidity with which it takes fire, when in contact with vital air, or oxiginous gas, of which we shall presently treat: but as it is of itself, when separated from oxigine, incapable of being inflamed, the name is not suited to convey an idea of it. The term hydrogenous gas, therefore, has been adopted in the new nomenclature, because it is the constituent principle of water: the term, it will be observed, is a compound of two greek words, the one signifying "water," the other to "make." —

It may be obtained from various substances. Vegetables, particularly afford it in great quantities. the methods by which it may be obtained are extremely simple. Put the vegetable down a gun barrel; expose the closed end of it to a hot fire: fix a crooked tube in the muzzle, and make it air tight by a lute of clay, or other substance: let the tube be immersed in a vessel of water: after a while the air will be seen to rise out of the tube in bubbles: this may be caught by holding a bottle filled with water over the tube; in which case it will expel the water, and occupy its place. But the method of obtaining it, most deserving remark, is the decomposition of water: it is decomposed in the following manner: take sulphuric acid and water, and mix together one part of the first, and two of the latter: pour them upon zinc, or iron: the oxigen of the water combines with the metal, and its hydrogene escapes: the mixture should be made in some such receptacle as a bottle: a crooked tube may be fastened in the mouth of it, and immersed in a vessel of water, as is the method of extracting it from vegetables by means of a gun barrel; and in the same manner, as it was in that case may it be collected in a phial, or bottle.

The explanation, or rationale, of this process, is extremely satisfactory. Water is made up of two constituent principles, oxigene and hydrogene. In the above described process, the zinc is really reduced to an oxyde. The sulphuric acid is, however, not at all decomposed; no oxigenous gas is emitted from it: the oxigene, therefore, which reduced the metal to an oxyde was produced from the decomposition of water; and as soon as it combined with the metal hydrogene escaped. Water may be decomposed in many other ways, such as by passing it upon heated iron, &c.

The properties of this gas, I shall now enumerate.—

I. It has a disagreeable, stinking smell. That which is obtained from mercury, has scarcely any smell at all. If its water be taken from it, it is said, it will have no smell. If the crooked tube, thro' which the gas is received, mentioned in the preceding page, be immerged in mercury instead of water, the gas will be less offensive; a circumstance which corroborates the idea that the water it contains occasions this property.—

II. This gas is not fit for respiration. It appears that this property arises not from any thing in it noxious to the lungs, for it has been frequently respired; but it contains nothing to feed the lungs: the animal dies in it, as it were, from hunger. It is not at all changed by respiration: no part of it is consumed, as in the respiration of atmospherical air.

III. Hydrogene, tho' when mixed with oxigene, or atmospherical air, the most inflammable substance in nature, yet is of itself perfectly incapable of being inflamed, as we have mentioned before. If you plunge a candle into a phiol of this gas, it will be extinguished. Phosphorus itself will not burn in an atmosphere of it.

IV. It is lighter than atmospheric air. A cubic foot of the former weighs 72 grs; of the latter 720 grs. the barometer standing at 29.9, and the thermometer at 60° of Fahrenheit, according to Mr. Kirwan, the weight of this gas is to that of atmospheric air, as 84:1000; that is, 12 times as light.—

V. It exhibits various characters according as it is more or less pure. If it be obtained from vegetables, it is mixed with oil, and carbonic acid. The colour of its flame varies according to its mixtures. If the inflammable air (of pitcoal) be mixed with respirable air, it will afford a blue flame; the hydrogene mixed with nitrous air, a green one; the vapour of ether a white one.—

VI. It will dissolve sulphur. In this case it contracts a stinking smell, and forms hepatic gas; a term derived from a greek word, signifying sulphur. Since we have mentioned this gas, we will say something farther respecting it.

Hepatic gas, then, may be obtained, as just mentioned, by dissolving sulphur in hydrogene; and by decomposing artificial pyrites, formed by three parts of iron and one of sulphur, to which, spirit of vitriol is added. Sulphurated oxigenous gas may be obtained by dissolving the sulphures or hepars by acids. Pyrites are naturally decomposed in the earth; they produce this gas. "It escapes with certain waters, and communicates peculiar virtues to them." The most general properties of these gasses are, I. They render white metals black. II. They are improper for respiration. III. They impart a green colour to syrup of violets. IV. They burn with a light blue flame, and deposit sulphur by this combustion. V. They mix with the oxigine of the atmosphere, and form water; at the same time that the sulphur, before held in solution, falls down. VI. They impregnate water, and are sparingly soluble in that fluid; but heat and agitation dissipates them again. See Chaptal.

Part II. Of oxigene gas.

This gas, before the introduction of the new nomenclature, was known by the names of vital air, dephlogisticated air, &c; but the terms are now laid aside; the first is paraphrastical, and the second not only paraphrastical, but vicious: a new name, oxigene, has been introduced, because this air has been discovered to be the base of acids.

This gas is never found in the atmosphere in a state of absolute purity, being always mixed, combined or altered by other substances. Yet it is a very general agent: it combines with other matter, from those combinations, we extract it. For instance, if a metal be exposed to it, the metal becomes saturated with it, is reduced to a calx, and is then termed an oxyde. The vital air may be extricated from these oxides by means of simple distillation. One ounce of red precipitate affords a pint. It may be produced also by a distillation of some of the acids, and that very easily. A pound of nitre yields 1200 cubic inches of oxigine. It may be disengaged from its basis by means of sulphuric acid.

take, for example, an ounce or two of manganese: put it in a bottle: pour, of sulphuric acid, enough upon it to make it a paste: fix a crooked tube in the mouth of the bottle; and immerge the tube in a vessel of water in the manner described in part first of this lecture: apply then a small coal to the lower part of the bottle: immediately oxigene is disengaged from the manganese. In like manner it may be obtained from many other substances, with the assistance of heat. All the acids afford this gas, more or less easily, in greater or less quantities, by distillation, or some other means: the reason they do so is so obvious, that it scarce needs mention. This gas is a main, constituent principle in the formation of them. Oxigene is afforded in large quantities by vegetables. We have before remarked upon the double office vegetables perform, first absorbing atmospheric mephitis, and deriving their nourishment and growth from it; and secondly, emitting oxigene to administer to the wants of the animal world. In order to obtain oxigene from them, you have only to take the green leaves of any plant, put them in a vessel filled with water, invert the vessel into another vessel with water in it, set it in the light of the sun; and soon the bubbles of oxigene will rise to the top of the vessel containing the vegetable. It is the green part of the plant that affords this gas most readily, and in the greatest quantity. Pine, and cedar leaves, evergreens, in general, are those from which it is most readily obtained. The flowers of plants, it is to be observed, emit a noxious air: they are, therefore, not proper to be kept in bed rooms.

Oxigene exhibits different characters or properties according to the state of purity, in which it is obtained. The following are the most general properties it possesses.

I. It is heavier than atmospheric air: a cubic foot of it weighs 765 grs; and a cubic foot of the latter weighs 720 grs. — According to Kirwan, the weight of oxigene is to that of atmospheric air, as 1103 : 1000.

II. Oxigene is the only air proper to combustion. We have already made many remarks, in more places than one, upon this subject. Yet it is in its nature so interesting and curious, that we may be justified in making more particular observations upon it here, even tho' we should be, in so doing, justly chargeable with tautology. Our observations may be reduced to four general principles: first, combustion never takes place without oxigene: secondly, in every combustion there is an absorption of oxigene: thirdly, there is an augmentation of weight in the products of combustion equal to the weight of oxigene absorbed: fourthly, in all combustions, there is a disengagement of heat and light.

1. The first of these principles cannot now be questioned. The proofs of it have been anticipated. The most inflammable substances in nature, phosphorus, hydrogene will not burn, we have already said, without the presence of oxigene.

2. That oxigene is absorbed in every combustion, is a truth no less certain and general. Sulphur confined in oxigene, and set on fire by a sun glass, will absorb every particle of the gas: if burned in an atmosphere composed of many gases, the oxigene will be the only one effected. The rancidifying of oils, is (according to Chaptal) a species of slow combustion. They, in becoming rancid, absorb oxigene. In order to purify them, the oxigene they have contracted, must be extracted. In order to extract it from them, you have only to agitate charcoal in them, which has a great affinity for it. Thus rancid butter, putrid water, and stinking meat, which have become so from no other cause than from their combination with oxigene, may be restored to their former sweetness by agitating charcoal in them.

3. We have already mentioned a fact, which leaves not a doubt behind, that in the products of combustion there is an augmentation of weight; and that this augmentation of weight is precisely equal to the diminution in the weight of the air, in which the process of combination is carried on. We have mentioned that in the calcination, or rather in the oxidation of metals, this phenomenon took place. The oxyde, to become such, must have absorbed oxigene: oxigene is matter, and matter cannot be annihilated: it must, therefore, add its own weight to that of the matter it oxigenates.

4. In every combustion, the oxigene combines with the body burning: it abandons its caloric: the caloric is disengaged, and produces immediately sensible heat, and light; because it endeavours to combine with neighbouring substances. The

combination of oxigene is constantly attended with the production of heat by the disengagement of caloric. Whence we may infer, that oxigene is eminently possessed of caloric; that the greater and more rapid the absorption of the oxigene, the greater the heat produced; that to produce heat the most violent, combustion must be carried on in oxigene; that the condensation of air renders more intense fire and heat; and that currents of air are necessary to maintain, and expedite combustion.

III. Oxigene is the only gas proper for respiration. It is this property that has entitled it to the honorable denomination of vital air. In every respiration, the animal takes in a quantity of atmospheric air, rejects the nitrogene part of it, and absorbs the oxigene. No animal can live without the assistance of this air: but all do not require it should be in the same purity: birds, men, and most quadrupeds, require it, in a purer state, than reptiles. The manner of respiration varies in different animals. Amphibious animals respire by means of lungs; yet some of them, frogs for instance, have the power of suspending the functions of these respiratory organs. Fish come from time to time to inhale air, to the surface of the water, which they retain in a vesicle, and digest at leisure. Insects inhale air by means of trachea, placed along the sides like those of vegetables, which they resemble in many points. Count Morozzo placed successively many full grown sparrows under a glass bell, which was filled first with atmospherical air, and then with oxigene: the experiments gave rise to the following results. 1st That animals live longer in oxigene, than atmospheric air. 2. That one animal can live in air, in which another has died. 3 That independent of the nature of the air, respect must be had to the constitution of the animals, as the 6th lived 47 m. and the 5th only 30. 4. That there was either an absorption of air, or a production of a new kind of air, which is absorbed by the water as it rises.

	h. m.
In atmospheric air,	
The first sparrow lived	3. 0
2nd	0. 3
3.	0. 1
In oxigene	
The first sparrow lived	5. 23
2	2. 10
3.	1. 30
4	1. 10
5	0. 30
6	0. 47
7	0. 27
8	0. 30
9	0. 22
10	0. 21

We shall now make a few remarks upon the effects of respiration upon the air, and upon the blood.

I. The air emitted by respiration, is a mixture of nitrogene gas, carbonic acid, and vital air. If this mixture pass through tincture of turnsole, it will redden it. It will precipitate the lime in lime water. The air, in which five sparrows have perished, contains 17 hundredth parts of oxigene. Frugivorous animals vitiate air, it is said, less than carnivorous ones.

II. Air turns the blood of animals to vermillion colour. The animal blood which is distributed from the lungs to the other parts of the body is possessed of a brighter colour than the venous blood, which is blackish. That this effect is produced by the air absorbed by the lungs, is clear from the following experiment of Beccaria; he put blood under the receiver of an air pump, exhausted the air out of it: the blood became blackish: the air was let in again; and the blood recovered its former hue.

The lungs are a real focus of heat in the animal body. They absorb the oxigene of the atmosphere. They distribute its caloric to the remoter parts of our frame. Those who breathe oxigene, know that they feel a kindly vivifying warmth running through them. There is a difference in the heat of different animals; and of the same animals at different times. Those animals that have the largest lungs in proportion to their size, have the greatest portion of animal heat. In the winter the air is more dense: the animal, therefore, absorbs more atmospheric air; consequently more oxigene; consequently more caloric: animal heat, therefore, according to the wise dispensations of heaven, is greater in winter, and less in summer.

From a comparison of what has been said concerning combustion, and concerning respiration, a very great similarity will be observed between the phenomena they present.

Oxigene gas has been used as a remedy in certain complaints of the human body, especially those of the lungs. It relieves the patient. But it must, I apprehend, be a dangerous remedy. It must be productive of some inflammation. Ardent liquors, when properly diluted, may be salutary: when they are not so diluted, they are the worst of poisons; they are slow in their operation, but sure in their effects. In the same manner, it appears ought oxigene to be diluted with nitrogene gas, in order that we may enjoy the health it holds out to us, and avoid the evils an improper use of it would occasion. Chaptal, after relating a case of the phthisis, in which oxigene had been used, concludes: "I am very far from being of opinion, that the respiration of vital air ought to be considered as a specific, in cases of this "nature. I am even in doubt whether this powerful air is adapted to "such circumstances; but it inspires cheerfulness, renders the patient "happy, and in desperate cases it is certainly a precious remedy, which "can spread flowers on the borders of the tomb, and prepare us in "the gentlest manner for the last dreadful effort of nature."

Part III. Of Azotic, or nitrogene gas. Air which has once served the purposes of respiration, or combustion, is no longer fit for either of those purposes. Such air has been termed phlogisticated air, mephitized air, atmospherical mephites &c. Lavoisier called it azotic (a word derived from the greek signifying its property of destroying life) gas. Yet as it is not the only air destructive of life, it has been rejected by Chaptal, who has substituted another name in its stead, viz. nitrogene gas; because it is the radical, constituent principle of nitric acid.

Although the atmosphere is composed of this gas, and oxigene; and altho' in respiration and combustion oxigene is absorbed; yet those processes do not absorb all the oxigene; and the residue of the atmosphere, after it has served their purposes, is always mixed with a portion of oxigene: it has also a portion of carbonic acid: it is not, therefore, pure nitrogene. There are known, several methods by which it may be obtained. We shall only mention that of the celebrated Sheele. Expose liver of sulphur in a vessel filled with atmospheric air: the liver of sulphur will absorb the oxigene: the residue will be pure nitrogene. We shall now enumerate its principal properties.

I. This gas is improper for respiration and combustion. II. Plants live in this air, and freely vegetate in it. III. It is lighter than atmospheric air: it is to atmospheric air, as 985: 1000. IV. This gas mixes with other airs, without combining with them. V. Mixed with oxygen, in the proportion of 72 to 28, it constitutes our atmosphere. VI. It shows no signs of acidity.

Lecture XXIV.

Part I. Of Nitrous air.

The method by which Dr. M. obtained this gas was the following: he put into a glass bottle a certain portion of iron filings: upon these, he poured nitric acid (commonly called aqua fortis) diluted with water; he fixed in the mouth of the glass bottle, a crooked tube, which he immersed under water: quickly bubbles of air were seen to rise, as is usual in processes of this sort; and they were collected in the ordinary mode, in phials and bottles. We shall, by and by, explain the rationale of this process.

Having mentioned the acids frequently in a few preceding lectures, we shall take this opportunity to make some remarks respecting them; what they are, and how they are formed. Every substance which produces on the tongue a sharp keen sensation, usually termed sour;* which turns the syrup of violets red; and which effervesces when mixed with an alkali, is an acid. Acids are formed by the combination of oxigene with any elementary substance. This elementary substance is called the base of an acid; and the difference in their bases constitutes the difference in the acids. They take their denomination from their bases thus, the combination of oxigene with nitre, forms nitric acid; of oxigene with sulphur, sulphuric acid; of oxigene with sea salt, muriatic acid, &c. All acids may be decomposed. Some, however, may be decomposed more readily and easily than others. Those which part most readily with their oxigene, are in a state of weaker combination, and are most easily decomposed. The nitric acid is of this sort. Hence its speedy and powerful effect upon metals. The oxigene it contains has an affinity for the metals; and the acid, without reluctance, indulges that affinity: the oxigene immediately dissolves the metal.

We shall now enumerate the properties of nitrous gas. 1. It is invisible, and not miscible with water. 2 It is somewhat lighter than

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* It may not be improper to mention here, the difference between the terms "sour" and "acid." Sour is employed to express the lesser degrees of acidity; acid to express higher degrees. The juice of lemon is sour, aqua fortis is acid.

atmospheric air. 3. It is unfit for respiration, combustion, or vegetation. 4. It is not acid according to some experiments. 5. It combines with oxigene, and reproduces nitric acid. We shall add some remarks on each of these properties.—

1. That it is invisible, we need be at no pains to prove to any person, who has seen the phials in which it is contained: they look as if they were perfectly empty. That is not miscible with water, is evident from hence; that if a quantity of it be let into a phial together with water, and be agitated with violence; the water will have acquired no nitrous taste. 2. That it is lighter than atmospheric air, may be proved by weighing it; and by opening a phial of it in the atmosphere; when, all the phial contained, will soon have vanished; which would not happen, were not the nitrous air lighter than the atmosphere. 3. That this air is unfit for combustion, and respiration, will be acknowledged, if it can be shewn to be unfit for either of them. Now, if you plunge a lighted taper into it, the taper will immediately be extinguished. The reason of this is, that it does not contain a sufficient quantity of oxigene. How it is proved to be not proper for vegetation, I have not heard. 4. According to some experiments it is not an acid: for example, it does not change the colour of syrup of violets. We shall presently see that it does not contain as much oxigene, (which is the true acidifying principle) and, therefore, has not so good a title to the name of acid, as atmospheric air. 5. That it combines with oxigene, and reproduces nitric acid, may be thus proven: mix a certain quantity of oxigene with it; agitate them in water: the water will have a real subacid taste; as if it had been sparingly tinged with nitre.

When it is mixed with common air, the following remarkable phenomena are observable: a diminution in the volume immediately takes place: a red colour is immediately produced. If it be mixed with oxigene, the diminution will be greater; the red colour will be deeper: if with impure air, a contrary effect will ensue: and if the air be perfectly impure, no diminution at all will take place; no shade of the red colour will be observed. Upon these principles is founded the eudiometer. The name of this instrument explains its nature. It is derived from three greek words, which signify a measure of the goodness of the air. We are able to give an imperfect idea of this instrument. Let a tube containing atmospheric air, as low as a certain point, be below filled with water, and immersed in the same: then let in a certain quantity of nitrous gas; which will expel the water, and occupy its space: but as soon as a combination takes place between the gases, the water will rise, and the red colour will be formed; and according as the rise of the water is greater or less, as the shade of the colour is lighter or deeper, will be the purity of the atmosphere in which the experiment is made. But what is the nature of nitrous gas? It was first thought to be nitric acid saturated with phlogiston. But as the doctrine of phlogiston is entirely exploded, we need make no farther remarks upon this idea. From an experiment of Mr Cavendish, it may be presumed, that the acid is a combination of 7 parts of oxigene, and 3 of nitrogene: (with nitre deprived). These proportions constitute the ordinary nitric acid; but when a portion of its oxigene is taken away, it passes into a state of nitrous gas; so that nitrous gas is a combination of nitrogene gas, with a small quantity of oxigene. If this proposition be true, a combination of oxigene and nitrogene will produce nitrous gas; and a decomposition of nitrous gas will yield nitrogene and oxigene. The experiment may easily be made.—

From this account of the nature of nitrous gas, the rationale of the method, by which we obtained it, may be easily understood. As soon as the nitrous acid was poured upon the iron filings, a part of its oxigene combines with them: a small part of the oxigene escaped with the nitrogene of the acid, and yielded the nitrous gas.

Nitrous acid consists of three constituent principles, nitrous gas, oxigenous gas, and water, mixed in the following proportion;

See Chaptal.

Part II. Of the carbonic acid.

In the common temperature of the earth, this acid is almost always found in a state of gas. It was not unknown to the ancients. Van Helmont called it gas sylvestre, because it may be extracted from wood. Becher seems to have had some idea of this gas. Venel discovered that the properties of certain mineral waters, arose from a superabundant portion of air, possessed by them. Dr Priestly made many interesting discoveries respecting this acid, which he distinguished by the name of fixed air. It has been called mephitic acid, cretaceous acid &c. But having been discovered to be no more than a combination of oxigene with carbone, or pure charcoal, the new nomenclature has distinguished it by the name of carbonic acid. This acid exists in three states. 1. That of gas. 2. In that of mixture. 3. In that of combination.—

1. It is found in a state of gas in the grotto del cane, near Naples; at the well of Perols, near Montpelier; in that of Negrac in Vivarais; upon the surface of lake Averno in Italy, and on those of several springs; in various subterraneous places, such as tombs, cellars, necessaries, &c.— 2. Certain mineral waters such as the sweet springs, in Virginia, contain it in a state of simple mixture. 3. It is found in a state of combination in stone, magnesia, chaulk, &c. It may be collected or extracted by several different processes, which I proceed to mention.

I. When the carbonic acid exists in a state of gas, it may be collected, 1. by filling a bottle with water, which empty in an atmosphere thereof.— 2. by exposing lime water, caustic alkalies, or even pure water, in its atmosphere: the acid mixes with the substance, from which it may afterwards be extracted by means of re-agents.—

II. When the carbonic acid exists in a state of simple mixture, it may be extracted in three different ways. 1. By agitation of the liquid which contains it; as Mr. Venel practised, by making use of a bottle to which he adapted a moistened bladder. 2. By distillation of the same fluid. These two first methods are not accurate. 3. The process indicated by Mr. Gioanetti, consists in precipitating the carbonic acid by means of lime water, weighing the precipitate, and deducting thirteen thirty second parts for the proportion of carbonic acid; it having been deduced from analysis, by this celebrated physician, that thirty two parts of carbonate of lime contain 17 lime, 2 water, and 13 acid.

III. When the carbonic acid exists in a state of combination it may be extracted, 1. By distillation with a strong heat. 2. By the reaction of other acids, such as the sulphuric acid, which has the advantage of not being volatile, and consequently is not altered by its mixture with the carbonic acid which is disengaged.

We have said, that this substance can never be had, in the common temperature of the earth, in any other state than that of Gas. Why then is it called an acid? Because it has all the characters of one. If the syrup of violets be agitated in a bottle of this acid (or gas, if you please) the colour of it will become red: if you agitate water in a bottle of it, the water will acquire a taste strongly acidated: it will neutralize, and christalize alkalies.—

We shall now enumerate the properties of this acid

I. It is unfit for respiration. Tiberius caused two slaves to descend into grotto del cane: they expired. Peter de Toledo shut, in there, two criminals: they also expired. The birds cannot fly over the lake of Averne, without death. It was with great judgment, that Virgil made this place the entrance into hell. Bergman thinks that this air destroys the animal by extinguishing irritability. The chevalier Landriani joins in this opinion. The abbe Fontana, and count Morozzo contravene the opinion. Chaptal inclines to the latter.

II. The carbonic acid is unfit for vegetation. Dr Priestly kept the roots of several different plants in water impregnated with this acid: the consequence was that they all perished; which experiment is incontrovertible and conclusive.

III. This acid is easily soluble in water. We may impregnate water with it. The sweet springs owe their properties to this acid, though they are ridiculously called sweet. We can imitate the waters of those springs, by agitating carbonic acid in common water. The reason, that those springs are salutary, is, that they contain this acid; which, though destructive when taken into the lungs, has been found highly conducive to health, when taken in the stomach. Beer, ale, porter, and all fermented liquors contain it: hence their wholesomeness.—

IV. This acid is heavier than atmospheric air. According to Kirwan, the proportion between them is as 45,69: 68,74. This superiority of weight causes it to occupy the lowest situations. it may even be poured from one bottle to another, so as to displace atmospheric air. This curious phenomenon was remarked by Mr De Sauvages.

What is the nature of this caloric acid. It is a combination (as we have before said) of pure charcoal, or carbone, with oxigen.— To prove this, let carbone be burned in pure air, or oxigene: the