result will be carbonic acid. The proportions, which carbonic acid contains, is 12,0288 of carbone, to 56,687 of oxigene.

Dr. Black, of Edenburgh, discovered that lime stone is indebted for its solidity to this acid: take this acid from lime stone, it becomes lime immediately: restore this acid, it becomes stone again.

* Part III. Of the analysis of atmospheric air, and its division into two elastic fluids, oxigene, and nitrogene.

In our inquiries into the constituent principles of bodies, the surest road to arrive at truth, is the use of the two logical methods of reasoning, that of synthesis, and that of analysis. By the first, we compound principles together, and see what they produce: by the second, we resolve the compound substance into its principles, and examine them. In this way, the two methods serve as proofs of each other. Both these methods have been employed by Mr. Lavoisier, in determining the nature, and constituent principles, of the atmosphere. He caused mercury to be oxigenated in atmospheric air: the mercury (oxidated) was heavier than before: the air, which had supplied the process was lighter: the latter had lost, exactly, what the former had gained. When the remaining air was examined, it was found to be nitrogene: it was carefully preserved. The air, which the oxigenated mercury had imbibed, was extracted: that air was found to be oxigene. This oxigene was added to the nitrogene before mentioned: atmospheric air was reproduced; and their weight was restored to what it was, before the process had been carried on in it. — Here is both the analytic and synthetic methods: the air is first resolved into oxigene, and nitrogene, gases: these are then added together, and atmospheric air is reproduced. —

* In speaking of the carbonic acid, I omitted to mention the usual test of its presence; which therefore I here subjoin. That test is founded upon this circumstance, that the carbonic

acid precipitates lime in lime water. Whenever, therefore, you suspect the presence of this acid, cause the atmosphere, in which it is contained, to pass through lime water, the lime will be precipitated, if the carbonic acid be really in that atmosphere.

Lecture XXV.

Of Evaporation.

The subject of evaporation is highly interesting on account of the many phenomena with which it has enriched the science of physics. It was not till lately closely investigated. Many theories have had their day, and among them, that of Hamilton appears the most plausible. This essay on evaporation may still be read with much advantage, though it is not perfectly conformable with the doctrine now generally received. He makes the process of which we are speaking to consist wholly in the attraction between air and water. this is certainly an error, and arises from his extending the principle too far, without attending to caloric; whereas, philosophers at present attribute it to a combination of these two principles.

I. The atmosphere will dissolve a certain quantity of water. this is evident from its transparency. Take dry potash; weigh it in the dry state: you will find, in a short time, that it will have acquired weight let it remain longer, and it will begin to run. Ice will lose part of its weight, when suspended in the air, provided the temperature thereof is below the freezing point. Now in the first case, water was absorbed from the air: in the latter, it left the ice to combine with the air: in both, the air was perfectly transparent: transparency is the test of solution: therefore the atmosphere will dissolve water. We may add, that water contains air; for if pure water be drawn from a well and exposed to the atmosphere, it will soon lose the agreeable taste it at first possessed; which must be owing to the escape of air from it. A greater quantity of it is evaporated and suspended in the air by caloric than by its combining with the air.

II. That heat is the principal cause of evaporation, may be easily shown. When water is converted into vapour, the surrounding bodies are deprived of caloric. Every evaporation produces cold: a thermometer dipped in water, and then exposed to the air indicates the diminution of heat. By ether, we may sink the thermometer down to 0°, i.e., 32° below the freezing point. Put any vessel containing ether, in another containing water; put the whole under the receiver of an air pump; exhaust the air: the ether will boil, and the water freeze.— The experiment will succeed very well, if you put the ether in one watch chrystal, the water in another, and the one which contains the ether on top of the other. Dr. M. placed a vessel containing ether under a receiver, and a similar one he left exposed to the air: after a certain length of time, he plunged a thermometer into each of them: the mercury sunk 10° lower in the former than in the latter; which proves that evaporation is greater in vacuo.—

Evaporation may be great enough to produce ice, in a hot summer day, or by the fire. The method of cooling liquors by wrapping wet cloths round the bottles which contain them, is frequently practised, particularly by sailors. In hot countries, as Egypt and Syria, they cool liquors by putting them in porous vessels, because the evaporation is greater in proportion to the porosity of the vessel. When the human body is heated by violent exercise, the vapour which goes off by perspiration, counteracts the warmth of the body; and, were it not for this perspiration, hot fevers and the most fatal consequences would ensue. The more the air is conveyed away, the greater is the evaporation: hence the use of fans.

All experiments prove that caloric causes bodies to evaporate. That it is the principal cause of evaporation, may be thus proved: steam will immediately condense and become water, if caloric be withdrawn from it. The moisture which is often, after a sudden coldness in the atmosphere, seen on brick walls &c is owing to the abstraction of their caloric. Upon the same principle, we account for the phenomenon observed in the summer time, when we pour cold water into a tumbler, in which case the glass, according to the vulgar expression, will sweat. The same may be said of dews, fogs, and the breath of animals. When the latter is emitted from the mouth, a part of its caloric combines with the atmosphere, which is of a cold temperature: in consequence of this, the breath is condensed, and becomes visible.—

We have shewn, 1st. That water may be dissolved in air. 2dly. That it may be dissolved in caloric; in which case it becomes steam. Let us now proceed to the investigation of other facts relative to this subject. What is the cause of devaporation, or the falling of vapour? If a region of vapour comes from climates warmer than ours (as when brought by south winds) its caloric is attracted by the earth, its moisture condenses, and is forced to descend. Vapour dissolved in caloric expands, and, on account of its specific levity, must ascend until it meet with colder air.

Another method by which air becomes cool, and deposits part of its moisture, is by mechanical expansion. There is little doubt but a fall of rain may be produced by electricity, a fluid repulsive of itself; for, after much lightning, the drops always become larger. When water once boils, you cannot, by continuing the ebullition, increase its temperature (212°); yet you may confine water, with sufficient pressure, so as to melt lead. There is an easy method of judging when caloric is disengaged, and when it is combined: in the former case, the surrounding bodies are heated; in the latter, they are cooled.— The transition from the solid to the fluid, and from the fluid to the aeriform state, produces cold. We have seen by what means vapours are raised, and the general cause which separates them from the atmosphere, and which causes them to descend. The particles of the atmosphere may be divided into two classes. I. Those which partake of water.— II. Those which partake of oil.—

Meteors are of three kinds; aqueous, luminous, and inflammable. Of aqueous meteors only we are to speak at present. They are those produced by water and found in the atmosphere, as dews, fogs, &c: they are precipitated by the loss of their caloric in which they had been previously dissolved. All these meteors are produced in the same way. A person standing in a porch, in a summer evening, will have his clothes moistened rather from the vapour ascending than descending. The more a body is rarefied, the greater is its capacity to receive caloric. The coldest part of the 24 hours is just before sun rise.— Get up early in the morning, and you will find no white frost at all until just after sun rise.— You frequently find white frost only upon particular substances, as straw and boards, but never upon a pewter plate: the reason is, that the former are non conductors of heat; whereas the latter is an excellent conductor. When the nights become long, the earth and bodies upon it, have time to cool: then we see white frost. It appears, that there is a great quantity of aqueous particles imperfectly dissolved in air. This solution may take place either in air or in caloric. The fogs which are seen in the morning arise from hence: during the night, the waters retain a considerable part of the heat they had acquired in the day: in the morning, the sudden refraction causes them to rise. Clouds are formed by the mixture of warm and cool air. Water mixed with air or vapour, also forms clouds, which are nothing more than thick vapours. Rain is formed by the condensation of the vapours which compose clouds: the drops are large or small according to the elevation of the cloud. The region of clouds is frequently cold enough to freeze vapour, and in this case snow is formed. Hail is formed when the aqueous particles have time to unite before they freeze. Hail stones are sometimes found 4 or 5 inches in circumference: but their texture proves them to be formed of many parts or pieces, and to have been at first very small. What is the quantity of water evaporated on the surface of the earth? Upon an acre of ground, in a summer's day, upwards of 1600 gallons are evaporated.

Various theories have been offered to account for the phenomena of evaporation; in all of them, except Hamilton's, fire, or heat and refraction, by which watery vapours are supposed to become specifically lighter than the air, are made to be principal, if not the only causes of their ascent into the atmosphere.

Doctor Nieuwentyt, and some others supposed, that the particles of fire, by adhering to those of water, make up molecules or small bodies specifically lighter than air.

Dr. Halley thought, that by the action of heat, the particles of water are formed into hollow spherules filled with a finer air, highly rarefied, so as to become specifically lighter than the external air. This last was the opinion most commonly received, as Dr. Desaguliers tells us in his dissertation on this subject (published in the philosophical transactions, in the year 1729) in which he examines and refutes the two former opinions, and endeavours to establish his own. Desaguliers ascribes the ascent of aqueous vapours to their being turned into an elastic steam, and always rarefied more than the air is by the degrees of heat, to which bodies are usually subject, in the different seasons of the year.

Hamilton attributed evaporation to the attraction between air and water; and says that evaporation is nothing more than a gradual solution of water in air.

Caloric is now generally allowed to be by far the principal cause of evaporation.

Lecture XXVI.

Part I. Of Winds.

Wind is nothing more than the motion of the air upon the surface of the earth. Winds may be divided into three classes, viz. 1st the perpetual. 2. the periodical, and 3d. The casual winds: the perpetual winds are those, which blow continually from one point of the compass; such as the wind which blows invariably from East to West, at the equator: the periodical winds are those, which blow in certain directions, at certain seasons of the year; such as the monsoons, which blow half the year to the north, and the other half to the south, point; the casual winds are those, which blow first in one direction, then in another, according to circumstances; such as the winds which blow upon the coast of very warm countries, the atmosphere of which is, in the day much rarefied by the reflection of the intense heat of the sun from the land.

Various opinions have been entertained as to the cause of winds. Some of the ancients supposed them to be an air issuing from caves and subterraneous places in the earth; some, that they were exhalations from the earth. Some of the modern philosophers, who have embraced the cartesian doctrine of a plenum, imagine that when the air is much heated; the atmosphere not being able to rise higher than a certain point; one part of it, being less elastic, gave way to the more heated, and of course more elastic part. It has been imagined that the perpetual wind which, at the equator, blows from east to west, was owing to the daily rotation of the earth from west to east, whence the atmosphere being left behind appeared to move in a contrary direction, from east to west. This idea is incorrect to the minds of others; because there are many casual winds near the equator; and because the atmosphere passing upon the earth, would, if nothing prevented, acquire its motion. The most probable and philosophical theory of the cause of winds, is that of Dr. Halley. It is now generally admitted, and, from its simplicity, may be easily explained. It frequently happens that one part of the atmosphere is more heated, and of course more rarefied, than another. That part, being lighter than the surrounding parts, naturally rises higher from the earth. It leaves, therefore, a vacant space. But as all fluids are subject to the law of equilibrium, and as air is a fluid, the neighbouring air rushes to restore the equilibrium, to fill the vacant space, which the rarefaction, and consequent rise of any portion of air, endeavours to create.

Upon this theory, we may very rationally account for many phenomena relative to winds. There is, at the equator, a perpetual wind, which blows invariably from east to west. This wind is accounted for upon Dr. Halley's theory. The earth moves from west to east. It presents different points of its atmosphere, to the vertical rays of the sun. Those rays rarefy the air, and the air rushes from the east, to restore the equilibrium: hence the easterly wind that blows. But a difficulty has been started upon this point; it has been asked, why does not the western air rush in to restore the equilibrium, as readily as the eastern? The answer is, that as the earth, revolving on its axis, presents to the sun new points, still more west than those he has just rarefied, he rarefies the western air as soon as it attempts to rush in to restore the equilibrium, and thus prevents it from doing so. Some have reckoned, that the air presses from both the poles, meets at the equator, and thus resolves itself into the trade winds. No facts can be adduced sufficiently strong to support this theory. Were it true, there could be no reason that the trade wind should not indifferently blow either to, or from, the east point. The monsoons may be accounted for upon the same theory. While the sun is moving towards the southern tropic, the air follows his course, and blows towards the south: when the sun turns back, and moves towards the northern tropic, the air follows him, and blows towards the north. Indeed all the regular winds, usually distinguished, I believe, by the general name of trade winds, admit of a similar explanation upon Halley's theory. It is needless to mention others of them.

The principal agents, which influence the atmosphere in producing winds, are heat and cold. When heat has rarefied the air, that air rises, and the neighbouring air rushes in a current, or wind, to restore the equilibrium. When, owing to some great degree of cold, a part of the atmosphere is condensed, that part continually exerts itself in a wind to produce an equilibrium; thus, the condensed atmosphere of the poles, it is said, presses towards the equator. But I imagine, that the degree of cold, by which the air is condensed at the poles, operates to keep it in a state of condensation; prevents it from pressing towards the equator. It is only when the condensing cold ceases, that the condensed air disperses in wind. It is supposed by some, that the attraction of the moon produces wind. A protuberance of the atmosphere, an aerial tide, attends the course of the moon. This draws, after it, a current of inferior air, which will be weaker if other circumstances, other currents, oppose it, stronger, if they combine with it. Martin advocates this idea. Rowning seems to think, that the motion in the air, produced by the moon, must be very inconsiderable. —

A wind constantly blows, from the ocean, to the coast of some countries. Why? — The heat of the sun, if very intense, will be reflected from the land, so as to heat the atmosphere; consequently, to rarefy it. The air therefore, rushes from the ocean to restore the equilibrium; a wind blows. This effect is produced, in a remarkable degree, by the heat reflected by the barren sands of Africa; nor can the chill of night so cool the atmosphere heated by the sun in the day, as to reverse that effect: a breeze constantly blows upon the coast of Guinea.

In some islands, it is observable, that a current sets in from the sea to the land, in the day; and from the land to the sea, in the night. This may be said of sea coasts in general. The reason is, that the land reflects the heat of the sun, so as to warm the atmosphere in the day which lies over it, more than the atmosphere over the ocean is warmed by a similar reflection; and the air rushes from the ocean to restore the equilibrium. The cold of the night chills the earth more than the ocean; and a current of air in this instance, rushes from the land to the ocean.

The easterly winds, in summer, are cold and chilly: why? They come immediately from the ocean, which is colder than the land. I allude, in this observation, to the easterly winds of America.

The countries, lying to the north west in America are colder than those lying more southerly and easterly. The air rushes in the winter to restore the equilibrium between the two territories: it rushes from the north west.

I shall introduce what Rowning has remarked upon the subject of Eolian caves. "We are told, says he, of certain caves that emit wind: if so, it is when the included air is rarefied by heat, and, therefore, rushes out for want of room; or, when the pressure of the external air, incumbent upon the mouth of the cave is diminished, and so permits the internal air to dilate itself, and issue out.

Whirlwinds are generally accounted for, upon the meeting of two currents of air in directions opposite to each other. They take, in consequence of that meeting, a circular course.

The velocity of winds is from one, to fifty miles, an hour; but the velocities depends upon the causes that produced them, and the circumstances, that altered them.

Winds are calculated to answer many useful purposes. We have already mentioned the manner, in which they purify the atmosphere. Winds are what principally aid commerce. In this view, the benefits they produce must be vast, and incalculable. I leave others to depict and appreciate them.

Part, II. Of Sound.

The first proposition, upon this subject, is, that air is necessary to the propagation of sound. To prove this, put a bell under the receiver of an air pump: shake the bell and it may be heard very distinctly; then exhaust the air out of the receiver: the bell cannot be heard but very imperfectly: and if the air could be entirely exhausted, this experiment authorises us to presume, there would be no sound at all. The manner of the transmission of sound has been thus explained. If a sonorous body be struck, its parts are put into a tremulous motion; that tremor is communicated to the neighbouring particles of air; those particles communicate the tremor to their neighbouring particles, and so on, till the tremor becoming less and less every time it is communicated, ceases altogether. The air, thus put into a tremulous motion, strikes upon the tympanum of the ear, a fine membrane distended across it; and by means of the tympanum, this tremor is made to effect the auditory nerve; and by such an affection of that nerve, the idea of sound is excited. Sounds are propagated in every direction. Like all other emanations, the strength diminishes as the square of the distances they pass through increase.

Two different sounds may be produced in the same room at the very same instant of time. How is this to be accounted for? Some have thought that the air contained different kinds of particles; some being adapted to the propagation of one sound, others to the propagation of another; and that whenever a sonorous body was struck, it put into motion its appropriate particles, not at all affecting the rest.

\+ Others have thought that when   of sounds were produced in the same body of air, all of them produced their tremors, while none of these tremors interfered with any other tremor; just as if you should throw a number of stones into the same pond of water, all of which stones have their concentric circles, none of which circles interfere with each other. Others have thought, that the different sounds gave different peculiar tremors to the air, and that the organization of the ear enabled it to give different, and peculiar ideas of those sounds. The identity of sounds seems to be dependent upon the tremor given to the air, and that tremor depends upon various causes. The strings of the same length, the same thickness, + and the same   on, will communicate the same tremor to the air, will produce the same sound, if circumstances do not prevent.

It has been found that sound travels uniformly at the rate of 1142 feet in a second. This has been ascertained by observing the time which elapsed between the appearance of the flash, and the hearing of the report of a gun, fired at a certain distance from the observer, then by dividing the distance in feet, by the number of seconds. Heat and cold seem to make a very small alteration in the velocity of sound; for sound appears to travel a little faster in summer than in winter. Different altitudes of the barometer, as also different quantities of moisture in the air, seem to occasion a small alteration in the velocity of sound. Upon the whole it appears, that whatever increases the elasticity of the air, accelerates the motion, as also the intensity of sound, through it, and vice versa.

The same sound is stronger in dense than in thinner air; the actual fall of rain, snow, &c. or a good deal of moisture in the air, diminish the intensity of sound. In calm, serene weather, when everything is quiet, a sound is heard much stronger, and of course much farther than otherwise.

That all the parts of a sounding body are in a state of vibration may be proved by striking a bell, or by rubbing your hand along the upper edge of a glass vessel containing water.

The vibratory motion communicated to the air, corresponds with that of the sounding body.

The intensity of sound is dependent on the elasticity and density of the air. On a damp morning, it has been found that sound is more intense than otherwise.

By knowing the velocity of sound, you may determine the distance of objects from you, by noting the time which elapses between the appearance of the flash and hearing the report of a gun fired at those objects; then multiplying the number of seconds by 1142, which will give the distance in feet.

Water is a nonelastic fluid, it will convey sound, and it is known that air conveys sound in consequence of its elasticity. Sound must therefore be transmitted thro' water and other solid bodies, in a manner different from that in which it is propagated through air. The best way of accounting for this, is, that sound is conveyed through solids in the same manner that ivory balls communicate motion to each other; as has been explained in a preceding lecture.

A remarkable phenomenon attending the echo, is, that it alters with your distance from the reflecting surface. The nearer you come to the reflecting surface, the farther will the echo recede from it.

Some say, the effect of the speaking trumpet is owing to the union of so many echoes reflected from the sides of the instrument. Another way of accounting for it is the following. We know that a small ivory ball will communicate to a larger, a greater momentum than it possesses itself. — Suppose, then, the speaking trumpet AB to be divided into any number of parts, a, b, c, d, &c. decreasing from B towards A. — a will communicate to b a greater degree of sound than itself possesses; b will act in the same manner upon c, and so on.

The different tones, or notes we hear, depend upon the general principle of the quicker or slower vibration of the air. When the vibration is slow, the tone is grave; when quick, acute. These notes vary according to the difference in the length, tension, and diameter of the string.

Lecture XXVII.

Of Hydrostatics.

It is the intention of that part of natural philosophy, which we denominate hydrostatics, to explain the nature, gravity, pressure, and motion of fluids in general. As all fluids, except air, exhibit the same phenomena, as air differs from other fluids in a very slight degree, and as all fluids are governed by the same laws; the experiments in hydrostatics are made upon one of the fluids, water. A fluid is a body that yields to the least pressure, or difference of pressure. Philosophers have mentioned as the characteristic properties of a fluid, that the particles composing it must be extremely minute, smooth, and round; and they deduce these properties from the facility with which those particles move amongst each other. But when we know that the most solid bodies may reduced to fluidity by an addition of caloric, we can hardly suppose, that it is essential to fluidity, — that the particles of the fluid should be minute, smooth, and round; because we cannot suppose that an addition of caloric produces any alteration in the shape of the particles of bodies. and it has never been suggested that it is essential to solidity, that the particles of a solid should necessarily be minute, smooth, and round: neither, therefore, is it necessary that the particles of a fluid should be minute, smooth, and round.

It is generally laid down, that all fluids, except air, are incompressible. In our remarks upon the porosity of bodies, we had occasion to mention the famous Florentine experiment. That experiment incontestibly demonstrates that if water be at all compressible, it is compressible in a very small degree; the experiment is this: a globe of gold, the densest of metals, was filled with water. the globe was pressed by a powerful screw: the water, instead of being compressed, oozed through the small pores of gold and stood on the outside, like drops of dew. I believe that water is now acknowledged to be compressible, though in a very small degree.

Fluids, like all other bodies, gravitate towards the earth: but but their gravity is always proportionate to their perpendicular height.

In their pressure, they observe the following singular law. They press equally in all directions, upwards, downwards, obliquely, and laterally.

Some of the ancients supposed the particles of a fluid were totally devoid of gravity, or weight, when in a fluid of the same sort. They were naturally led to this conclusion by observing that in drawing up a bucket out of a well, they were not sensible of its weight, until it was out of the water. That this conclusion was erroneous is evident from the following experiment. Let there be a pair of scales; to one of which let there be suspended a phial with a few shot in it, which let be barely sufficient to sink it in water: see what weight put in the other scale will maintain the equilibrium: then let the water into the phial: the phial will immediately sink: see what additional weight will restore the equilibrium: take the phial thus filled with water out of the water in which it is immersed: the same weight will maintain the equilibrium in the air: pour the water out of the phial and weigh it: it will be found to weigh just as much, as was added to restore the equilibrium, after it had been destroyed by letting in the water: all which proves that water weighs just as much in water as in air.

The relative and specific gravities of bodies may be readily determined by means of the hydrostatic balance. You weigh the same body in different fluids. That body will at each time lose as much of its weight, as is equal to the weight of an equal bulk of the fluid. The different weights, therefore, which, placed in an opposite scale, maintain the equilibrium, accurately express the relative gravity of the fluids.

The heaviest body may be made to swim in a fluid, of which an equal bulk is infinitely lighter than itself. Brass is 9 times heavier than water. If now you immerse a plate of brass 9 times deeper than it is thick, and if you protect it from the pressure downward, exposing it to the pressure upwards only, the brass will swim.

As fluids yield easily to the least pressure, or motion, and adjust themselves to every change of situation, as they are continually subject to the force of gravity, their surfaces are always level, as all the particles composing those surfaces are placed at equal distances from the centre of the earth. I say their surfaces are level: but they are not strictly so: they are level only as being part of the vast circumference of the globe. Large surfaces, being larger parts of that vast circumference, are sensibly convex. The masts of ships are, on this account, the first parts that an ocean at sea. You may find by a trigonometrical calculation, the distance requisite to render this convexity sensible. See Martin. That distance is calculated to be 2 miles and ½, or thereabouts.

The pressure of a fluid upon the bottom of a vessel, is always equal to the area of the bottom, and to the perpendicular height of the fluid. Upon this principle is founded the hydrostatic paradox, which is, that the smallest quantity of water may be made to balance the largest. Let there be two vessels A and B, the area of whose bottoms are equal; and let them be filled with water both to the same altitude CD: it is ascertainable, that the pressure upon the bottom of A is as great as that upon the bottom of B: that is, the smallest quantity of water in the vessel A would be able, if properly managed, to maintain an equilibrium, against the large quantity of water in B.

To account for this surprising phenomenon, draw the lines HL & GN in the large vessel B. It is clear that the water comprehended within the triangles CNG, and HLM, press on the sides of the vessel, not on the base; and that none but the perpendicular column GNLH presses on the base NL. Again in the vessel A the particles of water on the base press with a force equal to that they would acquire by falling from the top D to the bottom, for they are pressed by the particles above them: action is equal to reaction: the particles on the base then press upwards against the circular sides x n and e a: here again action is equal to reaction: and the water presses downwards with a force equal to what it would have acquired by falling from M to n, or from D to a. The same pressure, therefore, is upon the base na, that there is on the base NL.

The syphon is a crooked tube: the long leg is put in the water: you exhaust the air out of the tube: the pressure of the atmosphere upon the water in the vessel drives it up in the tube, and would drive it as high as 33 feet: but as soon as the water in the vessel gets as low as the outer leg extends, the water must cease to flow.

Additional Observations.

The difference between hydrostatics and hydraulics is this: hydrostatics considers fluids at rest; hydraulics fluids in motion, and the construction of machines in which fluids are principally concerned.

A fluid is any body that yields to the least pressure, and, in yielding, has its parts easily moveable amongst each other, and whose surface is always parallel to the horizon.

The general division of fluids is, into elastic, and nonelastic: the latter only are concerned in hydrostatics.

The experiments in hydrostatics are performed with water, because it is less subject than other fluids, to the attraction of aggregation, and of cohesion.

The particles of a fluid act independently of each other. Hence the impression made by a certain quantity of any fluid, in falling from a given height, may scarcely be felt, whereas a solid of equal bulk and specific gravity with the fluid, might, in falling from the same height, produce the most serious consequences.-

The general hydrostatic laws are the following. —

1st. All fluids, besides air, are incompressible, except in a very small degree.

The conclusion deduced from the florentine experiment, was, that water is not compressible.- Mr Cavendish has made an experiment which led to a contrary conclusion. He placed a tube, similar to that of a thermometer, and filled to a certain height with water, under the receiver of an air pump: on exhausting the air, the water rose in the tube: he then placed it under a condensing engine, and on compressing the air, the water fell below the original height.

2nd. Law. A fluid weighs as much in a fluid of the same kind, as out of it.

3rd. Law. Fluids press not only downwards, like other bodies, but have the singular property of pressing equally in every possible direction.

4th. Law. All fluids gravitate in proportion to their quantity of matter, because the earth's attraction, which is the cause of gravity, equally affects the particles of all sorts of matter, and therefore excite the same tendency to the earth.

5th Law. The pressure of a fluid is always proportional to the altitude or depth thereof.

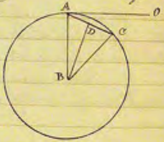
6th Law. The pressure of fluids upwards is equal to the pressure downwards, at any given depth.

7th Law. From the mutual pressure and equal action of the particles, it follows, that the surface of a fluid must be perfectly smooth and even.

8th Law. The figure of the surfaces of all fluids is spherical or convex.

9th Law. The weight, pressure, or effect of a fluid upon the bottom of a vessel, is proportional to the altitude only, and not to the quantity of the fluid in the vessel. This is proved by the hydrostatic paradox, which shows that a pint of water may be made to balance the ocean. -

The greatest distance at which the convexity of water becomes sensible, may be found in the following manner. An object to be visible must subtend an angle of at least one minute: therefore make the angle CAO equal to 1', its complement DAB will be equal to 89° 59', and consequently the angle ABD equal to 1': then, Radius : AB :: Sine ABD : AD; double AD, and you have AC, the distance required.



Lecture XXVIII.

Of the densities & specific gravities of bodies.

Having already mentioned the principal laws of hydrostatics, and many interesting facts dependent on them, we shall now pursue still farther this valuable science, in treating of the densities, and relative gravity of bodies. How necessary a knowledge of this subject is, will best appear from attending to the following advantages which it affords. 1st. It is necessary to determine the nature of fossils. 2. To determine what bodies are mineral and what are not. 3. To discover the purity of metals. 4. To discover genuine stones of value. 5. To determine the purity of liquors, which are mixed, and which are not.

Before we enter on the subject, we shall make some observations that should previously be known. 1st. The quantity of matter in a body, considered in relation to its bulk, is called its density. The density of any body, must be as the weight of the body directly, and magnitude inversely. The two extremes of density are platina and air. The specific gravity of the latter is about 820 less than that of water. The specific gravity of platina when taken from the mine is 15 times greater, when in its pure state 23 times greater, than that of water. 2dly. By specific gravity is meant the relative weights of equal bulks of different bodies. By finding out the proportion between the specific gravities of bodies, their relative densities may also be known.—

1st. Proposition. When any solid body is immersed in a fluid, it will lose just so much of its weight, as is equal to the weight of an equal bulk of the fluid. The loss of weight is owing to the resistance of the fluid which presses upwards against the solid. This proposition may be established by the following experiment. Balance a cubic inch of metal in a pair of scales: immerse in water, the scale containing the metal: the other scale will preponderate; but if you put into it a cubic inch of water, the equilibrium will be restored.

2nd Propn.. Since a solid when immersed in a fluid, loses so much of its weight, as is equal to the weight of the fluid displaced, it follows that bodies of equal magnitudes must suffer a loss of weight equal to that of the fluid displaced. A cubic inch of gold is to one of water, as 18 to 1; a cubic inch of brass, as 9 to 1: hence the former would lose $\frac{1}{18}$, the latter $\frac{1}{9}$, of its weight, when immersed in water. The weight lost is gained by the fluid. Those bodies lose most of their absolute weight, which have the least matter in proportion to their bulk.*

3rd Propn. It is an obvious consequence of the last proposition, that two bodies of unequal bulk, in perfect equilibrio in air, will not be so in water. The application of this principle by Archimedes is well known. Hiero King of Syracuse, had a crown of gold made, but suspected it was not pure. Archimedes immediately endeavored to discover, whether the artist who made it, had been guilty of any fraud. He had observed, in bathing, that he must displace a quantity of water, the weight of which, was precisely equal to his own loss of weight. He ordered, therefore, another crown of gold to be made, of the same size with the former, and upon immersing them both in water, found, that the original crown lost considerably more of its weight, than the other: upon which, he was convinced of the impurity of the gold.

4th Propn. If a solid be immersed in a fluid of the same specific gravity, it will remain suspended in any part of the fluid: but if the solid be lighter than the fluid, it will sink therein, until the pressure is equal upwards and downwards, and of course in equilibrio: the weight of the fluid displaced, will be equal to the whole weight of the body. Hence is derived the method of finding the weight of a ship: in order to do this, you multiply the number of cubic feet of the ship under the surface of the water by 62.5 the number of pounds in a cubic foot of fresh water, or by 64.4 the number of pounds in a cubic foot of salt water, and the product will give the weight of the ship with its contents.

5th Propn. A body heavier than an equal bulk of a fluid, will descend with a force equal to the excess of its weight above that of the fluid. In short, bodies descend in a fluid as down an inclined plane; the same allowance being made for the diminution of weight ma-

* The true weight of bodies may be known by weighing them in vacuo; because then there would be no resisting medium.

-sioned by the resistance of the inclined plane, as for that caused by the resistance of the fluid. Hence we see the reason why some bodies sink and others swim; for if the weight of the body be destroyed by the resistance of the fluid it must swim; since it has no residual gravity to cause it to descend. But if this weight is not destroyed by the resistance of the fluid, it will then descend with its remaining gravity. It is to be observed, however, that a cork, or any light body, may be made to sink to the bottom of a vessel, if the fluid in that vessel be prevented from pressing upwards. The specific gravity of fluids may be determined by observing the loss of weight sustained by the same solid body when immersed in them; and by knowing the loss of weight you may find the relative density of fluids. You may also find the specific gravity of fluids by means of the hydrometer. The effect of heat and cold on the density of fluids is, that the former expands fluids and consequently makes them lighter; and the latter produces a contrary effect. A cubic foot of proof spirits weighs 235.7 grains; which, therefore, is the loss of weight sustained by a cubic inch of any solid body immersed in good spirits. In experiments to determine the specific gravity of fluids, we must pay attention to their temperature. Sixty degrees of Fahrenheit is the temperature usually adopted. A cubic inch of good brandy weighs 10 grs more, a cubic foot of spring water 3 grs. more, in winter than in summer: it is preferable on this account to buy liquors in winter.

We come now to speak of a very valuable instrument called the hydrometer; which depends upon the principle that a body will sink deeper in a lighter, than in a heavier fluid. It consists of a graduated rod or stem, to the end of which a bulb is affixed, and its use is to determine the specific gravities of fluids, by plunging it in them, and counting the number of divisions either above, or below their surface. So great is the accuracy of the best kind, that by means of them you may determine the relative gravity of water compared with other water, to 32000th parts. We must observe, however, that they are subject to the two following imperfections. 1st. They can serve only for those fluids which differ very little in specific gravity. 2ndly. The inequalities of the stem, and the small quantity of water, which from the manner of using the instrument, must adhere to the part of the stem just above the fluid, render it inaccurate in a greater or less degree.

The hydrostatic balance next claims our attention. It differs very little from a common balance that is nicely made: only it has a hook at the bottom of each scale on which small weights may be hung by horse hairs or by silk threads. So that a body thus suspended may be immersed without wetting the scale. Its use is to determine the specific gravities of bodies with accuracy. the necessity of a common standard must be obvious, for without it there would be no regularity or certainty of weighing different bodies, and comparing them with each other: which entirely destroys the use of specific gravities. 1st. To determine the specific gravity of a body heavier than water. Weigh it first in air, then in water.— divide its weight in air by its loss of weight in water: this will give its relative gravity. 2nd. To determine the specific gravity of a body lighter than water. Unite it with some other body so that the compound may be heavier than water: find the specific gravity of the compound: subtract it from the specific gravity of the heavier body, and the remainder will be the specific gravity of the lighter. To find the quantity of adulteration in different metals, you must first find the specific gravity of the compound, from this subtract the specific gravity of the lighter metal, the remainder will be the relative bulk of the heavier: then the specific gravity of the compound must be subtracted from that of the heavier, and the remainder will be the relative bulk of the lighter metal: and if these remainders be multiplied by the respective specific gravities, the products will shew the proportion of weights of each metal in the body).

Of the flowing of water through orifices and pipes.

The velocity with which water flows out of orifices at different distances from the surface of the water, is as the square roots of those distances. The horizontal distance to which water will spout at different heights, is equal to twice the length of a perpendicular to the side of the vessel, drawn from the mouth of the pipe to a semicircle described upon the altitude of the fluid.- Let us see how beautifully these principles coincide with the