TREATISE

ON

SOLUBLE OR WATER GLASS,

SILICATES, &C.

FEUCHTWANGER.

Rare

A PRACTICAL TREATISE

ON

SOLUBLE OR WATER GLASS,

SILICATES OF SODA AND POTASH,

FOR

SILICIFYING STONES, MORTAR, CONCRETE,
AND HYDRAULIC LIME, RENDERING WOOD
AND TIMBER FIRE AND DRY ROT PROOF,
&c., &c., &c.

WITH

**HUNDREDS of RECEIPTS for SOAP, CEMENTS, PAINTS & WHITEWASHES,
R. R. SLEEPERS, WOODEN PAVEMENTS, SHINGLES, &c.**

BY

DR. LEWIS FEUCHTWANGER,
CHEMIST AND MINERALOGIST.

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Concluded with Various Essays on the Origin and Functions of Carbonic Acid, Limestones, Alkalies and Silica; and a Complete Guide for Manufacturing Plain and Colored Glass.

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WITH SEVERAL WOODCUTS.

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PREFACE.

The object of this Treatise on Soluble or Water Glass is to give some information to the many inquiries, which have been directed to the Author for some years past, in what manner and purpose this valuable preparation, so highly recommended by the various scientific journals, can be usefully employed. There is, as yet, no book published, treating on all its applications, with the exception of a pamphlet in French by Kuhlman in 1859, containing mostly memoirs to the French Academy and the application of the water glass by calico printers and cotton manufacturers. It is for this reason that the Author felt the necessity of compiling, all that is scattered, abont the various uses of the soluble glass, in all the journals and Patent-Office reports. Not a day passes without receiving orders for samples, either in dry liquid or jelly state, with particular requests for explicit directions; nor does a day pass without being importuned by strangers and curious people, all desirous for information how the soluble glass would answer for many purposes in domestic economy. The soap-maker, who has been using it in Europe and this country for a number of years, wants to know more on the subject of producing a cheap and good soap. For slates, for a good and cheap whitewash, for a fire-proof paint, for a hoop-skirt or shirt-collar, for a mucilage, a fire and water proof cement, and for many hundred other uses the inquiries are made; and thousands of samples have, for the last ten years, been distributed to the inquisitive and speculative applicants.

It is generally known that the Author was the first to introduce the soluble glass in the United States, and has devoted much time in experimenting with it; and he has succeeded, after many fruitless trials, to create a demand in many branches of industry. From the extensive list of patents issued in Europe and the United States, he has collected all information, along with that obtained from the scientific and practical journals, and experimenters will find in this Treatise the various uses and applications. Kuhlman's Pamphlet, the Mining and Engineering Journal, the Transactions of the American Institute, the Manufacturer and Builder, Scientific American, the Annual of Scientific Discovery, have all furnished material for this Treatise.

Many interesting topics, such as the origin of the saltpetre and nitrate of soda and the manufacture of blanc fix, had to be related, and will, no doubt, interest the general reader.

Particular attention has been bestowed upon the formation of hydraulic cements and artificial stone, for the reason that more inquiries and experiments are performed in this branch than in any other of domestic economy; the natural stones, such as the brownstone, sandstone, limestone and brick building, will, sooner or later, after an exposure to the atmospheric elements and rain and frost, become decomposed; cracks and fissures will then produce the deterioration, while coated with the soluble glass, and mixing the mortar with the same and impregnating the bricks, much is gained for their preservation.

The editor of the Scientific American states, in a late article, that "it is somewhat remarkable that long before this the art of making artificial stone has not been brought to perfection. Yet, if we may judge from the great and increasing variety of processes, patented and otherwise, which now press their claims upon public notice, the time is ripe for the introduction of any process which can demonstrate practically its capacity to fulfill the requirements of the case." He states further: "We have, for the last two years, availed ourselves of every opportunity afforded us to examine and test specimens of artificial stone, and have met with many kinds which have very little merit. Some, however, are really good stones, and, as such, must, in our opinion, come largely into use."

The silicification of R. R. sleepers, wooden rails and blocks for pavement is in importance next to the preparation of artificial stone. The comparison of the wooden and iron rails has also been clearly stated here, and the future will, no doubt bring to light many facts here stated but not yet put to practice. The advantages of the wooden block pavement over all other kinds such as Macadamizing, gravelling, cinders, boulders and stone blocks are numerous, and if properly laid will withstand long years of the hardest kind of travel, and there are but two important points in the wooden pavement to be observed, which are a firm and even foundation and the good silicification of the foundation planks and blocks.

The reason why the Author has devoted so much space upon hydraulic limes, mortars, paints, whitewashes and the preparation for guarding timber against dry rot and conflagration is solely to prove and make it plausible that the application of soluble glass possesses great advantages, and may, with very little expense, give additional safeguards.

The receipts and directions for preparing an immense number of the most useful vehicles, cements for buildings and sidewalks, paints, varnishes, &c., cannot but be very acceptable.

At the close of the treatise the author added several essays which refer to the main subject, such as that on carbon and carbonic acid, in order to explain the wonderful properties of the latter, the effect the same has in the application of the carbonic acid gas to hydraulic lime, and to the construction of buildings. The other, on limestone, is proved for the purpose of throwing some light, in a philosophical point of view, on the sources and functions of this all pervading natural substance.

The essay on the alkalies potash and soda was written merely to show the sources from where they are derived.

The article on sand or silica is partially taken from the transactions of the polytechnical branch of the American Institute, before whom the author delivered a lecture on this subject, and he has added as a guide for the glass manufacturer all the details for producing plain and colored glass, and an extract of an article on the green sand of New Jersey, by Joseph B. Lyman, on account of the peculiar properties of that substance, which may at some future day be employed in the production of silicates. The manufacturers of glass will find this treatise a useful guide.

CONTENTS OF THIS TREATISE.

SOLUBLE GLASS,

Also called water glass, liquid quartz, or alkaline silicate, consists essentially of silex and one or two alkalies heated to fusion; it is, therefore, a silicate, either as silicate of potassa, silicate of soda, or a mixture of these two alkalies, a silicate of potassa and lime, the composition of Bohemian glass, or a silicate of soda and lime, like the English crown or spread glass; and if there is oxide of lead added to the mixture of silex and alkalies, and heated to continued fusion, we obtain thereby a flint glass, crystal glass, or strass, a paste used in mock jewelry.

According to the quantity of alkali employed in the mixture, the product is made soluble or insoluble. Bottle and window glass, for instance, which contain less alkali and some oxide of iron and alumina (clay), are more difficult of fusion than other kinds. The soluble glass was brought to practical uses by Professor Fuchs, of Munich in Bavaria, in the year 1823, by igniting strongly in a refractory furnace or crucible for six hours, a mixture of 10 parts of pearl ashes, 15 parts of powdered quartz, or fine sand, and 1 part charcoal: the mass was then pulverized and added in small portions to boiling water, until the whole is dissolved and evaporated to a specific gravity of 1.25, at which point the carbonic acid of the atmospheric air ceases to decompose it. The highest concentration of the liquid is 42° B; when still more evaporated it is obtained in a solid form, resembling common glass, but much softer and more fusible. The liquid standing about 30° B is, however, the most proper menstruum for application to wood, and preventing the same from being attacked or kindled by sparks of fire, such as shingle roofs, wooden bridges and farm houses. Fuchs prepared four different liquids, and employed them in his experiments:

1. The simple water glass, made from potassa.
2. The soda water glass.
3. The compound of both.
4. Another liquid which he used for fixing paints on a coating on wood, and called the jelly liquid.

In order to demonstrate the utility of the water glass in making wood fireproof, and on the occasion of the burning of the Royal Theatre at Munich, a wooden shanty was, by order of the King, erected, and coated inside and outside with a weak liquid of silicate of potassa, and was set on fire on each corner; to the satisfaction of all spectators it resisted the element nobly, and merely charred the wooden structure, without producing a life fire; and from that time the water glass was introduced in Germany. A few years later the same liquid was introduced in the manufacturing districts of England as a substitute for cow's dung by the cotton mills, and was called "Dunging Salt."

The author having studied with Doebereiner, a professor of practical chemistry in Jena, who was engaged in experiments on water glass, and who proposed an alteration in its composition, such as the compound of potash and soda, or 72 parts of carbonate of potash, 854 parts of carbonate of soda, and 152 parts of finely pulverized quartz, which proved to be a better substance, conceived the idea that water glass may be profitably employed in this country for many purposes. In company with ship captains and builders he offered to substitute it for coppering vessels, which is attended with that expensive metal the copper sheathing, and undertook to prepare the ship's timbers in such a manner that the cells of the wood could be filled up with Silica, or, in other words, to silicify them, and produce a petrification of the organic substance, all of which at a very inconsiderable expense, in the Brooklyn Navy Yard, he was permitted by the Ordnance Department, under the direction of Commodore Perry, then the Captain of the Yard, to perform the experiments with the spiles on the various docks, which were destroyed by the worms (*Teredo navalis*) so fast that they had to be replaced every three years. Also the cannon balls, exposed to the weather, becoming rusty and worthless in a few years, were varnished with his own preparation, and the addition of asphaltum, and his experiments proved highly satisfactory, as in both instances of applications many years afterwards indicated their preservation.

The water glass was neglected for many years except by the military authorities in Prussia, and we hear that the soldiers were instructed to wash their linen, and the State Prison at Spandau introduced it for washing the prisoners' under garments; and it was proved so economical that one gallon of concentrated liquid was sufficient for washing 1,000 pieces. The soap manufacturers began to use it in England for producing a cheap soap. Liebig devoted, in the year 1850, much attention to the subject, and at the same time Kuhlmann introduced it as a new paint under the name of stereochromic painting, for ornamenting the interior of houses. He applied the fluid silicate of potassa, obtained by dissolving flints in caustic alkali, with the aid of water of a very high temperature, to harden chalk and porous stone; for he observed that on soaking chalk with this fluid silicate, a change took place: part of the chalk, combining with the silicic acid of the silicate of potash, becoming converted into silico carbonate of lime, the carbonic acid, thus set free, combined with the potash, in time, particularly when assisted by heat and dry air, the coating of silico carbonate was found to pass into a true compact deposit of silica, hard enough to scratch glass. The solution of silicate of potash could be applied either with a brush or a syringe, the surface being first cleaned and scraped. Three applications were considered sufficient. Although successful in the laboratory, this method failed when applied to buildings, because a dry atmosphere is needed during the whole period of hardening. Not long after this suggestion had been made by Kuhlman, the English manufacturer, Ransome, of Ipswich, engaged in the manufacture of silicate of soda, following up the above experiments, attempted to fix the solution, when absorbed with the stone, to produce a double decomposition by absorbing another solution, thus leaving an insoluble deposit within the substance of the absorbent stones on which it was desired to act. He found that, by a weak acid solution, he could set free the silica, but in that state the deposited mineral had no cohesion. Following up, however, the application of the fluid silicate by a small portion of chloride of calcium (a waste product from the salines and acetic acid manufacturers), it resulted that the chlorine, parting from the calcium, attacked the soda of the silicate, forming common salt, which is easily dissolved away, while the silica acid, set free and combining with the lime, formed with it silicate of lime: This mineral is nearly insoluble, very hard, and adheres with great tenacity to foreign substances, as is illustrated in common mortar. Silicate of lime thus formed resists carbonic acid and dilute sulphuric acid, and is little affected by any of the common alkalies or ammonia.

The effect of this treatment on stones that have not already been inserted into buildings has been very favorable, and they appear to have stood without decay under exposures sufficient to produce much injury on the same stone unprotected and applied on a large scale to buildings that have already shown symptoms of decay, the result is less satisfactory; but years must elapse before a very decided opinion can be given on the process. After some time we will be able to see the result in the Houses of Parliament and Westminster Abbey, where the magnesian limestone has been treated by this process.

A combination of Kuhlman's process with a temporary wash of some bituminous substance has been tried on a large scale in the Speaker's Court of the Houses of Parliament, by Szereling, which will likewise be decided after some time upon its superiority.

The manufacture of the water glass, or soluble silicate, or soluble glass, has only been known since our present time, although the various kinds of glass, imitation of gems, belongs to antiquity, for Pliny states "that glass was first discovered by accident in Syria, at the mouth of the river Belus, by certain merchants driven thither by the fortune of the sea, and obliged to continue there and dress their victuals by making a fire on the ground, where there being great store of the herb *kali*, that plant burning to ashes, its salts, mixed and incorporated with sand or stones fit to vitrify or make glass." The word kali was explained by Boerhave as one of the materials of glass, *salt* and *sand*; the salt here used is procured from a sort of ashes, brought from the Levant, called polverine or rochetta, which ashes are those of a sort of water plant called kali, of the species of that found in some parts of England, called frog-grass, or crab-grass, cut down in summer, dried in the sun, and burnt in heaps, either on the ground or on iron grates, the ashes falling into a pit, grow into a hard mass or stone, fit for use." This material evidently means the kelp, which was burnt and converted into Barilla. It is also certain that Kunkel, in 1679, states that the art of glass was already brought to its highest perfection, and expressed that Neri in his treatise, "De Arte Vitraria," has communicated complete knowledge of artificial gems—much is said of flexible glass not rotting, of a fusible or soluble glass, of which Van Helmont, the chemist of the first part of the seventeenth century, knew nothing. The improvements in the manufacture of the soluble glass, particularly that of soda, were of great importance. He had, in the first place, discarded the sand, which he did not find compact enough for producing a good paint, and substituted the flints, found in the chalk: this species of silex he exposes under a pressure of 7–8 atmospheric, in an iron cauldron, to a hot soda lye standing 38°, which process was patented by the brothers Siemens, in the year 1845, with this difference, that they produce a liquid at a very high temperature corresponding in vapors of 4–5 atmospheres, by which process they obtain for 3–4 time the quantity of silica to a thin liquid.

Liebig proposes the employment of the infusorial earth, which dissolves readily the caustic soda lye, whereby he obtains 240 parts of silica jelly from 120 parts infusorial earth, and 75 parts soda ash. It is well known that the infusorial earth is pretty pure silica of 87 per cent. and 8 per cent. water. The beds of Bilin, in Bohemia, and belonging to the fresh water Tertiary, have a thickness of 14 feet, also in Planitz, in Saxony. Ehrenberg estimates that about 18,000 cubic feet of the siliceous organisms are annually formed in the harbor of Wismar, in the Baltic Sea; the deposit of infusorial earth in Richmond, Va., contains over 100 species, and forms a thick stratum.

SILEX, OR SILICA.

This substance is an oxyde of silicium, and being the main body of our preparation deserves a full and detailed description.

Silicium is the metallic basis of silica, or silex, and is equally abundant with oxygen as a constituent of the solid surface of the globe, and also constituting a large portion of aerolites, from the regions of space, and this metallic base was discovered by Berzelius, in 1823, and is obtained artificially in the following manner:—Weil dried silico fluoride of potassium, 10 parts, are mixed with 8 or 9 parts potassium in an iron or glass tube, and the potassium fused and stirred with the salt by an iron wire. It is then heated by a spirit lamp, when it suddenly becomes ignited from the reduction of silica by the potassium forming a brown mixture of fluoride and siliciuret of potassium. It is thrown in cold water, when hydrogen is evolved, the potassium of the silica not being oxydized by water and the silicium separating. When the effervescence has ceased, the solution is poured off, fresh cold water added and poured off, until it ceases to be alkaline, when boiling water is used to wash the silicium as long as it extracts anything.

Silicium is inflammable in the air, by heat, about one-third burning to silica, which removed by fluohydric acid, leaves a dark, chocolate, brown powder, heavier than oil of vitriol, is combustible either in the air or oxygen, or even when gently ignited with saltpetre.

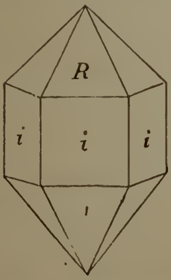
Silica, or oxide of silicium, is synonymous with silicic acid, silex and pure sand, or quartz, in its various forms and appearances, and constitutes a very large proportion of the solid crust of the globe, dnd is the principal constituent of all simple minerals, and forms a greater variety of salts than any other acid. It is easily prepared pure from powdered quartz, sand, Felspar, or other silicious minerals, by fusing them with four times their weight of a mixture of carbonate of potassa and soda, or by either carbonate alone, dissolving when in dilute muriatic acid, filtering and evaporating the solution to dryness by a gentle heat, digesting in muriatic acid, filtering and washing with hot water.

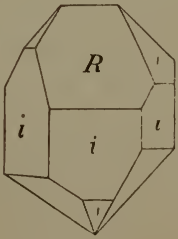
This silica has two modifications, the one soluble in water and acids, the other insoluble. The soluble is that obtained in the above process for preparing silica, and is always formed by fusing silicates with alkalies, but may also be formed by boiling fine Silex with strong alkaline solutions.

It is soluble in water and acids, and when the solutions are concentrated it usually separates as a jelly [gelatinous silica], and when evaporated to dryness, passes into the insoluble modification.

Silica is a white, gritty powder, insoluble in water and acids, infusible in the highest heat of our furnaces, but fusible in a stream of oxygen driven through an alcohol flame. It fuses in this case to a clear glass, which may be drawn out into flexible threads. When the fused bead is dropped in water, it becomes so hard as to indent a steel pestle and mortar. It is the feeblest acid at common temperatures, but by a high heat can expel all volatile acids.

Quartz is found in nature crystallized in a great variety of forms, the rhombohedral prevailing, and for the most part hemihedral to the rhombohedron, or tetrahedral to the hexagonal prism. The annexed two figures give some idea of its occurrence:





The cleavage is very indistinct, sometimes effected by plunging a heated crystal in cold water. The crystals are either very short or very much elongated, sometimes fine acicular usually implanted by one extremity of the prism, occasionally twisted or bent. The prismatic faces commonly striated horizontally, and thus distinguishable, in distorted crystals from the pyramid. Crystals often grouped by juxtaposition, not proper twins, frequently in radiated masses with a surface of pyramids, or in druses having a surface of pyramids or short crystals. Herkimer and Ulster Counties, of the State of New York, produce quartz crystals of the most complicated forms, which occur from the size of a pin's head to that of a foot. Quarts is also found massive, from the coarse or fine granular to flint-like or crypto-crystalline; sometimes mamillary stalactitic, and in connectionary forms.

Quartz has a hardness—7, and a specific gravity of 2.65; a vitreous lustre sometimes inclining to resinous; splendent and nearly dull; is colorless when pure, but often having various shades of yellow, red, brown, green, blue and black. The streak is white of pure varieties; of impure often the same as the colors, but much paler. Quartz is transparent and opaque; its fracture is perfect conchoidal and subconchoidal, is tough, brittle and friable. The polarization of quartz is circular, there being a colored centre instead of a central cross, and the rings of color around enlarging as the analyzer is turned to the right in right-handed crystals, or left, in left-handed, and colored spirals are seen which rotate to the right or left when the incident light and emerged light are polarized, one circularly, and the other plane.

Pure silica, which has the symbol of $\dddot{\mathrm{Si}}$, consists of 53–33 parts oxygen, and 46–67 silicon—100. It is unaltered if brought alone before the blow-pipe, but with soda, it dissolves with effervescence; it is unacted upon by any salt of phosphorus; it is only soluble in fluohydric acid. There are two varieties of quartz in existence—

I. The crystallized, or phenocrystalline, which is vitreous in lustre.

II. The fluid-like, massive, or crypto-crystalline.

The first division includes all ordinary vitreous quartz, whether having crystalline faces or not; while the second variety has been acted upon somewhat more by attrition and chemical agents, as fluoric acid, than those of the first.

The following species of quartz belong to the phenocrystalline, or vitreous varieties:

1. The ordinary crystallized quartz, rock crystal, which is the colorless quartz, or nearly so, whether in distinct crystals or not.

a. The regular crystals, or limpid quartz.

b. The right-handed crystals.

c. Left-handed crystals.

d. Cavernous crystals, having deep cavities parallel to the faces, occasioned by the interference of impurities during their formation.

e. Cap quartz, made up of separable layers or caps, one to the deposit of a little clayey material at intervals in the progress of the crystal.

f. Drusy quartz, a crust of small or minute quartz crystals.

g. Radiated quartz, often separable into radiated parts, having pyramidal terminations.

h. Fibrous, rarely delicately so, from Cape of Good Hope.

2. Asteriated quartz, star quartz, containing within the crystal whitish or colored radiations along the diametral planes. Part, if not all, asteriated quartz is asteriated in polarization, as already remarked.

3. Amethystine quartz, amethyst, clear purple or blueish-violet; the color is supposed to be due to manganese, the shade of violet is usually deepest parallel to the planes R.

4. Rose, rose red or pink quartz. It becomes paler on exposure, common, massive; and then usually much cracked, lustre sometimes a little greasy. The action is, according to Fuchs, due to titanic acid; the general impression is, however, that its color is owing to manganese.

5. Yellow, false topaz, yellow and pellucid, or nearly so, resembling somewhat yellow topaz; but very differant in crystallization, and in absence of cleavage.

6. Smoky quartz; the Cairngorm stone. It is smoky yellow to smoky brown, and often transparent, but varying to brownish black, and then nearly opaque, in thick crystals. The color is probably due to titanic acids, as crystals containing rutile are usually smoky. It is called Cairngorm, from the locality in Scotland.

7. Milky, milk white, and nearly opaque; lustre often greasy, called then greasy quartz.

8. Siderite, or sapphire quartz, of indigo, or Berlin blue colors. A variety of quartz occurring in an impure limestone at Golling, in Salzburg.

9. Sagenitic, containing within acicular crystals of other minerals: these acicular crystals may be rutile, or black Tourmaline, or Gœthite, stilbite, asbestos, actinolite, hornblende, or epidote.

10. Cat's eye, exhibiting opalescence, but without prismatic colors, especially when cut in cabochon, an effect due to fibres of asbestos.

11. Aventurine quartz, spangled with scales of mica or other mineral.

12. Impure quartz, from the presence of distinct minerals distributed densely through the mass, such as ferruginous, either red or yellow oxide of iron,

chloritic from chlorite, actinolitic, micaceous, arenaceous owing to sand.

Quartz crystals also occur penetrated by various minerals as topaz, corundum, chrysoberyl, garnet, different species of hornblende and Pyroxene groups, kyanite, zeolites, calcite and other carbonates of rutile, stilbite, hematite, Goethite, magnetite, fluorite, gold, silver, anthracite, &c. As quartz has been crystallized through the aid of hot waters or of steam, in all ages down to the present, and is the most common ingredient of rocks, there is good reason why it should thus be found the enveloper of other crystals.

13. Quartz containing liquids in cavities. These liquids are seen to move with the change of position of the crystal, provided an air bubble be present in the cavity ; they may be detected also by the refraction of light ; the liquid is either pure water, or a mineral solution, or petroleum-like liquid.

II. The crypto-crystalline varieties of quartz are the following :

1. Chalcedony ; it has the lustre nearly of wax, and is either transparent or translucent ; the color is white grayish, pale brown to dark brown, black, tendon color common, sometimes delicate blue ; also of other shades, and then having other names ; it is often mammillary, botryoidal, stalactitic, and occurring lining or filling cavities in rocks.

2. Carnelian; a clear red chalcedony, pale to deep in shade, also brownish red to brown; the latter called sardonyx, reddish brown by transmitted light.

3. Chrysoprase; an apple green chalcedony; the color is due to the presence of oxide of nickel.

4. Prase; translucent and dull leek green; taking its name from the Greek *πῤωσόν*, a leek.

5. Plasma; a rather bright green to leek green, and sometimes nearly emerald green color, and subtranslucent or feebly translucent, sometimes dotted with white.

Heliotrope, or bloodstone, is the same stone essentially, with small spots of red jasper, looking like drops of blood.

The jasper of the ancients was a semi-transparent or translucent stone, and included, in Pliny's time, all bright colored chalcedony, excepting the carnelian; the same author gives special prominence to sky blue and green, and mentions also a shade of purple, a rose color, the color of the morning sky in autumn; sea green, sepenthine color (yellow, like sepentine), smoke color, but in general there is a tinge of blue, whatever the shade.

6. Agate; a variegated chalcedony; the colors are either banded or in clouds, or due to visible impurities.

(Banded agate), where the bands form delicate parallel lines of white, tendonlike, waxlike, pale and dark brown and black colors, and sometimes bluish and other shades, they follow waving or zigzag courses, and are occasionally concentric circular, as in the eye agate. The fine translucent agates graduated into coarse and opaque kinds. The bands are the edges of layers of deposition, the agate having been formed by a deposit of silica, from solutions intermittently supplied in irregular cavities in rocks, and deriving their concentric waving courses from the irregularities of the walls of the cavity. As the cavity cannot contain enough of the solution to fill it with silica, an open hole has been supposed to be retained on one side to permit the continued supply, but it is more probable that it passes through the outer layers by osmosis, the denser solution outside thus supplying silica as fast as it is deposited within. The colors are due to traces of organic matter, or of oxides of iron, manganese, or titanium, and largely to differences in rate of deposition. The layers differ in porosity, and therefore in the rate at which they are etched by fluoric acid, and consequently the etching process brings out the different layers, and makes engravings that will print exact pictures of the agate. Owing also to the unequal porosity, agates may be varied in color by artificial means.

Irregularly clouded agate, the colors various, as in banded agate.

A whitish, clouded variety, which Pliny has described and given fully the characters.

V. Colored agate, due to visible impurities; a moss agate, or mocha stone, filled with brown moss-like or dentritic forms, distributed through the mass of dentritic agate, containing brown or black dentritic markings. These two have been fully described by Pliny as dentrachates.

There are also eight agatized woods, wood petrified with clouded agate.

7. Onyx, like agate, in consisting of layers of different colors, but the layers are in even planes, and the banding therefore straight, and hence its use for cameos, the head being cut in color, and another serving as the background.

The colors of the best are perfectly well defined, and white and black, or white, brown and black alternate.

8. Sardonyx, like onyx in structure, but includes layers of carnelian, along with others of white, or whitish and brown, and sometimes black colors.

9. Agate jasper. An agate, consisting of jasper with veinings and cloudings of chalcedony.

10. Siliceous sinter. Irregularly cellular quartz, formed by deposition from waters containing silica, or soluble silicates in solution.

11. Flint. Somewhat allied to chalcedony, but more opaque and of all colors, usually gray, smoky

brown, and brownish black. The exterior is often whitish, from mixture with lime or chalk, in which it is imbedded. Lustre barely glistening, subvitreous; breaks with a deeply conchoidal fracture and a sharp cutting edge. The flint of the chalk formation consists largely of the remains of infusoria, sponges, and other marine productions. This mineral contains, according to Fuchs, partly soluble silica.

12. Hornstone. It resembles flint, is more brittle, and fracture more splintry. Chert is a term often applied to hornstone, and to any impure flinty rock, including the jaspers.

13. Basanite, lydian stone, or touchstone. A velvet black siliceous stone or flinty jasper, used on account of its hardness and black color for trying the purity of the precious metals. The color left on the stone after rubbing the metal across it indicates to the experienced eye the amount of alloy. It is not splintry, like the hornstone: it passes into a compact, fissile, siliceous or flinty rock of grayish or other colors, called siliceous slate, and resembles ordinary jasper, of various shades.

14. Jasper. An impure opaque colored quartz.

a. The reducing to hematite, or sesquioxide of iron.

b. The yellow or brown, colored by the hydrous sesquioxide of iron, and becoming red when so heated as to drive off the water.

c. The dark green and brownish green.

d. The grayish blue.

e. Blackish or brown black.

f. Striped or ribbon jasper, having the colors in broad stripes.

g. Egyptian jasper in nodules, which are zoned in brown and yellow colors.

Porcelain jasper is nothing but a baked clay, and differs from true jasper in being fusible on the edges before the blowpipe. Red porphyry, or its base, resembles jasper, but is also fusible on the edges, being usually an impure felspar.

Quartz is also found in the following forms:

1. Granular quartz, or quartz rock, which consists of quartz grains very firmly compacted, the grains often hardly distinct.

2. Quartzose sandstone.

3. Quartz-conglomerate. A rock made of pebbles of quartz with sand. The pebbles are sometimes jasper or chalcedony, and make a beautiful stone when polished.

4. Itacolumite, or flexible sandstone. A friable sand rock, consisting mainly of quartz sand, but containing a little talc, and possessing a degree of flexibility when in thin laminae.

5. Buhrstone. A cellular flinty rock, having the nature in part of coarse chalcedony.

6. Pseudomorphous quarts. Quartz appears also

under the forms of many of the mineral species, which it has taken through either the alteration or replacement of crystals of those species. The most common quartz, pseudomorphs, are those of calcite, baryta, fluorite and siderite. Tabular quartz, Haytorite, Beckite, Babel quartz, silicified shells and silicified wood are found pseudomorphized by other minerals, either of carbonate lime, Datholite, fluorspar, shells and wood. The texture of the wood, for instance, is well retained, it having been formed by the deposit of silica, from its solution in the cells of the wood, and finally taking the place of the walls of the cells as the wood itself disappeared.

Dissolved quartz, or liquid silica, occurs often in heated natural waters, as those of the Geysers of Iceland, New Zealand and California, mostly as a soluble alkaline silicate.*

Quartz is one of the essential constituents of granite, syenite, gneiss, mica, shist and many related rocks. As the principal constituent of quartz rock and many sandstones, as an unessential ingredient in some trachyte porphyry, &c.; as the veinstone in various rocks, and for a large part of mineral veins; as a foreign mineral in the cavities of trap, basalt and related rocks, some limestones, &c., making geodes of crystals or of chalcedony, agate, carnelian, &c., as imbedded nodules or masses in various limestones containing the flint of the chalk formation, the hornstone of other limestones; these nodules becoming sometimes layers or masses of jasper occasionally in limestone. It is the principal material of the pebbles of gravel beds and of the sands of the seashore and river sandbeds.

Independent of the quartz proper, as has been just described, nature produces a vast many minerals composed either solely of silica, with slight variations in their degree of hardness or specific gravity, such as the following:

The opal, which is sub-divided, in

1. The *precious opal*, exhibiting a play of delicate colors.

2. The *fine opal*, of hyacinth red to honey-yellow colors.

3. The *girasol*, of bluish white color, with reddish reflections in a bright light.

4. The *common opal*, in part translucent, and milk-white to greenish, yellowish, bluish. Resin opal, wax or honey color, with resinous lustre. Olive green opal; brick-red opal; hydrophane, a translucent opal, whitish or light colored, adheres to the tongue, and becomes more translucent or transparent in water, wherefore its name. An orange, yellow opal, called Forcherte, it is colored by orpiment.

5. *Cachelong.* Opaque and bluish white, porcelain white; often adheres to the tongue.

6. *Opal agate.* Agatelike in structure, but consisting of opal of different shades of color.

7. *Menilite.* In concretionary forms, tuberose, reniform; opaque, dull gray and grayish brown.

8. *Jaspopal.* An opal, containing some yellow oxide of iron, and having the color of yellow jasper.

9. *Wood opal.* Wood petrified by opal.

10. *Hyalite.* Clear as glass and colorless, constituting globular concretions and crusts.

11. *Florite*, or siliceous sinter; also called pearl sinter, from Santa Fiora, in Italy, and other volcanic rocks, formed from the decomposition of the siliceous minerals of volcanic rocks, or from the siliceous waters of hot springs.

12. *Float stone;* also called swimming quartz; is light, concretionary or tuberose masses, white or grayish, sometimes cavernous.

13. *Tripolite.* Infusorial earth; formed from the siliceous shells of diatomous and other microscopic species, occurring in deposits often miles in area either uncompacted or moderately hard.

- *a. Infusorial earth*, or earthy tripolite, is a very fine grained earth, looking often like an earthy chalk or clay; but harsh to the feel, and scratching glass, when rubbed on it.
- *b. Randanite;* a kaolin-like variety from France.
- *c. Tripoli slate.* A slaty or thin laminated variety; fragile, often mixed with clay, magnesia and oxide of iron.

d. Alumocalcite. A milk-white material, very light, having a hardness of only 1 to 1¼, and a sp. gr. of 2.174, and probably a variety of tripolite.

This mineral is, probably, the most economical and useful material for the manufacture of the soluble glass.

The opal family is likewise a quartz, but a little softer and contains some water, is soluble in a heated solution of potash, while quartz does not.

In England and France the flints from the chalk are mostly employed in the manufacture of soluble glass; but in the United States clear sand, from the river-bed of New Jersey and Mississippi Rivers, are solely used in its manufacture. Sand generally consists of particles of quartz, but there is also a granitic sand, containing particles of felspar as well as quartz, where it has not been long enough exposed to meteoric agents to decompose the felspar. Sand usually consists of grains more or less rounded, but sometimes angular, and then preferable for mortar. There are several varieties of the sandstone, such as *micaceous*, *argillaceous*, *marly* and *flexible*. *Common sand* is mainly comminuted quartz. *Gravel* is a mixture of sand with pebbles. *Volcanic sand* is sand of volcanic origin: either the cinders or ashes or comminuted lava. *Alluvial sand* is the earth deposited by running streams, especially during times of flood;

it constitutes the flats on either side of the stream, and is usually in thin layers, varying in fineness or coarseness, being the result of successive depositions. In order to use the sand for the manufacture of soluble glass, which shall equal that manufactured from flint, or infusorial or siliceous earth, it is best to digest the sand with chlorohydric acid, which is capable of dissolving all the foreign substances, and then by frequent washings and drying in the sun, produces a pretty pure silica. Iron, clay, lime, which are, more or less, found in the mud, may easily be detected by the various chemical tests, such as by ammonia, the iron; by oxalate of ammonia, the lime; and clay, by carbonate of soda.

If the pure crystallized quartz, flint or hornstone should be used for the manufacture, the same must be reduced into coarse or granular condition, which is effected by calcining the mineral, and when red hot, cold water is thrown over it, whereby it becomes disintegrated and falls to pieces, and it is then ground in mills used by the glass manufacturers.

Before closing the chapter of silica, it must be stated that nature has given us a vast variety of silicates: that the alkaline silicates of soda, potash and lime, which are called the soluble silicates, are spread over the globe in such quantities, like oxygen compounds with the addition of many other bases in nature, that there are very few mineral substances known in which silica, representing the acid, is not combined with the various elements and forming silicates which are again divided in anhydrous and hydrous silicates, all of them having ternary oxygen compounds. The anhydrous silicates are again sub-divided, as 1. *Bisilicates;* 2. *Unisilicates;* and 3. *Sub-silicates;* while the hydrous silicates are again divided in various sections. The whole crust of the globe consists in silicates. The felspar mica is a pure silicate. We have a soda felspar, and a potash felspar, and a lime felspar, while the mica is a compound of silica combined with some other bases, such as alumina, magnesia, &c. The zeolites form a large class of silicates, which resemble the felspar, but contain water, and are less hard and more fusible, such as the analcime, chabasite, stilbite, heulandite, &c.

IN THE MANUFACTURE OF SOLUBLE GLASS, the alkali is in importance next to the quartz or silica such as the soda and potash, both of which are employed as the carbonates which ought to be pure.

The carbonate of potash, which is the pearlash, must be free from foreign saline substances. The glass manufacturers prepare that material by washing it freely with water and evaporating the solution to the formation of a precipitate of salt, and then the water is run off.

The *Soda* employed in the manufacture is the soda ash of commerce, and is never pure enough, containing water and other salts, which ought to be removed from it by dissolving, crystallizing, and then calcination of the crystals.

Sulphate of soda, or Glauber salt, has been used by some manufacturers in place of soda ash, which ought not be employed, as the same is partly converted into sulphide or sulphuret and oxsulphite of sodium, which is detrimental.

Fluorspar, a fluoride of calcium, may be added to the mixture of sand and alkali, as it produces a more fusible silicate, which will harden soon after application by the affinity for this alkali. In the production of hard cements, the fluohydric acid is of great service, for it assists in the hardening of the mortar, and forming a good, permanent cement.

White arsenic in powder [arsenious acid], and *nitrate of soda*, are used in this composition: they produce a white soluble glass; while, without any admixture, the product is green. From three to eight per cent. of either are used.

THE MANUFACTURE OF SOLUBLE GLASS.

I. The POTASH SOLUBLE GLASS.

It is obtained by mixing 15 parts powdered quartz or pure sand with 10 parts purified pearl ashes, and 1 part charcoal in a Hessian crucible, and exposing the mixture so long to a heat until the mass after six hours has become vitrified. Charcoal is employed for assisting, by its decomposition, the production of carbonic acid, as also some sulphuric acid which may have been produced. It is at present, however, omitted, and if manufactured on a large scale the vitrification is done in a reverboratory furnace capable of holding from 1,200 to 1,500 pounds. The ashes and sand must be well mixed together for some time and the furnace must be very hot before throwing the mixture in it, and must be constantly kept up until the entire mass is in a liquid condition. The tough mass is then raked out and thrown upon a stone hearth and left to cool. The glass mass so obtained appears to be hard and blistery, of blackish gray color, and if the ashes were not quite pure it will also be adulterated with foreign salts. By pulverizing and exposing it to the air it will absorb the acidity, and by degrees the foreign salts will, after frequent agitation and stirring, be completely separated, particularly after pouring over the mass some cold water, which dissolves them, but not the soluble glass. The purified mass is now put into an iron cauldron, containing five times the quantity of hot water, in small portions, and with constant agitation, and replacing occasionally hot water for that which evaporated during the boiling, and after five or six hours the entire mass is dissolved; the liquid is removed and left to settle over night, in order to be able to separate any undecomposed silex. The next day it is evaporated still more until it has assumed the consistency of a syrup, and standing 28° B, and is composed of 28 per cent. potash, 62 per cent. silica and 12 per cent. water. It has an alkaline taste, and is soluble in all proportions of water, and is precipitated by alcohol, and if any salts do effervesce they may be wiped off. The color is not quite white, but assumes a greenish or yellowish white color.

II. The MANUFACTURE OF SODA SOLUBLE GLASS: To 45 parts silica or white river sand are added 23 parts carbonate of soda fully calcined, and 3 parts charcoal, and is then treated in the same manner as the other glass. The proportions of the mixture are altered by the different manufacturers, some propose to 100 parts silex, 60 parts anhydrous glauber salt and 15 to 20 parts charcoal. By the addition of some copper scales to the mixture, the sulphur will be separated. Another method is proposed by dissolving the fine silex in caustic soda lye. Kuhlman employs the powdered flint, which is dissolved in an iron cauldron under a pressure of 7 to 8 atmospheres. According to Liebig the infusorial earth is recommended in place of sand on account of being readily soluble in caustic lye, and he proposes to use 120 parts infusorial earth to 75 parts caustic soda, from which 240 parts silica jelly may be obtained. His mode is to calcine the earth so as to become of white colors, and passing it through sieves. The lye he prepares from 75 ounces calcined soda, dissolved in five times the quantity of boiling water, and then treated by 56 ounces of dry slacked lime; this lye is concentrated by boiling down to 48 deg. B; in this boiling lye 120 ounces of the prepared infusorial earth are added by degrees, and very readily dissolved, leaving scarcely any sediment. It has then to undergo several operations for making it suitable for use, such as treating again with lime water, boiling it and separate any precipate forming thereby, which by continued boiling forms into balls, and which can then be separated from the liquid. This clear liquid is then evaporated to consistency of syrup, forms a jelly slightly colored, feels dry and not sticky, and is easily soluble in boiling water.

The difference between potash and soda soluble glass is not material; the first may be preferred in white washing with plaster of Paris, while the soda glass is more fluidly divisible.

It may be observed that before applying either soluble glass, it ought to be exposed to the air for ten to twelve days, in order to allow an effloresence of any excess of alkali, which might act injuriously. There are, however, many methods proposed to obviate this difficulty, and which will be mentioned hereafter.

III.—The DOUBLE SOLUBLE GLASS.

This is a compound of potash and soda, is prepared from 100 parts quartz, 28 parts purified pearl ashes, 22 parts anhydrous bicarbonate of soda, 6 parts of charcoal, which are spread in such manner as already described. If the mass is fully evaporated to dryness forms a vitreous solid glass which cannot be scratched by steel, has a conchoidal fracture, of sea-green color, translucent and even transparent, has a specific gravity of 1.43.

IV. The SOLUBLE GLASS, after Kaulbach, for the use of sterro-chromic painting.

It is obtained by fusing 3 parts of pure carbonate soda and 2 parts powdered quartz, from which a concentrated solution is prepared, and 1 part of which is then added to 4 parts of a concentrated and fully saturated solution of potash glass solution, by which it assumes a more condensed amount of silica with the alkalies; and which solution has been found to work well for paint. Siemen's patent for the manufacture of soluble glass, consists in the production of a *liquid quartz* by digesting the sand or quartz in a steam boiler tightly closed and at a temperature corresponding to 4–5 atmospheres, with the common caustic alkalies, which are hereby capacitated to dissolve from three to four times the weight of silica to a thin liquid. The apparatus, which was patented in 1845, is well known in this country; as some persons, many years later, obtained a patent for the same apparatus in the United States, which on inspection does not differ from that of Siemens Brothers.

Description of Siemen's Apparatus for dissolving silica in soda lye, under a pressure of five atmospheres, or sixty pounds to the square inch.

The whole apparatus consists of the boiler A, and the dissolving kettle B.

Fig. 1 represents the front side, and 2 the horizontal. A and B are connected by the pipe *a*. The kettle B is constructed of two strong walls, with a space *b* of the width of 1–2 inches.

The steam passes through the pipe *a* into the space *b*. In order to reach the inner kettle, which is perfectly tight, the wall *c* has to be unscrewed. Under the middle of this wall the box *d* is now attached, which encloses the iron pipe *e*, passing through the length of the kettle. Then the shovels, or agitators, *f f*, are now applied with a wheel *g* at the end for effecting the revolutionary movement. The steam-cocks *h* as seen at the front wall *c*, for indicating the stage of the water in the interior kettle; the cock *i* serves for pumping and discharging the solution, and the cock *k* for letting off the water, which was condensed in the steam chamber C.

The outer kettle is surrounded with ashes, or any other non-conducting substance.

The boiler is supplied with ventils and manometers, and the kettle B is tested to stand a pressure of 80–100 pounds per square inch.

The kettle is now filled with the necessary quantity of silex, after the front wall has been screwed on by means of the cock *i*, and is filled up with the caustic lye, which is composed of 100 lbs. carbonate of soda

APPARATUS FOR DISSOLVING QUARTZ

UNDER PRESSURE OF FIVE ATMOSPHERES.

Fig. 1

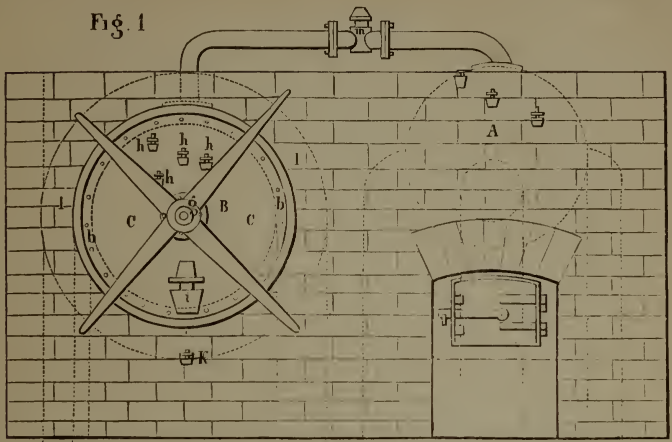
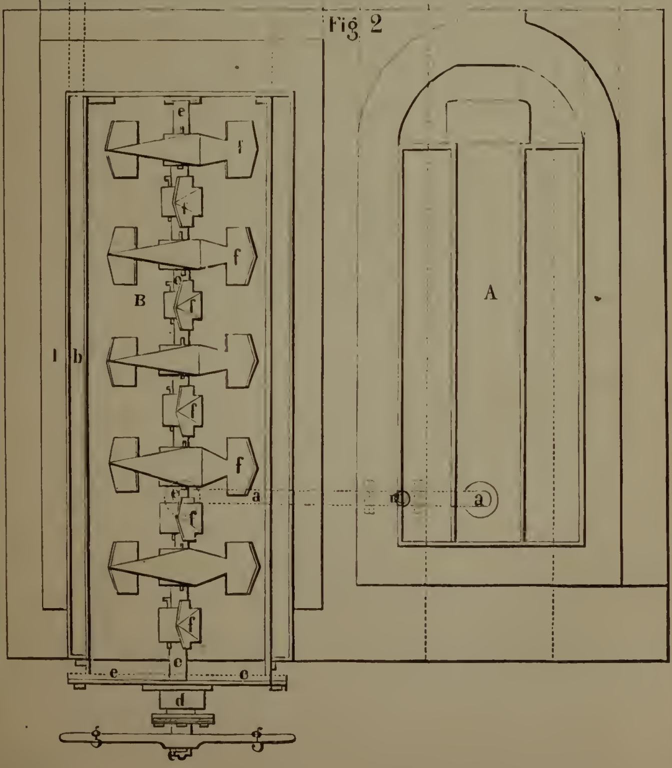


Fig. 2



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to 20 gallons water, and 1 lb. of silex for each quart of water; when filled, and the steam having assumed the tension of 60 lbs. to the square inch, as indicated by the safety ventil, the cock *m* is opened, when the steam passes to the other kettle, and condenses on the cold wall of the inner kettle; here the temperature is raised, and assumes soon a pressure of sixty pounds, which point is indicated by the escape of steam from the safety valve. Fire is now kept up for six to eight hours under a constant escape of vapor.

During all this time the shovels or agitators are kept in motion by the workmen, and then the silex contained in the kettle will have dissolved from 80–90 per cent., and is drawn off, and may be re-filled for a new operation.

The apparatus may undergo some modification as the agitators get a different form, etc., etc.

The silica to be employed is, as already stated to be, the common sand, which is at first calcined and thrown in water; when dry, it is ground as fine as flour.

The liquid silica when discharged from the kettle may be evaporated to dryness, when it assumes a compact mass, a vitreous and conchoidal fracture and a hardness, so as to give sparks on steel, without the brittleness of flint.

The solution as it is obtained from the kettle may be converted into a white fine stone, by adding fine sand, until it assumes a plastic mass, say 3–4 parts with the addition of a little chalk or lime and white clay; by exposing this mass when formed into pressed stones or objects to the atmosphere for some time, the stone is now in the best condition.

Instead of fine sand, fine powdered dry silicate may be substituted, and a better stone thereby obtained.

When the mass is dried, it must undergo the pressure of a hydraulic press.

The addition of chloride of calcium and chloride of iron, either in liquid state or in dry powders, is highly recommended for promoting the hardening process.

Siemens' remarks of the application of the silex liquid, that the sand to be employed must be first calcined and then thrown into cold water, and afterwards ground into fine powder, which, when mixed with his liquid, becomes compact, insoluble and white, possessing a vitreous and conchoidal fracture, and a hardness so as to give sparks by steel.

The same gentleman also recommends for the production of a white stone, to work up the fine silex with so much liquid soluble glass so as to form a plaster mass, say from 3–4 parts of the sand may be required, similar to potter's clay, and adding, at the same time, a small quantity of chalk and fine clay, whereby the mass becomes more uniform and compact. Prepared in this manner, objects moulded or pressed from the mass must be exposed to the air for some time.

For monuments, millstones and other building material, he uses 1 part liquid silica to 2 parts fine sand and 12 parts coarse sand, which mass formed into the desired sizes or objects, after being dried long enough in the air, are left in a heated room of 75° for several days, and even to the boiling point of water; they become so hard, after a lapse of four to six days, that they never crack or fall to pieces. It is also recommended to expose the mass to the pressure of a hydraulic press before exposing to the air. For obtaining a cement—roofing and wall body—it is advisable to add the chloride of calcium to the mass, and thereby the excess of alkali is absorbed.

The mass so formed may be steeped in a solution of chloride of calcium, or chloride of iron, before exposing to the atmosphere. In all these cases the silica ought to be employed very concentrated, even in jelly form.

The uses of the soluble glass are here condensed in a short sketch intended as a circular to those desirous of obtaining some information:

"THE USES OF *SOLUBLE GLASS (LIQUID SILEX), SILICATE OF SODA, SILICATE OF POTASH, SILICATE OF SODA AND POTASH (COMBINED.)

"Liquid silica is now employed in the arts for many useful purposes, and particularly for preserving stone buildings from decomposition; for preparing an artificial stone, and thereby reducing the price of building, and making a composition more ornamental. Its introduction for architecture is but of recent date, and the true and proper method of application not yet on an infallible base; but the subject is of so vast importance, that experiments are continually going on for making a perfect stone from its original ingredients.

"The cause of gradual decomposition of building stone is attributed to the expansion and contraction of water absorbed, as well as to the chemical action of carbonic acid of the atmosphere, which abstracts portions of the gases from the silicates, and liberating thereby silica. Many palaces in Europe, churches and other public buildings, have been refinished by the silicate, such as the Louvre and Notre Dame Cathedral in Paris, the Houses of Parliament in London, and in other cities. Still, its general application has met with many failures. It was found that rain

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* In the year 1832 Dr. F. prepared a quantity of soluble glass for the U. S. Government to preserve the cannon, guns and bomb shells from rust or oxidation at the Navy Yard in Brooklyn, to the fullest satisfaction of the late Commodore Perry.

counteracted the effect before the alkali has had time to take up a sufficient quantity of carbonic acid from the atmosphere and to liberate the insoluble silicate, the coating will produce cracks, and a gradual disintegration of the surface or compound is caused thereby. Numerous remedies were suggested to counteract this evil—the chloride of calcium, oxychloride of magnesium, the bittern of the salines, and hydrofluoric acid. At present a concrete stone of considerable hardness and durability is now prepared by means of greater pressure and proper manipulation, the main object being to neutralize and extract the alkali, and to form a solid chemical compound by a second application of a weak wash of chloride of calcium or magnesium. The object is now fully achieved.

"Another important application of the soluble glass is to render wood non-inflammable, and stop any communication of the fire, and at the same time proof against water and damp. The wood, timber, or other substances, after being boiled for several hours in the soluble glass, then exposed in tanks, containing solution of lime water and solutions of chloride calcium, are hereby petrified.

"Railroad sleepers, cross-ties, house, ship and bridge timber will also be silicified by this process. Telegraph poles become more durable and better non-conductors of electricity. The lining of barrels for oil and other liquids, the coating of tanks, tubs and cisterns, flour barrels, to prevent the flour getting musty, is very easily and effectually done by the proper and judicious use of the liquid silica.

"Soluble glass may be mixed with paper pulp, or cheap vegetable and animal fibre, and serve for the manufacture of a variety of useful articles, such as boxes, trunks, soles for boots and shoes, patterns, moulds and handles. *Invaluable and of the highest usefulness, the soluble glass can be employed in fireproof paints, cements, varnishes, etc., for which purposes the daily demands are sufficient proofs.*

"The dentists make use of the silica for mending their plaster moulds, or in case of an accident to the cast of a set of teeth. Valuable documents are made fireproof, and parchment board, slates and marbles are cemented together, and cracks and crevices filled up.

"The woolgrowers apply the silicate of soda and potash to the greatest advantage for cleansing or degreasing the fleece wool and make it soft.

"A hard and ornamental cement, which can be moulded like plaster of Paris, is obtained from the mixture of silicate of soda and ground dolomite or magnesian limestone, which may be used both natural and calcined in equal quantities, and before the mass is dry the bittern (chloride of magnesium) from the salines is added, which will harden it at once. A good cellar and roofing cement is made by adding to this mass three parts of white sand.

"The silicate is also used for penetrating firebrick and clay, in order to make them more fireproof, and also used for cementing the walls. For producing a durable putty in iron castings, such as furnaces, heaters, stoves, etc., and also for mending air-holes. Boiler makers can produce a very durable lining by making a cement of silicate with asbestos and manganese finely ground, it renders boilers and other metallic vessels perfectly fireproof, and the best fire and anti-rust paint for iron, steel and brass. There are a great many more useful applications in which the silicate may be used."

The alkaline silicates, as have been here described, have a bright future for their application: the genius of the nineteenth century cannot fail to accomplish the perfecting the work begun fifty years ago, and to this moment still liable to faults. Ere long we will be enabled to produce an artificial stone which shall excel nature; we will be able to produce a perfect silicification of wood and other organic matter; we will challenge the atmosphere and other chemical productions to do their best for forming a decomposition of those materials obtained by the new acquired skill to resist their action. The labors of Fuch, Liebig, Kuhlman, Vicat, Temy, Guerin and Ransome have fairly begun their work, and in ten years more the ship builder, carpenter, mason, painter, the rail road contractor and the mechanic in general will consider this valuable substance indispensable.

Among the most simple processes in the silicification or manufacture of artificial stone is that of Ransome, which consists in the following manner:

The sand after being dried is worked up in a mill with the soluble silicate, prepared from caustic soda and flints, the latter being dissolved by the former, and evaporated down to a specific gravity of 1,700. The plastic mass thus produced is obedient to the will of the moulder, and can be manipulated into any form, from a cube to elaborate screens, from a grindstone to an exceedingly chisseled fountain. The mass so prepared is then saturated with chloride of calcium, applied simply by immersion or assisted by the action of an air-pump; in either process the solution being gradually heated to a temperature of 212° F.

The indurating action of the chloride of calcium is promoted in closed chambers connected with a steam boiler. When this has been carried on for a sufficient length of time, by opening a cock the solution is forced by steam pressure into a separate chamber, leaving the stone to cool gradually in partial vapor, by which all danger of cracking is avoided; a casualty which is liable to happen when large masses are exposed to rapid extremes of temperature in the open air. In order to remove or extract the soluble salts of calcium and sodium from the body of the stone, which is effected in the same closed chambers by the admission of steam, or steam and water alternately, which as it condenses and becomes saturated with the salts referred to, is returned into the boiler, where the steam is generated, and the chloride of calcium is again made available for future operations, thus obviating the serious loss incurred by washing the stone in the way hitherto adopted.

Mr. R. was led to his last experiments from the many faults which he discovered in manipulating; he supposed, at first, that by mixing sand and fragments of stone with the fluid silicate into a kind of paste and exposing them to the air, they would be permanently solid. But he found that stones they made very soon became disintegrated in any moist atmosphere, and particularly in England, and could never indurate. To remove this serious objection, he subjected them to the action of heat in a kiln, and he found then that at a bright red the cementing material or silicate parted with some of its free alkali, the portion thus renewed combining with some of the sand to produce an insoluble glass, unaffected by exposure to any of the acids present in the air and not cracking by exposure to frost when damp. This artificial stone could be made so porous as to be well adapted for filtering slabs, or it could be so compacted by mechanical pressure before burning as to yield a material not inferior in its power to resist atmospheric action and even absorbtion. Paving slabs, garden vases, balusters, tombstones and various architectural features, often constructed of terra cotta, were produced of superior quality and greater durability. The stone thus made, however, after some exposure, was found to become unsightly, owing to the efflorescence of the saline matter.

This patent siliceous stone was also found too expensive to come into general use on a large scale, but the inventor has, at last, succeeded in reaching to a satisfactory result.

The author has, many years ago in the course of his experiments, succeeded in preparing an artificial stone in the following manner:—Fluorspar, finely ground, is mixed with the powdered soluble glass, 2 parts of the first to 1 part of the latter, the mixture made into a thin paste by the concentrated liquid soluble glass, and then as much finely powdered shell limestone, or magnesian limestone added until the mass becomes thick enough to form into moulds or blocks, whichever may be desired, after an exposure of three to four days to the atmosphere are treated by a weak solution of chloride of calcium (2 pounds dry chloride to the gallon of hot water), this liquid will soon be absorbed by the stone; it is then exposed again to the atmosphere for a week; a dilute hydro-fluoric acid is then applied with a sponge, and again exposed to the atmosphere; after a lapse of a week the stone is as hard as a natural stone, and not liable to crack or to disintegrate.

This composition is much easier prepared, and instead of common lime, chalk may be substituted, and the result is still more favorable. Instead of the entire quantity of lime, coarse sand may be partially added, and after the stones are moulded, are exposed to hydraulic pressure, and then exposed to the air, previous to which the chloride of clalcium has to be thrown over it. The price of hydro-fluoric acid, as is used for this purpose, costs about 25 cents per pound, and this suffices for ten square feet. It must be, however, observed, that the soluble glass used in this process was the potash silica and not the soda silicate, as he found by his experiments to be indispensable, the soda silicate does not produce that durability and hardness that the potash silicate.

Furthermore it may be remarked, that exposing the stone so prepared may be subjected to a high temperature or not; it may be left to the operator to decide whether it will improve the stone by this manipulation.

For the sandstone imitation, when 1 part liquid soluble glass is to be mixed with 2 parts powdered soluble glass, and 15 parts of sand is added, it is necessary to expose the mass to great pressure, but requires not the addition of chloride of calcium, while exposure to great heat is indispensable.

An artificial stone may be also obtained by the use of the alkaline silicates with common chalk, which by mixing even cold with the liquid silica, is at once converted into silicate of lime and carbonate of soda or potash: this composition, when exposed to the air, becomes in a few days hard enough so as to resemble a hydraulic lime, to adhere, when wetted again, like a cement, which may be used for restoring cracks and crevices in marble works and monuments.

The silification of chalk has led to numerous experiments, and resulted in the production of artificial stone, in the formation of hydraulic lime, hydraulic mortar and the various cements. The first successful result of the treatment of chalk with the silicate solution has shown that the hardening of the chalk extended to the depth of four inches, which not alone was produced from the decomposition of the silicate by the carbonate of lime (chalk), but also by the carbonic acid of the atmosphere. If two balls of chalk of equal size and quality are silicified at the same time, and one of them is exposed to the atmosphere, the other kept under a bell glass, where the carbonic acid of the atmosphere is withdrawn, the first will acquire more hardness than the other, which proves that the silification has assumed a hydrate of silico—

carbonate of lime—which looses by degrees its water of crystallization and a contracting precipitate of silica, which contributes mainly to the hardening of the stone.

A *hydraulic lime* may be obtained by the mixture of a fat or rich limestone combined with soluble glass in a dry state, say 10 parts silicate to 100 parts of air lime, both fine powder, which proves plainly the theory of the part which the silicates play in the production of the native limestone, the artificial hydraulic lime, mortar, cements, and the application of all silicates for the purposes of building, production of artificial stones, and the conversion of organic into inorganic materials, as we shall show hereafter.

HYDRAULIC LIMESTONE, CEMENTS AND PLASTERS.

It is necessary to explain the main material used in building, which is lime, before we can proceed farther with our subject of silicification, or imitation of the same substances by means of art, latterly acquired, and which bids fair to excel nature. From one of Anted's lectures on practical geology, the following article on cements and plasters gives a good idea of their importance:

"The earliest architectural constructions to fasten together the bricks or stones of which buildings are made were of various kinds; the most common and familiar is called *mortar*. It is obtained by first calcining common limestone in a kiln, and converting it into quick lime, by depriving it of its carbonic acid. After calcining, the resulting quicklime is a whitish or grayish powdery and cracked substance, which, on the application of water, absorbs a certain quantity with the evolution of much heat, and falls into a fine powder. This powder, further moistened, made into a thin paste with water, and mixed with two to three times its own weight of sharp sand, is called *mortar*.

Slaked lime, or hydrate of lime, as moistened quicklime is called, absorbs carbonic acid from the air, and in time mortar is reconverted into limestone; but the operation goes on under peculiar conditions, and the result is also peculiar; for a film of silicate of lime is formed round each grain of sand, and thus the whole mass and the stones, between which it is placed, become in time more compact than the particles of limestone.

"As, however, there are different kinds of limestone, more or less impure, the result will be limes of very different qualities and properties. These require special treatment to obtain from them the best results. The purest carbonate of lime, such as marble, or chalk, make what is called a rich lime, setting firmly only in dry air, while the very impure carbonates, in which clay is largely mixed with the limestone, result in the production of hydraulic limes, which set more or less rapidly in moist air or even under water. Some of the impure limestones are used in the manufacture of cements by the admixture of definite proportions of foreign ingredients. Sometimes by the admixture of certain substances [as puzzuolana] with the rich limes instead of sand hydraulic limes are produced. There are few subjects connected with the application of geology that are more important than the determination of the material that should be used and the treatment adopted in various countries in the manufacture of cements, mortars and stuccoes.

"Commencing with nearly pure carbonates of lime, it is not difficult to trace the changes that take place in their conversion into cements; a layer of such mortar, not too thick, placed between bricks or stone, which are themselves absorbent, and kept in dry air, dries gradually and holds together such substances with extraordinary tenacity. But this is a work of years, and sometimes even centuries must run out before the extreme of hardness is attained! It is not unusual to find imperfectly hardened mortars in very old constructions. The mortar that fastened together the bricks in the old Roman walls is now almost everywhere so far hardened that a fracture takes place in the brick rather than the cement.

"Limestone is widely distributed, and almost every variety, however impure, can be burnt for lime. In the manufacture of good common mortar to set in the air, pure limestones and those of fair ordinary quality are available; but in using them attention must be given to their composition and even texture; thus the hardest limestones and marbles make the fattest lime, other things being the same, but each variety yields a lime of different quality, distinct in color, in weight, in the greediness with which it absorbs water, and in its ultimate hardness. The method of calcination also varies, but the general result is that, after burning the limestone, the resulting quicklime is lighter than the original stone, and differs from it essentially. To determine the nature of lime, and its peculiar properties, perfectly fresh samples should be placed in a small open basket and immersed in pure water for five or six seconds; removed from the water, the loose unabsorbed water must be allowed to run off, and the contents of the basket emptied into a stone or iron mortar. According to the nature of the limestone the lime will now exhibit some one of the following phenomena:

"1. It will hiss, crackle, swell, give off much vapor, and fall into powder instantly.

"2. It will remain inert for some short time, not exceeding five or six minutes, after which the results stated in (1) will be energetically declared.

"3. It will remain inert for more than five minutes, sometimes extending to a quarter of an hour; it then gives off vapors to a moderate extent, and cracks without noise and without much evolution of heat.

"4. The lime will crack without noise and with little steam, but not until an hour has elapsed.

"5. The lime will become scarcely warm to the touch, will not fall to powder, and will crack to a very small extent.

"In each case, before the effervescence (if any takes place) has quite disappeared, the slaking should be completed by the addition of water, not thrown upon the lime, but by the side of it, and the result should be frequently stirred, more water be added, till the whole is brought to the consistence of a thick paste. When the mass has cooled, which will not take place for two or three hours, the whole should be beaten up again, until a firm but tenaceous paste is produced, resembling clay prepared for pottery manufacture. Vessels being then filled with this paste, or obtained from each variety of limestone, the day and hour of immersion should be marked upon them, after which they are left to solidify.

"We thus obtain a test of the nature of the materials used, which may belong to one of five classes—

(1.) Rich Limes.
(2.) Poor limes.
(3.) Moderately hydraulic limes.
(4.) Hydraulic limes.
(5.) Eminently hydraulic limes.

"The word hydraulic, as applied to lime, means only, that it possesses the property of setting, or becoming solid, in moist air or under water.

"Rich limes are obtained from the purest and hardest limestones. When slaked, they increase to double their volume ; if employed alone they remain unaltered even for years, and they are soluble in pure water. Limestones that contain from 1–6 per cent. of foreign substances, such as silica, alumina, magnesia, &c., yield rich limes ; but such as contain from

15 to 30 per cent., are poor limes; they increase in bulk but little on slaking, do not set under water, and are soluble, like the rich limes, except that they leave a residuum. The fossiliferous limestones make bad mortar, as the slaking is irregular; limestones containing much silica, swell in setting, and may dislocate the masonry executed with them. Where alumina is in excess, the lime is apt to shrink and crack. Where carbonate of magnesia is combined with carbonate of lime, as in the magnesian limestones, the original bulk is retained. For ordinary purposes, moderately pure limestones with a mixture of foreign substances is a moderately pure limestone. Hydraulic limes are of great value in construction, and are extremely interesting; and are either obtained naturally from the burning of certain varieties of calcareous rock, or are manufactured artificially by mixing limestones with the requisite foreign ingredients, or by combining quick lime with foreign materials, such are the Roman cement, Portland cement, Parker's and Rosendale cements. The Portland cement is largely manufactured at the mouth of the Thames from a mixed river mud, while Roman cement is formed from the nodules found in the cliffs near Harwich, all owing their quality to argillaceous admixture and limestone containing from 15 to 25 per cent. of a silicate of alumnia, will burn into a good hydraulic lime. It is also quite certain that the

oxide of iron and carbonate of magnesia exercise a great influence in rendering limes more hydraulic. All materials intended for the manufacture of cements require to be burnt carefully and ground down to a fine powder, and the best cement is the lightest. When these cements are intended for the production of an artificial stone, from ten to twelve times the weight of broken stones and pebbles are added, and form also an excellent *concrete.* A stone made from these cements, just described, will bear a strain varying from 20–60 pounds to the square inch.

The plaster cement is obtained from the gypsum, or sulphate of lime, abundant in England, France and the United States, is treated like common limestone for a cement. The calcining of gypsum does not involve its decomposition, but the water of solidification being driven off by the calcination, leaves only a soft white powder called plaster of Paris; when this is again united with water, the latter is absorbed, and the mass becomes, first, plastic, and then solid, but it cannot be brought back to its original condition as a crystalline mineral, but it is converted into various substances used as cement, such as *Keene's* cement, if alum is added to the fine powdered plaster; parian cement, if borax is used; Martin's cement, if pearl ashes are employed; a *stucco* is a very useful material for ornaments in in and out-door work, is nothing else but a plaster of

Paris, finely ground, and a weak glue added before mixing it with water.

One of the richest kinds of hydraulic lime may be obtained from volcanic minerals mixed with limes, such material is the Puzzuolana, found near Naples, as well as other substances found in large quantities in the neighborhood of extinct volcanic districts, as in France and on the Rhine; and which, according to its chemical analysis, consists of 44 per cent. of silica, 15 per cent. alumina, 87 per cent. lime, 4 per cent. magnesia, and 12 per cent. oxide of iron; combined with lime instead of sand, have the property of rendering even the richest limes hydraulic, and fit for use for every description of works executed in the sea or in fresh water; they have been used from time immemorial with great success, and may be mixed either with fat or hydraulic limes and silicate of soda to form a plastic mass and assist in the setting of the lime.

In regard to hydraulic cements, Frémy says that the setting of cements is due to two different chemical actions: 1. To the hydration of the aluminates of lime, and 2. To puzzuolanic action, in which the hydrates of lime combine with the silicates of lime and alumina: he found that alumina is even a better flux for lime than silica, and he suggests that the very basic compounds of these two substances, those, for instance, containing from 80 to 90 per cent. of lime, may be useful in the iron furnace for absorbing sulphur and phosphorus, and free the metal from those noxious impurities; and he finds that no substance is capable of acting as a puzzuolana except the simple or double silicates of lime, containing only from 30–40 per. cent. silicate, and sufficiently basic to form a gelatinous precipitate with acid; and he confirms Vicat's theory, that the cause of the setting of hydraulic cements was owing to the formation of a double silicate of alumina and lime absorbing waters, forming hydrates and causing the setting of the materials.

"THEORY OF HYDRAULICITY.

"Frémy has lately published his researches on hydraulic cements, and in giving the theory of their hydraulicity, he rejects the commonly received opinion that the setting of hydraulic cement is due to the hydration of the silicate of lime or that of double silicate of alumina and lime. These salts form no combination whatever. He attributes the setting of hydraulic lime to two chemical actions: 1st. To the hydration of the aluminate of lime; 2d. To the reaction of hydrate of lime upon the silicate of lime, and the silicate of alumina and lime which exist in all cements, and in this case act as puzzuolanas.

"The calcination of the argillaceous limestone produces good hydraulic cement only when the proportions of clay and lime are such that they form in the first place, an aluminate of lime, represented by one of the following formulæ: $Al\ O_3\ Ca\ O$—$Al_2\ O_3\ 2\ Ca\ O$;—$Al_2\ O_3\ 3\ Ca\ O$; in the second place a very simple or multiple silicate of lime which gelatinizes with acids and approximates to the following formulæ:—$Si\ O_3\ 2\ Ca\ O$—$Si\ O_3\ 3\ Ca\ O$; and thirdly, free lime which may act upon the preceding puzzuolanic silicates.

"In many cases the chemical composition of an argillaceous limestone is not only the condition which determines the quality of the cement, the reaction of the lime upon the clay must take place at the highest temperature. Indeed, this excessive heat produces the hydraulic elements of the cement in the basic conditions which the setting in the water requires, and which, by melting the aluminate of lime, gives it all its activity.

"Hydraulicity of Magnesia Hydrates.

"Since the publication of Frémy's paper, Deville has read a note before the Academy of Sciences, 'On the Hydraulicity of Magnesia,' in which he alludes to a specimen of magnesia prepared by the calcination of the chloride sent to him, seven years before, by M. Donny. A portion of it was left under the tap of his laboratory, constantly exposed to running water. In time it took a remarkable consistence, became hard enough to scratch marble, and was clear as alabaster. After six years exposure to the air, it has not perceptibly changed, and its analysis gave the following results : Water 27.7 per cent., carbonic acid 8.3, alumina and oxide of iron 1.3, magnesia 57.1, sand 5.6. Total 100.

" Thus the substance appeared to be essentially a crystallized hydrate of magnesia, like brucite, which does not absorb carbonic acid. To prove that it was really so, M. Deville prepared magnesia by calcining the nitrate, powdered it, made it into a plastic mass, and sealed in a tube with some boiled distilled water. After some weeks, the mass became as hard and compact as the other, and also crystalline and translucid. After drying in the air, this mass was found to consist of 30.7 per cent. water, and 69.3 per cent. magnesia, showing it to be a simple hydrate of magnesia. With similar hydrate, cast of medals were taken, which, on being placed in water, assumed the appearance of marble.

" M. Balard's magnesia, prepared by calcining the chloride, obtained by treatment of sea water, when brought to a red heat shows astonishing hydraulic qualities, which are partially destroyed by calcining at a white heat. A mixture of chalk or marble and magnesia, in equal parts, forms a plastic mass, which, placed under water for some time, becomes hydrated and extremely hard.

"Deville finds that dolomite rich in magnesia, when calcined below a red heat, powdered and made into a paste, forms, under water, a stone of extraordinary hardness. When dolomite is heated to bright redness and all the chalk is converted to quick lime, the paste formed with it breaks up under water. All these important experiments of Deville, show that magnesia is the binding material which, on becoming hydrated, holds together the particles of chalk or marble, and thus forms a compact, homogenous stone.

"HYDRAULIC CEMENTS.

"Hydraulic cements owe their property of setting to some compound formed by the calcination of inferior limestones containing clay and silica. What the change is that is produced by the calcination has hitherto not been sufficiently well understood to enable the manufacturers of cements to work with absolute certainty of producing a uniform product. M. Frémy has recently been studying the subject, and has communicated his observations to the Institute of France. He found that the calcination of a calcareous clay gives rise to an aluminate of lime and a silicate of lime, with some free caustic lime.

"It is this mixture that hardens when brought in contact with water. According to Frémy the setting of the cement is due to the hydration of the aluminate of lime and the combination of silica with the quick lime. The presence of four compounds is necessary to a good result: 1, silicate of lime; 2, silicate of alumina; 3, aluminate of lime; 4, caustic lime. Frémy prepared every one of these compounds, and studied them separately and together. He made the interesting observation that alumina was an excellent flux for lime, and combined with it quite as readily as silica.

"The calcareous clays, or poor sorts of limestones, which are capable of setting under water, do not acquire that property until they have been exposed to a high heat. One of the secrets of the preparation of Portland cement is the high temperature employed in its calcination. The lime and alumina must be fused to secure the property of hydration. The aluminate of lime is the most important agent in hydraulic cements.

"Hydraulic limestones will not yield a good cement unless the proportion of clay and lime be such as to form a compound of alumina, with one, two or three of lime, and the silica and lime be in the proportion to yield a bibasic or tribasic silicate of lime, which will gelatinize with acids, and there must be an excess of lime to be left over in a caustic state. The presence of magnesia, manganese or iron, is not at all necessary, although the latter is always contained in the poorer limestones.

"An average sample of Portland cement will yield, upon analysis, in one hundred parts: Lime, fifty-five; iron, seven; alumina, eight; silica, twenty-four; potash and soda, three; sand, two; water, one. The essential constituents are the lime, alumina and silica."

The Author delivered a discourse on cements before the Polytechnic Association, 26th April, 1866, of which the following is the substance:

"CEMENTS.

"The subject for the evening—cements—was here taken up, when Dr. Lewis Feuchtwanger exhibited a number of minerals used in different kinds of cements, and read the following paper:

"'The meaning of cement is, a paste used for uniting solid surfaces without always forming a combination with the constituents of either surface. Many cements contain pulverulent substances which are mingled with a glutinous or very adhesive material and do not combine chemically; others again form chemical combinations. Furthermore, many substances are capable of assuming a liquid or semi-fluid form, and are thus applied between the surfaces of bodies which are firmly united when the fluid has solidified.

"'The most common cements are mortar and hydraulic cement. We have also lutes and fire cements;

but as it is important to ascertain the best mode of obtaining a good hydraulic cement, that is, a cement which hardens under water, I will at once take up this branch of the subject, premising, however, that common mortar is simply a mixture of lime, water and sand, the best proportions being one cubic foot of fresh burnt lime, weighing about thirty-five pounds, and three and one-half cubic feet of good river sand, not round, but angular; these, with one and one-half cubic feet of water, produce about three and one-half cubic feet of good mortar.

" 'Hydraulic or Roman cement is composed of certain proportions of lime, sand, clay and water: after it has been applied a few days, and placed under water, it becomes very hard and like stone. We now find walls and piers which are known to have been built more than a hundred years ago, and have been exposed under water, and have remained as solid as iron. The name Roman cement is derived from the district of Puzzuoli, near Naples, where the natural material, the tufas and puzzuolanas, are in great abundance. The Pontine marshes around Rome and the volcanic tufas near Naples have always afforded a natural cement, for they are composed of silica, alumina and lime. Besides these tufas, many marls, belonging to the sedimentary rocks, are used as hydraulic cement. The cement stones allied to the oolitic formation and found in argillaceous strata alternating with limestone beds, and of very curious nodular and lenicular forms and concretions, on the English and French coasts, and in this country the septaria, toadstones, ludus helmontii of various sizes and consisting of siliceous clay and lime strata interwoven, yield the proper material for hydraulic cement. All these marls contain, according to analysis, about seventy per cent. of carbonate of lime, twenty per cent. of silica, and twenty per cent. of clay, and the lime when calcined becomes caustic, and, in combination with silica, forms, under water, a chemical compound, as a hydrated silicate of lime; and, by the presence of clay, which is a silicate of alumina, forms double silicates of greater solidity. $Ca\,O—CO_2—Si\,O_3—Al_2\,O_3$.

" 'The Roman or hydraulic cement mostly contains, also, magnesia and iron, whether of any essential benefit or not has not been fairly tested. It is certain that neither of these substances exercise a pernicious influence, for the reason that dolomite, a magnesian limestone found in great abundance in this country, offers a fine material when calcined with any marls so abundant along our coast. It produces an excellent hydraulic cement.

" 'The analysis of the hydraulic lime from Rondout, on the North River, gives in one hundred parts:

Carbonic acid	35	Lime	23
Magnesia	12	Silica	15
Alumina	10	Iron	2

" 'Sand or quartz, which by itself is unfit for a mortar, when calcined with lime becomes very suitable for a hydraulic cement or artificial stone, for it forms a silicate of lime. More than thirty years ago, I entertained the idea of preserving timber by the infiltration of silicate of lime into the cells of planks, timber, and through the double chemical affinity of silicate of soda and sulphate of lime. The experiments I made then, in the Brooklyn Navy Yard, with pier piles and wooden vats, were very satisfactory.

" 'For water-proofing cellars and buildings, not alone the best hydraulic, but other cements have of late years been introduced in this city; for instance, the asphalt cement, which is very extensively employed in the foundation of buildings. Having made, myself, many experiments, for a number of years past, in order to introduce the silica cement, or the soluble glass in combination with alkaline earths as a base, and met with varied success, I beg to offer here a sample of a cement which consists of silicate of lime combined with manganese and fluorspar, or fluoride of calcium, which becomes very hard, and which, I think, will, after some improvement in the preparation, be found highly useful in keeping dry walls and cellars. I have mixed equal quantities of manganese, limestone, fluorspar and dry soluble glass, and make the whole mass plastic by the liquid soluble glass, and apply it while soft;

after the lapse of a few hours it becomes very hard.

" 'Fire cements are lutes, for crevices and joints, which are intended to be used for furnaces, iron pipes and retorts exposed to constant red and white heat, or for joining gas and water pipes, and many other substances, may, if judiciously applied, prove very acceptable. I beg to offer a few which I consider useful:

" 'No. 1. *Iron Cement or Lute.*—Brick dust and fire clay in equal parts, borax, red lead and sal ammoniac, one-tenth of the other ingredients; cast iron turnings. The whole mixture made up with water so as to knead them together, and spread it in layers. It is suitable for crevices or joints of iron pipes, furnace doors, man holes of boilers, etc.

" 'No. 2. *A Steam-resisting Cement.*—Two parts litharge, one part sand, one part slacked lime; made plastic with hot glue.

" 'No. 3. *An Iron Cement.*—Manganese twenty-four parts, red lead five parts; formed into a paste with linseed oil.

" 'No. 4. *Cement for Fastening Iron and Stone.*—Calcined plaster, iron filings and hot glue.

The three following are good cements for cisterns, etc.:

" '1st. Ten parts of plaster of Paris, two of Glauber salts, four of clay, and four of lime

" '2d. Twenty-two parts of clay, nine of iron filings, sixty-three of lime, one of magnesia, one of peal ash, and ten of charcoal.

" '3d. Thirty parts of sand, seventy of lime, three of litharge, made up with linseed oil.

" 'A very remarkable cement, for almost any substance, is made in the following manner: Either glue or gelatine is swelled up in water and then immersed in linseed oil and heated. It dissolves and forms a paste of great tenacity, which, when dry, resists dampness perfectly. Two pieces of wood joined by it may separate anywhere except at the joint.

" 'The china or diamond cement, for joining glass or china ware, consists of gum mastic and ammonia dissolved in alcohol, to which is added hot glue. Spalding's glue is the old Berzelius paste, that is, glue dissolved in acetic acid. The Japanese cement is rice flour made into a paste and dried.

" 'In 1841, a patent for a lime cement was obtained by Kuhlman, who adds an alkali, like soda or potash, before calcining the limestone with sand and clay, so as to produce a soluble silicate with the ingredients of hydraulic cement.

" 'The Portland stone or cement, so extensively used in England, and exported largely from there to all parts of the globe, and forming the base of many patent cements, such as Reese's and others, is nothing but powdered oolite, a mineral lime deposit. Hamelin's mastic cement, another very celebrated cement, is prepared from sixty-two parts of oolite, thirty-five of sand, and three of litharge.

" 'The celebrated French cement of Bouilly is said to be prepared from the Boulogne pebbles, called golets, which are marly nodules of all sizes, like the septarias and marly concretions of other countries. A number of years ago, I prepared a good hydraulic cement from one part of the poorest limestone, one of clay, and three of sand. I also prepared a terra cotta, which is likewise a cement, composed of clay and sand, slowly dried and calcined.

" 'COMMON MORTAR.

" 'Limestone, an impure carbonate of lime, when exposed to a red heat, loses carbonic acid gas, and the oxide of calcium or lime remains. This process of burning lime, as it is called, is accelerated by the presence of moisture in the stone, or by the introduction of a small quantity of steam into the lime kiln. The hydrate of lime reacts with considerable power on siliceous compounds, but the action only takes place at the surfaces, and unless the lime is used in very thin layers, between smooth stones, it still retains, in the centre of the layer, its own soft and friable condition.

" 'In order to make the hydrate of lime effective as a cement, it is mixed with sand, one of the most abundant of natural compounds, now regarded as consisting of two atoms of oxygen and one of silicon. Equal parts of fine and coarse sand are said to be better than either quality used separately with lime. Mortar designed for exterior or surface work is generally made with fine sand. When lime is comparatively free from impurities and crumbles to a fine powder on being slaked, it is called fat lime, and will require about six times its own weight of sand, or, if estimated by bulk, one cubic foot of semi-fluid lime and water, called the milk of lime, will require about three or four cubic feet of sand. This mortar is very effective as a cement when well dried or set, but if it is placed in water the lime is gradually dissolved and the mass is disintegrated.

" ' HYDRAULIC CEMENT.

" ' For all permanent structures under water it is, therefore, essential to use a material called hydraulic cement, which is a mixture of lime with other oxides possessing the valuable quality of hardening until it has the solidity and permanency of the masses of rock bound together by it. The varieties of limestone from which hydraulic cement is made, when burned, yield a lime that is very slowly slaked. All that is required is to add water until it attains the consistency of dough, it will then harden and become concrete. These hydraulic limes may be made artificially by mixing with impure slaked lime a quantity of burnt clay in the proper proportions. The celebrated Roman cement was a porous volcanic rock found at Puzzuoli, near Naples, and called there puzzuolana. It consists of silicate of alumina, soda and lime. This substance is pulverized and mixed with common lime.' "

THE SILICATE HYDRAULIC CEMENT IN THE PREVENTION OF WALL-DAMP.

In laying the foundation of any building, the matter of particular consideration should be the thorough drainage of the site, and next to that complete prevention of wall-damp, that is, the rising of moisture by capillary attraction or otherwise, in the heart of the brick or stone work, the particulars of which have been lately described in the *Manufacturer & Builder's Journal*, to which the author had added the silicification of the bricks and plaster. It states that wherever brickwork comes in contact with the earth, or even with adjacent walls which may happen to be damp, there the infection is certain to take, and there is no easy cure for it, if once it makes an entrance.

The readiest remedy in all cases is a layer of fine concrete, which may be thinly coated on the top with asphaltum laid on hot. This done all around the top of the walls, external and internal, the piers and every piece of brickwork, that in any manner has connection with the ground, then the bricks, which ought to be specially prepared before calcination with a silicate solution, should be heated over charcoal furnaces and their beds dipped in the asphaltum before being laid. It is evident that a preventive course could thus be formed above ground at a trifling expense, wholly impervious to wall-dam, at the same time giving a bedding to the superstructure of a quality very far superior to any now in use. Coating the outside face of the walling with waterproof silicated cement, as has been before noticed, is only the safeguard against capillary attraction from below, and excluding the external air which might let the artificial heat of the rooms to attract the enemy of wall-damp. It is known that common brick will absorb 1–5 of its weight of water, and where the storm drives the rain continually against the face of a wall for a sufficient time to permit the interior heat to attract it, the inside of the wall must, of necessity, be damp, and the papering become mouldy, as well as the ceiling, will next be rotten. This cause of wall-damp is one that cannot be too carefully guarded against, as it is one to which may be referred the early decay of many residences, as well as the inception of these pulmonary symptoms which so surely steal away the health and ultimately the life of many a victim.

The mortar to be used in the foundation and the wall ought to be very well prepared so as to possess all the hydraulic properties and silicification, and caution should be taken in not using sea sand, which will certainly create the damp by absorbing all the water in the atmosphere, this being the chemical effect of its saline property.

The surface of the walls of the rooms must be well attended to: the plaster of Paris, which is generally employed, ought to be properly silicified, so as to prevent the absorbtion of the natural damp of the atmosphere created in uninhabited and unheated rooms.

It is preferable to paint rooms than to paper them, for the white lead and linseed oil, with a little litharge to facilitate the drying, becomes hard after a short time, and assists the fresh plaster wall of preventing the admission of the moisture; as the fourth coating of white lead is applied with equal proportions of oil and spirits of turpentine, which has the property of being very volatile, will evaporate entirely, leaving the surface of the paint of a very compact and hard nature, and rendering the plaster incapable of absorbtion.

Among the great variety of cements in which silica is the active principal, the two following are very useful:

1. A mortar to be made as hard as any cement, and which does not crack in setting, and even of great usefulness as hydraulic cement under water,

is obtained by mixing finely slacked lime with fine sand [the angular grains are always preferable to the round grains for producing a good mortar]. By mixing the sand thus prepared with finely powdered quick lime, and stir the mixture thoroughly. During the process the mass heats, and may then be employed as mortar, to which has to be added one-eighth of the mass the liquid silicate of soda.

One part of good slacked lime was used with three parts of sand, and to this was added three-fourths of its weight of finely powdered quicklime; the mortar containing one-eighth of the liquid silicate of soda was then used as a foundation wall, and in four days had become so hard that a piece of sharp iron would not attack it; and in two months afterwards it had become as hard as the stones of the wall.

2. A thin coating of slaked lime made into paste with water or whitewash is put at once on the stone, and before becoming quite dry apply the silicate solution over the paste, by which the mass becomes completely insoluble; a petrification takes place if applied to vegetable substances, decomposition is prevented, porous building stone and brick are protected against air and damp.

Damp Walls and Cellars.

The application of silicates for preventing the penetration of rain or moisture in houses, whereby the walls are absorbing the same, and render the paper-hangings or delicate paint unfit, so as to destroy their appearance, has been amply and satisfactorily proved. The silicates of soda and potash, or either of them, are mixed with pure white lead or zinc, and applied soon after upon the walls, which will dry immediately.

The presence of damp in walls arises from three causes: either from the porous condition of the materials of which they are built, allowing the penetration of damp from without; from the existence of salts in the mortar, bricks or stone, which absorb and give out moisture, according to the changes of the weather, or from damp foundations. The first only can be remedied by the application of external coatings, the second by battening the walls, and the last by removing the adjacent earth from the foundations.

As has already been stated that a single application of a paint formed with lead or zinc has proved very successful. The second application is the silicate solution with china clay, or pure alumina, which has the advantage of not drying so quick as that with lead or zinc. In all cases the paints must be put on uniformly, so that the whole wall surface should be completely covered with the solid coat, and in order to effect this a rough stucco surface, from two to three coats, may be required. It is found also useful to apply the second coat thinner than the first.

The mixture of liquid silicate of soda with clay and that of whiting, or washed carbonate of lime, may probably be the most reliable for keeping out damp from walls as well as cellars.

On applying the lead or zinc as the first coat, either of them or both, it may be done in the following manner ;

Mix them with a little water and lay them on the stone, they will dry very soon ; apply then the silicate solution by means of a syringe. If the application is to be made on stone which shows some decay, it is necessasy to remove first the same, apply then the aluminous silicate of soda (by an equal mixture of liquid silicate with fine white clay), and then apply the carbonate lime and silicate wash with an ordinary paint brush, stippling it so as to give it the appearance of the granulated surface of the stone. When dry it will adhere sufficiently to allow of other washes of silicates being brushed on it.

The conditions necessary for success are :

1. The wall should be coated with a porous material, such as lime or Portland cement.

2. The coating must be perfect. A wall which has been once painted is altogether unfit for any application of siliceous washes, for the reason that it is not absorbent enough.

The best ground for any siliceous work is lime and sand. In new buildings it would be better to use lime and sand at once, and then to cover it with lime and silicate of alumina and soda. The precipitated sulphate of baryta may safely be applied in the silicate of soda for all the above purposes, and it will produce a good coating and a fine paint.

Under the name of liquid stone, Fleury describes the application of the alkaline silicates in the following manner:

"The first idea that suggests itself of the use of such a liquid is the preparation of *artificial stones for ornamental and building purposes.* Should it be possible to produce this petrifying liquid cheap enough, building-stones in all their variety could be made and cemented together with the same petrifying solution. The cost of cast flint-marble statuary, tombstones, baths, tables, mantel-pices, and ornaments of all kinds, would be, of course, much less than if laboriously cut from the stone, and they come quickly into universal use. In a similar way, as photography now diffuses the masterpieces of the art of painting among all classes of society, and cultivates their taste, the art of *casting flint-marble* would multiply and diffuse the masterpieces of sculpture, and adorn our public buildings, gardens and parks. Bas-reliefs, cameos, cornices, columns, pillars, etc., might be produced at comparatively cheap prices. Should the liquid be of a kind to permit its application to outside or inside walls, like plaster, then we could cover our brick and stone houses with white or colored flint-marble fronts, and our churches, halls, theatres, parlors and rooms with *glass-like walls* and ceilings, colored *ad libitum* with elegant frescoes as durable as the still fresh paintings at Herculaneum and Pompeii; while the floors could be inlaid with beautifully colored stones in mosaic style.

"Another important application for such a liquid would be the one to *render wood non-inflammable, rot and water-proof.* By making wood non-inflammable, we should greatly diminish the danger to which most of our old and new buildings are now exposed. This could easily be effected, and with not much cost, by impregnating the wood with a properly prepared solution of flint; for, if once the pores of the wood, which by their capillary action cause the communication of the fire to the whole structure, be stopped up by the incombustible and non-conducting silica, the wood becomes non-inflammable, and at the same time proof against water and decay. Not less important would be the partial silicification of rail road-sleepers and cross-ties, house, ship and bridge timber: they would be stronger and last longer. Telegraph-poles would, when properly treated, become more durable, and be, in addition, better non-conductors of electricity. What a new field would such a petrifying fluid open to the manufacture of incombustible paints and varnishes? It might also be mixed with paper pulp, or cheap vegetable or animal fibre, and serve for the manufacture of a variety of useful articles, such as staircases, boxes, trunks, soles for boots and shoes, patterns, moulds, handles, parts of machinery, photographic instruments, piano-keys; and, further, it might be used as a coating for preventing the oxidation of iron or other metals. We must not overlook another important application in the use of the liquid flint—the one for the preservation of old monuments and stone buildings. It might, perhaps, also serve as a medium for the preservation of meat, fruit, vegetables, eggs, etc. The linings of barrels, for oils and other liquids, the coating of tanks, tubs, sulphuric-acid chambers, etc., are other useful applications of this liquid.

"Metallurgy could be very materially benefited by a process whereby quartz could cheaply and speedily be dissolved in water; for we could then take the gold quartz of Nova Scotia, New Hampshire, or Canada, and dissolve the quartz, and obtain all the gold as a precipitate. Of course, as the liquid flint could be used for so many useful purposes, and be sold for a good price, the extraction of the gold would be very cheap, and, so to speak, cost less than nothing, as the extraction price of the gold would be more than paid for by the amount realized from the sale or use of the liquid."

Hydraulic Mortar from American Limestone.

These limestones contain mostly lime, silica, alumina, oxide of iron and magnesia, which form the proper materials for the preparation of mortars; they will withstand the action of water and moisture better in proportion as the quantity of silica, alumina and magnesia is larger; they contain 40 per cent. carbonate of lime, 30 per cent. carbonate of magnesia, and 20 per cent. silica, the balance is alumina and oxide of iron, and they form a good mortar and a good building material; but when the magnesia is too prevalent, will deteriorate it for building purposes, it being too friable. The dolomite, which is also called bitterspar, a magnesian limestone, is a double carbonate of lime and magnesia, and abundant in the United States, is a granular limestone, and a hardness of 3.5, a spec. gr. of 3.1, and consisting of 70 per cent. lime and nearly 40 per cent. of magnesia and some oxide of iron and manganese, is unfit by itself as a building material, having a great tendency to crumble into small fragments, and forms likewise an inferior material for burning and converting it into cement, because it lacks the silica indispensable for this purpose. By an addition of an alkaline silicate, either the silicate of potash or soda, and an addition of some alumina, will, after burning, produce a good hydraulic cement, particularly in such localities where no good native hydraulic limestone is found. Not alone France and Germany are particularly rich in deposits of hydraulic lime, and in the United States likewise, but these in our neighborhood may be particularly mentioned at Rondout, on the western shore of the Hudson River, 100 miles distant from New York. The quarrying in those subterranean rocks for hydraulic cement and also common limestone is carried on in that region, along a large extent of the valley of the Rosedale River; through this valley the Hudson and Delaware Canal is constructed, which brings the coal from the Lackawanna valley at Carbondale directly to the Hudson River. This coal being a very pure anthracite is admirably adapted for use in the limestone and cement furnaces situated at the junction of this canal with the Hudson River.

In burning hydraulic limestone not only the carbonic acid and water of hydration are drawn off, as is the case with common limestone, but after the lime and magnesia have parted with their carbonic acid, at the high temperature of the furnace, they act on the silica and alumina, as it were, like two powerful bases, and a silicate of lime and magnesia, as also silicate of alumina and aluminate of lime, are formed. The exact chemical reaction during the burning process is however as yet not well understood, and undoubtedly varies in different limestones, according to their chemical constitution, which latter appears also to vary considerably, but without affecting materially their useful properties.

In regard to the theoretical causes of the hardening process, which takes place under water, it may be remarked that this curious and interesting phenomenon, being of an entirely chemical nature, has largely drawn towards itself the attention of eminent chemists, who have attempted to explain it in accordance with well known chemical laws. All hydraulic limestones may, by the ordinary method of analysis, be decomposed into two component parts; the one consisting of the carbonates of the earth, such as lime, magnesia, etc., which, like ordinary limestones, yield a fat lime; the other, a silicate, or rather a mixture of the silicates of alumina, magnesia, lime, and sometimes potassa, as we find in the felspar, which is a silicate of alumina and potash, and a greater or less excess of free silica; the latter constituent is, therefore, simply a kind of clay. The reaction during the burning process has been already alluded to. Now when such freshly burnt cement is mixed with water, the excess of caustic lime as well the compound into which the siliceous clay has been converted during the burning, react upon one another in such a manner, that a solid stone-like silicate is produced in the humid way, the water has a double action, dry substances, such as lime and silicate of alumina, do not act one upon another, unless the solvent power of water is brought into play so as to bring them into close contact; the water transfers continually the lime it dissolves to the silica. The absolute necessity of keeping such mortar under water, in order to have it harden, is thus explained. Another action of the water is this: it enters into a state of hydration in the silicate of lime as soon as formed. It must also be observed that the molecular condition of the silica is of the utmost importance in this process. Fine sand will not combine with lime, when the latter is dissolved in water that is in a form known under the name of limewater, but silica precipitated from a soluble glass solution by means of an acid, which produces the gelatinous form of silica, will at once combine with the lime in limewater and form a silicate of lime. The silica in the hydraulic mortar is also in a state, not like fine sand, but chemically combined and dissolved in the mass, and therefore ready to combine with the lime in limewater. Next in importance to silica is the magnesia, which renders the lime hydraulic, which, according to Fuchs, has been proved that lime and magnesia well mixed will harden under water to a certain extent without the addition of silica; for we have in Germany a hydraulic lime containing only 4 per cent. When silica is found to the extent of 52 per cent., the point of saturation is reached, and such limestone is no more hydraulic. Alumina and iron may be entirely absent, although the former is always present in the best kinds of hydraulic mortars, of which that of Rondout, usually called Rosendale cement, and with the employment of which the Croton Water Works of New York City were built, is the best on this continent.

It is confidently to be hoped that by the proper application of alkaline silicates will contribute much to the manufacture of an artificial hydraulic cement.

GERMAN HYDRAULIC CEMENT.

This material, artificially prepared, is in great use and is of very peculiar composition: unquestionably it is intended to form a silicate-aluminate of lime, or, in other words, an argillaceous silicate, but the admixture, such as charcoal and iron filings, cannot be explained, but the base being obtained by the production of an alkaline silicate bespeaks for it a useful vehicle as a cement.

It is prepared with 25 parts common clay, 60 parts lime, 10 parts magnesian limestone, 10 parts iron filings, and 10 parts of black oxide of manganese; these materials, in very fine powders, are made plastic by the liquid silicate of soda, at once applied as a cement or mortar, but it will not set at once, six hours being required for the mass to harden.

Hardness of Ancient Mortars.

Mr. Spillar communicated a paper on this subject to the British Association, in 1868, of which the following are the conclusions, from the chemial examination of the ancient mortars from Burgh, Pevesney, and other Roman castles: that the lime and carbonic acid are invariably united in monatomic proportions, as in the original limestone rock; and that there is no evidence of the hydrate of lime having at any time exerted a power of corroding the surfaces of sand, flint, pebbles, or even of burned clay, with which it must have been in contact for long periods. Further, that the water originally combined with the lime has been entirely eliminated during this process of recarbonation; and, this stage passed, the amorphous carbonate of lime seems to have been gradually transformed by the joint agency of water and carbonic acid into more or less perfectly crystallized deposits or concretions, by virtue of which its binding properties must have been very considerably augmented. Messrs. Abel and Bloxam assign, as one of the causes of the hardening of mortars, the formation and subsequent crystallization of the carbonate of lime.

Stinde proposes the silicate as a very useful cement by mixing equal parts of oxide of manganese and oxide of zinc, and making them into a thinnish paste with the silicate of soda, which paste, quickly applied, sets very rapidly; and by mixing the hydraulic lime to this composition, it is a cement which will resist permanently also the action of water and heat:

"CEMENT AND MORTAR OF THE ANCIENTS.

"We all know how enthusiastic some are in their praises of those ancient structures which have resisted for ages the ravages of time. They imagine that they are at liberty to draw conclusions which are not the most favorable to the architecture of the present time. Although they may be in a measure correct, it can not be denied that such critics are too partial in their admiration for things ancient as opposed to things modern. We frequently hear the remark that some of the Roman mortars have endured for eighteen centuries the vicissitudes of time, while many buildings of now-a-days present, in a very brief period, the sign of quick decay; but they forget that these ancient buildings constitute an exceedingly small fraction of the enormous number of those erected during many centuries in Egypt, Greece, Rome, and her provinces. They do not consider that thousands of temples, palaces, and private dwellings have been entirely destroyed. And what answer can they assign to the fact that the very complaints they indulge in were even more frequent then than now? Pliny asserts that the reason of the falling in of many buildings in Rome was to be attributed to the fact of the bad quality of the mortar.

"Still more important than this argument is that of Vitruvius, the architect of Augustus. He has left a work on Roman architecture in which we find nothing that entitles us to place the architects of antiquity above those of the present time. Again, it has not been taken into account that a great part of the extraordinary strength of antique architecture is more the effect of time than the mechanical skill of the builder, or the virtues of his cements, as we propose to show hereafter. Pliny and Vitruvius both explain, to the best of their knowledge, what kind of materials the builders selected for their cements, and how they were prepared. The process was identical with the modern *modus operandi*. It is true that the old Romans were particularly careful in the selection of materials for their mortar, as well as in its preparation. They were aware that they must calcine the limestone, and mix it with sand, in order to apply it; but did not possess any correct idea of the change which limestone undergoes in the process of calcination, nor of that which is the cause of the cohesive quality of mortar.

"Many centuries elapsed before these facts were understood and explained. Black, in 1757, started the explanatory theory by the discovery of carbonic acid. A few years previous to this, Marggraf, the discoverer of sugar in beets, found the elements of gypsum, which was already employed by the Romans; and, in 1768, Lavoisier demonstrated the causes of the hardening of burnt gypsum when it is mixed with water.

"The ancients, therefore, put their practical knowledge to the best possible account. As they were deficient in chemical knowledge, they were guided only by what observation taught them. Their chief care was centred in the exterior. In the selection of limestone, the color decided. The white ones were considered best, and the colored ones were seldom used. Those taken from the interior of the earth were preferred to the stones which were met with upon the shores of rivers. A law provided that the lime must have been slacked three years before it could be used. The same also prescribed the quantity of sand which must be mixed with the lime, mentioning also that crushed cherts imparted a greater strength to the mortar. Its preparation was, as it were, a state affair, the censors watching carefully over it. In spite of all this, it often happened, as Pliny states, that they did not attain the object in view.

"But in the advance of chemical science, the fact has been established that a mortar can be prepared that, in the course of one or two years, will be as strong and durable as Roman mortar after the lapse of two thousand years. The builders of the ancients were not farther advanced than those of the middle ages. The walls of the Bastile, for instance, were so strong that they had to be blasted away. This had likewise to be done in the removal of the remnants of a bridge at Agen, built about the year 1200; and the mortar of a bridge erected at Cahours in 1400 was even found to be considerably stronger than that of the antique theatre of the same city.

"The Romans were also acquainted with hydraulic cement. The merit of this knowledge is, however, considerably lessened when we consider that the same is found in the volcanic districts of Southern Italy. A mere accidental observation, the same being, perhaps, mixed with sand instead of lime, may have led to its application. Says Vitruvius: 'There exists a kind of dust which produces strange things; it is found near Baja and the Vesuvius. When mixed with lime, it forms a mortar which not only imparts great strength to buildings, but also to water works.'

"The natural cement in question is a volcanic pumice-stone, like breccia, which is still found in the environs of Naples. At a less remote period of time, when the Romans invaded the valleys of the Lower Rhine, they easily recognized the volcanic nature of the Brohl Valley. Here, as well as amid the surroundings of the beautiful Laacher Lake, which lies like a jewel set in the midst of the long-extinct Rhenish volcanoes, they discovered another natural cement — the trass — in such considerable quantities that the quarries which were opened at that time are still in existence. The use of hydraulic cement in ancient times could, therefore, have been only a limited one, as it was found only at the two places mentioned. Its artificial preparation was not understood. The solution of this problem was reserved for the investigating minds of the present progressive century."

" HYDRAULIC CEMENT.

" This material is justly esteemed far superior to metal of any description for the lining of cisterns, the water-proofing of cellar-bottoms, and similar purposes. A few directions for its preparation and use may not be out of place. To make water-proof work, it must be borne in mind that *common lime* must not be used at all; for on common lime water or moisture has an effect just the opposite to that which it has on the *water lime*, rendering it soft and quite friable when dried; whilst on the water-lime the well-known effect is to make it perfectly hard. No mixture of these two varieties of lime can, therefore, be made under water. But, although they do not act well together even under ground, they serve well in dry places, such as buildings whose walls are of extra thickness; and if proper care be taken, they will conjointly form a very compact and powerful cement. The fact that water-lime shrinks when wet, while common lime, in the same state, swells, at once points out the manner of treatment to be pursued in uniting the two thoroughly. Thus, it is necessary to ascertain the per centage of shrinking of the one and increase in the other, as nearly as possible, before the proportion of one to the other can be determined, with a view to their intimate combination. Such experiments are the more necessary when we consider the great difference which exists in the quality of both kinds of lime in various localities. The simplest and most effectual mode of testing water-lime is to put several portions of different makes into small bags of flannel, and throw them into a basin of water. After three minutes' immersion, take them all out at once, and squeeze each in the hand. Then take off each bag, and that which is best is *firmest*, and when thrown naked into the water again, loses least of its outer coat. If none of them will bear uncovering at three minutes, try four, five minutes, but this latter should be the longest test. The test for common lime is, on the contrary, the bursting open and evolving of caloric in a greater or less degree; and the consequent action of the water will show, by its bubbles, the power of the lime.

"It is the per centage of clay contained in any specimen of lime that determines the solidifying property of the cement made from it. The best hydraulic lime contains silex, lime and magnesia, or alumina. Its solidification is attributable to the formation of silicate of alumina and lime, or of magnesia and lime, which combines with water, and produces a hydrate excessively hard and insoluble in water. The hardening of hydraulic lime may, then, be compared to that of calcined plaster, which also combines with water to form a solid hydrate; which calcined plaster, from the large quantities of it manufactured near that city, is commonly known as *Plaster of Paris.* A limestone containing thirty per cent. of clay makes a quick-setting cement; and we have in the United States the Rosendale and the Bellville cements, having forty and fifty per cent. They become exceedingly hard when plunged in water for from two to three minutes. Both these cements, especially the former, have been used extensively by our engineers.

"Inferiority in the quality of hydraulic lime may be produced by the want of proper care during its manufacture, the stone being calcined at too high a temperature; the double silicate in such case becoming a sort of *frit*, which does not hydrate in contact with water.

"As hydraulic lime is expensive, according to the distance of its transportation, we will here give the method of making an artificial hydraulic lime, according to the highly successful experiments of M. Vicat a celebrated French engineer and the author of a much esteemed work on hydraulic cement, who first pointed out the method to be adopted in its formation. It is prepared by stirring into water a mixture of one part of clay and four parts of chalk; these materials should be mixed by a vertical wheel turning in a circular trough, and made to flow out into a large receiver. A deposit soon takes place, which is formed into small bricks, which, after being dried in the air, are moderately calcined. Hydraulic lime thus prepared enlarges about two-thirds in volume when placed in water. Like the natural hydraulic lime, it can be completely dissolved by acids. This invention of artificial hydraulic lime has rendered Vicat deservedly famous, as it has been in use for many years in the public works throughout France, and was even employed in the hydraulic masonry of the St. Martin canal. That it can be made in this country there is no doubt, as the argillaceous or potter's clay required is to be found almost everywhere.

The new cement which M. Sorel proposed to the French Academy consists in the application of a basic hydrated oxychloride of magnesium, may unquestionably be improved by means of a silicated hydraulic lime and the bittern of the salines, which is a chloride of magnesium in a concentrated condition.

Lime, sand and clay, when mixed with water, form the so-called composition of a hydraulic cement: they are fit to unite solid surfaces by hardening after a few days application, under water, by forming a combination with the constituents of either surface. Walls and piers have been built for over one hundred years, and after being exposed under water have become harder and harder. This cement is also called Roman cement, because the natural materials are found in abundance in the Roman district where the tufas, puzzuolanas and trass, all products of volcanic districts, like the Pontine Marshes of Rome, and near Naples, are abundant, and consist of those elementary substances. In the volatic formations of the triassic period the marls or green sand, the curious nodular and lenticular concretions, the Septarias and ludus Helmontii, of turtle shape, all found in argillaceous strata of the sedimentary rocks which are alternating with limestone beds, and all found in abundance on the English and French coasts and the United States, all of them form a siliceous clay intermixed with lime, and are, therefore, the proper material for a hydraulic lime or cement; the Portland cement is largely manufactured at the mouth of the Thames, the Roman is also manufactured in England from the materials or nodules picked up or found in the cliffs near Harwich; the septarias are from the London clay, and yield good cement. The marls of New Jersey, which are called green sand, occur in a large belt of cretaceous rocks, have of late years been of great importance to the Jersey farmers, and have a similar composition of lime, silica and clay forms, all excellent materials for a hydraulic cement.

This cretaceous belt with its clay as a foundation and boundless supplies of silica forms the most productive strip of country and is well worth the consideration of a reflecting mind and the manufacturers of these substances. Most of the above materials contain about 70 procent Lime, 20 procent clay, and 20 procent silica, which when calcined, the Lime becomes caustic and forms with the silica and clay a double silicate of this form such as $CaO—CO_3$, SiO_3, $Al\ O_3\ H.\ O.$

The Portland cement is exported largely from England and according to the manufacturers name is called Reess, Hamilton and other cements and will bear a strength varying from 20—60℔ to the square inch.

The celebrated french cement of Bouilly is prepared in Boulogne from the pebbles called Golets which are nodules found in that region. The Terra Cotta is also a cement of clay and silica.

Silicate of soda or potash may be mixed with the particles of any material or body, such as common sand, dust, sawdust, clay, chalk, marble-dust, metal-filings, etc.; a paste may be formed of the same, which, in a short time, will become hard and tenacious. Common clay thus mixed forms a fine and plastic mass, and becomes very hard. Saw-dust can be formed into any shape, acquires considerable strength combined with lightness, and has been proposed as an excellent non-conductor of heat. A cake of the same five-eighths of an inch thick may be placed on a white-hot iron for half an hour, and while its under side in contact with the iron will get charred, the upper side will get but little warmed.

The adhesion of all these various pastes to glass, minerals and metals is most remarkable, but, unfortunately, all of them except those formed with the carbonates of lime and some woods, do not resist humidity or water. However hard any article formed of sand, clay, etc., and silicate, may have become, however dry and old, the same is soon dissolved or reduced to its component parts when coming into contact with water, or when exposed to humid air.

The combination of the silicates with the carbonates of lime form a remarkable exception to the above. After the lapse of a comparatively short time, the objects formed of a paste of the same and silicate become hard and perfectly indissoluble in cold or hot water, and will resist humidity and weather. But their property to adhere to metals, more especially to iron, is so remarkable that the idea suggested itself to use the same as a coating for iron, either merely for ornamental purposes, for protection against rust or fire, etc. A series of experiments and tests fully proved the practicability of the process, and a patent was applied for and granted to B. Oertly and X. Fendrich for the same.

This *coating* of iron with marble and silicates, it may safely be said, constitutes one decided step forward in the use of silicates, and even of iron. While offering the most comprehensive protection to iron, the coating is susceptible of any coloring and of any finish of marble. Iron columns, especially wrought-iron columns, can thus be rendered beautiful, while receiving additional security in cases of fire from the low power of conducting heat of the coating. Table plates, billiard plates, counter tops, doors or door-panels, shutters, etc., while vieing in appearance with stone, are rendered strong by their iron skeleton. In connection with saw-dust the coating forms the best coating for boilers and steam-pipes. As the co-efficient of contraction and expansion of the coating is almost identical with that of iron, exposure to heat and to great differences of temperature will not injure its sticking qualities, and this singular quality of the coating really constitutes its excellence.

The science of heating and ventilating public and private buildings has been extensively investigated and discussed for the last thirty years, and not without many practical and beneficial results. The mechanical laws governing the subject, if no better understood than in the days of Peclet, are more generally heeded. The chemical constitution of fresh and pure air, of vitiated or contaminated air, has been ascertained by the most refined methods, in the valley, on the mountain, in town and country, in the bed-room and public hall, almost all over the globe. An endless number of hot-air, hot-water, or steam-heating systems, of more or less or no value or merit, are at the choice of the wealthy, but no devices have until now been suggested to improve the means of heating the dwellings of the mass of the people. The iron stove forms as yet the great and simple apparatus for warming the inhabitants of the million, and from its cheapness, its portability, and its elastic adaptability to differences of temperature of a wide range, continued to be the great means of heating the homes of the people. And indeed, if we are to believe the graphic accounts of a more recent lecturer and professional engineer of ventilation, (L. W. Leeds, Esq.,) it must also be regarded as a providential protection of the people, that the introduction of those hot-air devices could not become more general.

To correct or ameliorate the obvious defects of the iron stove by means at once cheap and easy applicable, is the object of the invention now brought to your notice. Acknowledging the great importance of ventilation, it is not proposed to interfere with that question, which moreover cannot be considered settled or ripe for a popular formula when such great discrepancies occur in the precepts of the most indefatigable investigators, and when the air in the halls of Congress, though renewed twelve times an hour, and having a purer chemical constitution than the air of the Alps, is nevertheless considered oppressive by our national legislators.

The defects of the iron stove are well known—excessive heat one hour, deficiency of such the next hour, burning of the air, waste of fuel, etc. Perhaps nowhere are these defects more apparent, more oppressive, and more dangerous, than in the iron stoves of our railroad cars. Though many improvements have been made in iron stoves, it is certainly a patent fact that, in a great majority of cases, especially during the severer portions of the winter season, the iron stove is allowed to become red-hot until the heat emanating from it does become unbearable and dangerous, when of a sudden the stove-door is thrown open and draft shut. The red-hot iron, being of a temperature about 1,000° F., decomposes or burns the organic particles, gas, or even animalcules, which float in ordinary atmospheric air, to a greater or lesser extent, and which are exhaled from the human body. Air thus acted upon must become disagreeable and offensive, if not positively injurious. A serious waste of fuel does also take place by the above method of heating. The air of the room, when the stove-door is open, is heated over the burning fuel, and escapes through the stove-pipe without contributing anything to heating the room, and the balance of the air, heated by the lower and hottest parts of the stove, follows the same line; the draft being shut off or checked, but a small portion of air finds access to the heated coal, and on account of the great preponderance of incandescent carbon over the supply of oxygen, the combustion does not take place by producing carbonic acid $C \ddot{O}$, but by producing oxide of carbon $C \dot{O}$; a fact well established by chemists. This form of combustion, while consuming the same amount of fuel, produces but one-quarter ($\frac{1}{4}$) of the caloric which is produced when carbonic acid $C \ddot{O}$ is formed, that is, when a full supply of oxygen or fresh air is furnished to the burning fuel, as is the case with stove-door shut and draft open. The combustion is retarded, not as might be supposed, by spreading the same amount of caloric over a longer period of time, but by actually reducing its measurable amount to one-quarter of that due to the consumed fuel when properly burned. Some of the oxide thus formed will find its way into the room, where its presence is by far more dangerous than a large amount of carbonic acid, it being a positively acting poison.

The stove now offered for the first time, and for which a patent was granted to B. Oertly and X. Fendrich, on the 18th of August, 1868, obviates or remedies the above defects *in toto.* It will be but a trifle more expensive than the common iron stove; will be as portable as the latter; will require as little extra mechanical skill in its setting and handling, while it substantially has all the advantages of the porcelain, the soap-stone, the sand-stone, etc., stoves, and excels them all in the finish it is susceptible of.

The mass of silicate and minerals, either applied as coating to cast-iron or wrought-iron stoves, or forming exclusively the body of a stove, with or without an iron framework embedded in it for purposes of strength, radiates heat by far more freely than iron, while its conductive powers to that of iron are in the ratio of 16 to 27. Its superior radiating powers over those of iron can be readily tested and ascertained by any ordinary thermometer. It diffuses a pleasant and sufficient heat at a temperature at which iron scarcely makes itself felt, except by immediate contact, and thus allows of a sufficiently rapid transmission of heat to warm an enclosed space without assuming itself such a high temperature as to burn or decompose any organic gases or particles floating in the air of any occupied room, and all of this while admitting the most favorable circumstances for a full combustion of the fuel. Fresh air for ventilation can, and ought to be, introduced in the various manners it is now introduced in connection with iron or porcelain stoves. The invention accomplishes, at less cost, all of what the most improved earthenware or soap-stone stoves of the present day accomplish.

Kuhlmann, in his theoretical view on the behaviour of the alkaline silicate towards the artificial production of hydraulic lime, cements and silicified stones, says of the artificial hydraulic lime as follows: If water is mixed with slaked rich lime and a solution of a Potash or Soda silicate, the Potash or Soda are separated and the silica combines with the lime in place of a part of the water, which saturated the same and forms a paste, capable of disseminating in the fluid to all extend. This combination renders the lime plastic, which when exposed to heat and put into water, will keep clear. All particles of lime are so to say luted by the silica cement. This lime if combined with a basic silicate and exposed to atmospheric air, attracts, if in buildings, carbonic acid which by degrees is converted into silicate of lime.

Similar products are obtained by substituting aluminates of these bases to the Potash or Soda silicates.

THE SILLIFICATION OF THE MORTAR FROM FAT LIME.

If walls are moistened with the solutions of the silicates, a reaction takes place at once to convert the hydrate of lime, no matter how old the same was, into a lime silicate, whereby a part of the Potash or Soda are separated; the silicate which may have been bound to the carbonate of lime, forms a new combination analogous to that hydraulic mortar, produced artificially by the moist way. If the alkaline silicate is in excess, the reaction on the carbonate goes on according to the property described. The silification of porous limestones is explained in this manner: The native carbonate of lime, if coming in contact with the potash or soda silicate, acts partially like caustic lime. Potash and soda are separated by the contact of the alkaline silicate, and the silica forms the same carbonated silicate, like that formed in the above manner.

In support of this explanation must be stated, that the alkalis potash and soda are in all cases rendered caustic, and that the chalk must withdraw the last trace of the silica by the boiling it with the soluble alkaline silicates, and invariably retaining the carbonic acid in the composition. It is clear, therefore, that the carbonates of lime exercise a basic effect in the presence of silica, which is retained by the potash or soda through some affinities. It is likewise obvious that these phenomena so indicate the invariable result of the formation of a hydrated silico carbonate of lime, which is capable of parting with its water by degrees, and to assume the characteristic hardness of hydraulic cements. The silification of gypsum is thus explained: The effect of the soluble silicates on gypsum, in plaster of Paris, is materially different from that which the silicates perform on lime. In a practical point of view, its results are unreliable and difficult to produce. The alkaline silicates undergo a decomposition if coming in contact with sulphate of lime, they form a sulphate instead of a silicate.

It is, however, known that sulphate of soda, on account of its crystalization, has a tendency of destroying the porous limestones, and it is therefore used to test the weather-worn stones; it is advisable to use a potash salt if intended for hardening gypsum. Another important circumstance is in the application of the alkaline silicates on gypsum; while the effect of the alkaline silicates on porous lime acts favorably for the hardening of the silica molecule, that of those bodies on gypsum is quick, almost instantaneous, which, when gypsum is brought in contact with the silica solution, produces a raising or effervescing, giving great porosity to the gypsum, which scales off very soon, while weak silicate solutions produce more satisfactory results. For the purpose of possessing good results in plaster works it is proposed an intricate mixture of 80 parts burnt and pulverized gypsum, 3 parts slaked lime, 10 parts powdered silicate in sufficient hot water. All must be boiling.

Cause of the Hardening of Hydraulic Cement.

In order to test the truth of the different hypotheses made concerning this subject, A. Schulatschenke, seeing the impossibility of separating from a mixture of silicates each special combination thereof, repeated Fuch's experiment, by separating the silica from one hundred parts of pure soluble silicate of potassa, and, after mixing it with fifty parts of lime, placing the mass under water, when it hardened rapidly. A similar mixture was submitted to a very high temperature, and in this case also a cement was made. As a third experiment, a similar mixture was heated till it was fused; after having been cooled and pulverized, the fused mass did not harden any more under water. Hence it follows that hardening does take place in cement made by the wet as well as the dry process, and that the so-called over-burned cement is inactive, in consequence of its particles having suffered a physical change.

A STRONG CEMENT FOR IRON.

To 4–5 parts clay, dry and powdered, 2 parts iron filings, 1 part manganese, ½ part salt, ½ part borax in a paste made with soluble glass, or equal parts zinc white and manganese, made to a paste, must be used immediately.

THE PEASLEY CEMENT.

The manufacturer of this cement has made himself celebrated and wealthy by his perambulations throughout the United States with a span of horses attached to a load of hay, so it is thought advisable to enlighten the reader with its composition :

White glue, dissolved in a large quantity of hot water, also 50 parts of isinglass, and 3 parts of gum-arabic, and 3 parts of gum traganth, and to this solution an alcoholic solution of white shellac ; 1 part of the latter is then mixed with the watery solution. To the whole are added 24 parts of white lead and 12 parts of glycerine, and 200 parts of alcohol. It is immediately put in bottles and well corked. In other words : 200 parts white glue, 24½ parts lead, 12 parts glycerine, 200 parts alcohol, 50 parts isinglass, 3 parts gum arabic, 3 parts gum traganth, 1 part bleached shellac.

THE SILICATION OF FRESCO PAINTING.

The same phenomena attending those of mortar take place in fresco painting. It is known that the colors prepared by water on the rough mortar of fat lime and sand are fixed by the carbonate of lime which envelopes them, appearing dull in many respects, of an agreeable appearance, as has been demonstrated in the durability of the old paintings of Herculaneum and Pompeii, which have been overthrown by rains of ashes 79 years after Christ, and were buried in a depth of 100 feet. By moistening with the liquid silicates the walls so painted, the surfaces of the rough mortar of fat lime assume the properties of hydraulic cement and acquire hardness.

SILICATE PAINTING BY MEANS OF A BRUSH.

The colors rubbed up with a silicate produce an intimate combination of the carbonated salts and acids, and the alkaline of the silicates are separated thereby. If the color is composed of a material unsusceptible for a chemical affinity, a silicate mass is formed by the action of the atmospheric carbonic acid, which makes an extraordinary binding cement, and by the separation of the alkali assumes a perfect insolubility in a very short time. This operation is accelerated if a coating of gypsum has been laid on the lime, and becomes more solid and intimate, because the alkaline and silicate acts at the same time on the coloring and carbonate of lime; in which case it is very serviceable to moisten the wall before applying the colors with a weak solution of liquid silica, in order to prevent the too rapid withdrawal of the silicate and cement from the colors.

INJECTION OF SILICATES.

While engaged in impregnating the soluble silicates into the porous stones, and carrying this operation into all organic and inorganic matter, the convincing proof was manifested that the hardening of those bodies are only owing to the decomposition of the silicates, effected by the slow action of the atmospheric carbonic acid and the gradual condensation of silica. This phenomena led to the observations that the natural silicates and aluminates, as well as other mineral species, were similarly formed in the moist way.

This remarkable reaction of hardening porous bodies by silica proves, by geological observations, highly probable that not alone all the enveloped and crystallized minerals found in limestone formations, but also an endless variety of silicated and alluminated substances found in nature, owe their existence to analagous causes; that the flints, agates, and petrified wood cannot have any other origin, but that they are formed by the slow decomposition of a silicated alkali from the carbonic acid, either atmospheric or generated during the process.

This fact is of the highest interest in the chemico-physical investigations, and is the key to the investigations of the formation of the natural silicates, even under many various circumstances, of the condensation of silica by other bodies than the carbonic acid; many experiments undertaken have proved the gradual decomposition as already stated, and in a great variety, of the formation of such as opal, quartz, and others depending, likewise of the state of concentration of the original decomposed materials. The iridescence of the opal, which disappears if exposed long to dry atmosphere, but revives if moistened in water or sweet oil, gives a beautiful example. Many important facts have come to light by the investigations made on hydraulic limes and artificial stones, which prove that a considerable quantity of potash is contained in the natural hydraulic and other cements; the origin of which is attributed to the decomposition of the alkaline silicates by the lime, and this may be proved by the formation of saltpeter or nitrate of potash in the efflorescenses of walls and earths in caves, called an eremacausis of substances which contain nitrogen, and form, therefore, ammonia, and in contact with porous substances undergo an oxidation and conversion into nitric acid, and at once is combined with the alkalies contained in the native lime occurring in the older formations, and was separated, under certain circumstances, from the alkaline silicates found in those limestones, nitrate of potash the result. In general terms, nitre, or nitrate of potash, which is found in crusts on the surface of the earth, on walls and rocks, and in caves, is found in there localities abundantly in certain soils of Spain, Egypt, Persia, and E. Indies, especially in hot weather succeeding rains, it is also manufactured from soils where other nitrates (nitrate of lime or nitrate of soda) form in a similar manner, and beds called nitraries are arranged for this purpose in many countries. Refuse animal matter also, putrified in calcareous soils, gives rise to nitrate of lime, as we find it so frequently in cow and horse stables, and is then converted into nitrate of potash; old plaster walls, when lixiviated, afford about 5 % of nitre. It is known that nitre requires for its formation dry air and long periods without rain; the potash comes mainly from the debris of felspathic and lime rocks in the soil, or in the cements, if they have been used for building walls, and the oxidation of the nitrogen of the air is promoted by organic matters, hence the nitre is generally associated with azotized decomposed organic substances. A nitre crust from the vicinity of Constantine, Algeria, afforded Boussingault 85% nitrate of potash, with some nitrates of lime, soda and magnesia. In the Mammoth cave of Kentucky, where the nitre is found scattered through the loose earth in great abundance, and was utilized during the war of 1812, also in the Mississippi Valley, in Missouri, many caves have yielded the nitre which was of great use to the secessionists of the late war, when Tennessee, along the limestone slopes and in the gorges of the Cumberland table land, produced a large amount of saltpeter.

The nitrate of soda, formed in a similar manner like that of nitrate of potash, but more particularly found in the dry pampas of Chili, where it is found at a height of 3,300 feet above the sea, and contains beds of several feet in thickness, along with gypsum, common salt, glauber salt, and the remains of recent shells, indicating the former presence of the sea.

Kuhlman has proved by his investigations that the larger number of limestones from various geological periods contain both potash and soda, deriving their existence from various plants growing in a calcareous soil, and has also shown the development of the efflorescense of the carbonates of potash, chlorides of potassium and sodiums, which make their appearance on the surface of walls from their construction, to which he was led by the fact that the alkaline salts in general are obtained in larger quantities from hydraulic limes than from the lixiviation of air limes, and that the hydraulic limes contain mostly more alkali, and that it exerts much influence upon the quality of lime, and it has been ascertained by Vicat that the occurrence of the potash and soda is neither accidental nor less influential upon the proportion of the hydraulic limes. It is presumed that the silicated limestone, and any fat lime mixed with clay by the influence of potash or soda are during the burning converted into double compounds; analagous to the natural silicates, which are known under the name of zeolites, such as mesotype, stilbite, apophyllite, etc., which all form hydrates, and lose their water of crystallization by burning, and absorb it again on moistening; one of the species of that class of mineral, such as the laumonite which, when exposed for some time to the atmosphere, effloresces and crumbles to pieces to the chagrin of the mineral collectors, but it is sufficient to confirm the remark just made regarding their constitution and similarity of the artificial silicates of lime and alumina. It is apparent that, in the hardening of hydraulic lime a process takes place analagous to that of gypsum when hardening, and forming a hydrate. It may, however, be possible that the hydraulic limes be still formed without the presence of potash or soda, and that the silicium or aluminium in contact with lime fills the same office in possessing the property of binding the water, and to convert them in certain conditions to a hydrate. Respecting the cement which is formed by the moist way, it is a fact that when chalk is brought in contact with solutions of alkaline silicates, an exchange of the acids of both salts takes place, one part of the chalk is converted into silicate of lime and the corcorresponding quantity of potash in carbonate of potash: this explains the true artificial stone which has become, on exposure to the atmosphere so hard, that, if the mixture contains a sufficient quantity of a silicate, possesses the property to adhere firmly to such bodies where it has been applied, the materials so formed with the silicate of potash or soda are analagous to cements without burning, and may be used for restoring monuments, etc. In the sillification of artificial stones the affinity of lime to the silica contained in the soluble glass is manifest, and shows the effect of the alkaline silicates on limestones; and how the influence of the atmosphere in the hardening of silicates or artificial limes is brought to bear through the atmospheric carbonic acid by the separation of one part of silica in the silicates, and how the other parts of the silicate, when in close contact with a sufficient quantity of carbonate of lime, a lime silicate is formed.

This acquired knowledge has produced numerous applications in industry, it has proved that, by artificial impregnation of mineral substances into the interior of porous substances organic as well as inorganic matters are preserved, or silicified. The silification of a fine sandstone is easily effected by the mixture of 1 part of liquid silica and 2 parts of fine sand, with the addition of a small quantity of chalk and white clay, all of which are wrought into a paste and then formed into desired objects and exposed to the atmosphere for some time, and the finishing process continued by means of hydraulic pressure and heating in hot chambers, the particulars of which have been indicated in a former chapter. It has been ascertained that always if any salt insoluble in water is brought in contact with the solution of a salt which forms with the acid of the base of the insoluble salt, a less soluble substance, an exchange takes place, which, although but partial sometimes, produces the formation of double salts. This discovery led to a direct application that white lead, chromate of lead. chromate of lime, and the majority of the carbonated metallic salts are suitable for silicification.

THE SILICATE PAINTING ON STONE,

STEREO-CHROMIC.

The use of the brush in the application of colors has so far been but partially accomplished. The substitution of the potash or soda silicate for the fixed and volatile oils with mineral colors has at first been attempted by trituration of white lead with the liquid silicate. It has been found that a transformation of the white lead takes place the moment they come in contact together, which is so rapid that no time is allowed to transfer the paint into the brush. In order to make this paint more suitable, and to prevent a kind of decomposition, it was found advisable to add a large portion of the sulphate of baryta, artificially prepared, as this paint operates but slowly on the silicate solution.

It appears that this baryta may be used with more advantage by itself, as it unites perfectly with the silica and appears to form a chemical compound, but a disadvantage presents itself in forming but a half transparent color, which does not cover well, and the addition of oxide of zinc is therefore recommended, which agrees well with the paint in connection with baryta and silica; this application has produced very satisfactory results, forming a cheap white paint, which can be easily transferred with a brush.

Many mineral colors, mixed with white bases, produce such difficulties on account of their drying too quick, others too slowly, according to the behavior of the bases to the soluble glass. Many combinations retain the alkali obstinately, and it was attended with many difficulties to apply the colors with the liquid silica, yellow ochre, blue and green ultramarine,. sulphuret of cadium, manganese peroxide the oxide of chrome have proved to unite well with the silica.

The painting on stone is much easier when silica has been used on the stone than on that where it was not applied, for the reason that the absorbing quality of the silica, serving a binding material, withdraws it from the color, and it is therefore very advisable to apply several times the liquid and exposing to the atmosphere before applying the paint. A single silification of the wall is indispensable on the painted coloring, which is done by preparing, as usual, with the liquid silica, as other paints are treated. The soda silicate used for painting on walls is easily effected by the use of the syringe. The painting on walls is attended with some difficulty likewise, for while that on stone remains unaltered, the wood is apt to shrink, or to crack, and many woods will not easily take the paint, and even change their physical appearance, becoming darker; oakwood assumes the appearance of an old wood, and only the white and hard woods, such as the ash and maple woods, will take up the silicate painting. Another difficulty takes place in painting on wood, that it peels off, if applied too thickly. A weak solution of 1 part silica, of 28° B to 5 parts water, either alone or combined with other bodies, is recommended.

For protecting shingles against rot, or rendering them incombustible, 4–5 applications, during an interval of a day each, may be made, and another method is to season them, first by steam, then soaking them in green vitriol solution, and then impregnating with silica, quite hot, and at last to throw fine sifted sand upon them. Wooden stables, and other buildings exposed to vapors or great change of temperature, three or four coatings of the silica solution is recommended.

Further Remarks on Stereo-chromic.

This new art of painting derives its name from two Greek words *στερεοσ*, fast, or permanent, and from *χρωμα*, the color, and has been introduced as a substitute for fresco painting, and bids fair to be very extensively applied, and more than the encaustic painting, from the fact that the works executed by this art have given great satisfaction; the inner halls of the new museum at Berlin have been painted by Kaulbach with panels 21 feet high and 24¾ feet broad, and are said to equal the oil paintings in freshness and vigor, and with that particular advantage that the paintings may be viewed or examined from a certain stand to do so, and that it may be applied on many grounds without the rough mortar being first used. An experiment was made to expose a painting for one year to the atmospheric air, to the sun, fog, snow and rains, and retaining during the whole time its freshness. An important circumstance, however, is the formation of the groundwork, for any neglect in that of the lower and upper ground materially affects the beauty of the painting. In order to produce a uniform strong firmness, it is necessary to supply the soluble glass uniformly, so that it may be absorbed perfectly and uniformly.

The walls must be well cleansed in the first instance when the mortar is laid on, and then a weak solution of the liquid glass is passed over it and left to dry. Clean washed sand or limey sand is then mixed with a very small quantity of burnt lime, and made to a paste and laid on the wall. The surface is made even by an instrument, and the upper layer removed which was formed on coming in contact with the air; but the mass must be always kept moist during the whole operation. This rough morter will soon become dry, and may be rubbed off with the fingers, but it must not be left too long exposed to the air for fear of its attracting the carbonic acid, whereby the lime would be too much carbonized.

By the application of a solution of carbonate of ammonia a considerable hard consistency is produced, when the liquid may now be applied several times with a brush, but always at intervals, and enough to penetrate into the morter, and the liquid glass ought to be that made from soda, and quite clear, that liquid soluble glass which was used at the Munich Theatre consisted of silica 23–21, soda 8–20, and potash 2–52, and had a specific gravity of 1,381, and was then diluted by an equal quantity of water. In all cases, the liquid must be laid on by means of a brush, in order to produce a uniform impregnation of the same. When this groundwork, called the underground, is faithfully and carefully prepared, the upper groundwork which is to receive the painting may be commenced with; it does not differ much from the first operation.

The sand to be used must be of fine grain, and well washed, as also the quartz, etc., (the lime sand,) which is obtained from marble or dolomite, finely powdered, are to be used to the thickness of one line quite evenly, in order to obtain the necessary roughness on the surface indispensable to the process of painting. It may, perhaps, be necessary to use other substances before the application of the fine sand, in order to destroy any lime crust which might have been formed in the preparation of underground, and diluted phosphoric acid is now recommended to be applied with a sponge or brush on its surface, for it forms then a phosphate of lime with the soluble glass, which binds well and does not injure the mortar. The ground so prepared, and well dried, is now impregnated with the liquid glass, the same as the first, and diluted also with equal quantities of water, which is done twice, allowing sufficient time to dry between each impregnation.

Wood may be painted by covering it first with a chalk ground, which must be thick enough to allow a polishing with pumice: to chalk, glue, or a little silicate solution may be added, as a binding material. Another difficulty occurs after the first has been overcome, in the oozing out of the carbonate of potash in damp weather until the whole salt has been expelled, and many experiments have failed, and hydrochlorate of ammonia was first proposed in a weak solution, and an absolute insolubility of the color was thereby obtained, but chlorate of potash remained in this operation, which destroys the gloss of the colors if not at once removed by repeated washing; forced to resort to those few chemical agents, apt to fix the potash, which should enter as insoluble combinations in the color without destroying them; the perchloric and hydrofluoric acids were resorted to. It is well known that by washing with hydrofluoric acid the density of the colors is much increased, and it was thought therefore safe to use it, particularly in painting on glass, but only as a very weak solution. Hydrofluoric acid possesses the most remarkable property to dissolve most oxides when in a concentrated state. The application of the weak solution of hydrofluoric acid, either for fixing the potash in painting and in silification of limestone, was mainly calculated for such case where a silicate has been used with an excess of potash, and in hardening of soft and porous limestones by a partial conversion into a lime silicate it was found very expedient for fixing the potash, and making sure the insolubility to moisten, at first with a weak, and then strong solution of the hydrofluoric acid, the stones when the potash oozed out; the acid, however, penetrated the stone and produces an insoluble compound, in other words, it fixes the soluble potash, and produces an insoluble compound. Through this discovery hydrofluoric acid was found a very useful application in the fluosilicated lime.

If brought in contact with lime, hydrofluoric acid is capable of dissolving it considerably without producing an immediate precipitate of calcium, or a separation of the silica, but at a certain state of saturation any addition of lime decomposes entirely the hydrofluoric acid, and so much that not a trace of these bodies can be discovered in the fluid; the same results are obtained by the carbonate of lime, instead of the caustic lime, and that silicium and fluor are produced in the limestone, which hardens but slowly, and it is therefore simply a fluorsilication that produces the hardening of the lime. The effect of the hydrofluoric acid on gypsum is also produced in a cold mixing of both, when the surface of the gypsum is considerably hardened. If, however, the acid is used in excess, the gypsum is covered with raised postules, which owe their existence to the formation of bisulphate of lime, because sulphuric acid does not act as well as the carbonic acid in the treatment of limestone; a fluorcalcium, mixed with soluble glass, may be used as a paint, or paste, or a cement, or any coating of other substances, and becomes so hard and weatherproof that neither soda nor potash will detach from the combination and remain dry.

Painting on Metals, Glass and Porcelain.

Silica painting adheres strongly on metals, provided care is taken to keep the substances some time from the contact with water. The most durable paint is produced on zinc, also on porcelain and glass, the colors assume a semi-transparency if painted on glass, and no doubt afford much inducement for its use. - The sulphate of baryta, artificially prepared, combined with potash silicate, appled to glass, makes a milky white appearance, and is very beautiful, as it incorporates very intimately with the silica, so that after the lapse of a few days the paint cannot be removed even with warm water. If this glass is exposed to high heat (6° Wedgewood) a fine white enamel is formed on the surface, which will compare well with the oxyde of tin, and is much cheaper. Ultramarine, oxide of chrome, if converted into enamels, form a prolific source for the new art of painting. It is not quite necessary that a chemical combination should be produced in all these colors, if they only adhere strongly and produce the silicated cement which has become hard by its fine division and easy admission of air.

Emery, bloodstone, and peroxide of manganese, if finely powdered and prepared with a concentrated solution of soluble glass, produce cements of extraordinary hardness, resisting the effect of heat completely, and become perfectly insoluble in water.

For the production of an indestructible ink, soluble glass has been used and obtained by mixing finely burnt lampblack with the liquid soluble glass. *Braconnot's ink* is prepared by decomposing leather in caustic potash and adding to the black mass the liquid soluble glass. *A decoction of cochineal* mixed with the liquid soluble glass produces a red ink, resisting completely the action of chlorine and all other acids.

The alkaline salts, particularly the carbonates and chlorides, produce, when added to liquid silica, a gelatinous pasty precipitate, the chloride of ammonium with developing the ammonia; precipitates are also formed with the earthy alkaline salts, and from alumina and hydrate of lime, for in all these cases of precipitations a part of potash is withdrawn from the soluble glass, which either forms a part of the precipitate or remains free, or attaches itself to the acid of the added salt.

The same case takes place in the application of the salts of the heavy metals, such as iron, copper, etc. The effect of the soluble glass on salts, either insoluble or soluble with difficulty in water, such as sulphate of potash and carbonate of lead, phosphate of alumina, gypsum, etc., all of which become, when rubbed up with the silica solution and exposed to the air, a very hard mass.

The fixation of potash with silica painting on lime shows how the colors, after an exposure to air for some time, become quite insoluble in water, and is thus explained: The contact of carbonate of lime with the soluble glass determines always the decomposition of the first, and conversion in silicate of lime, which retains the coloring matter. If the colors are transferred on substances not acting upon the soluble silicates like wood, iron, glass, etc., then it becomes necessary to find the conditions of the insolubility in the reaction of the coloring matter in the silicate itself.

Much precaution has to be used not to close the pores of the underground, whereby the success of the painting is jeopardised, in case a mistake should have occurred before, and by waiting some time before proceeding farther, to allow the contraction of the liquid glass, so as to open again the pores, and which can also be accelerated by heat that is produced by burning alcohol over the groundwork. Now, after this operation of drying and preparing is performed, and the liquid glass applied uniformly, so that every paint is found uniform so as to begin the painting, the artist will have no difficulty to begin at the proper work. The colors are now perfectly rubbed up with the water and put on artistically after the wall has been syringed with pure water—for two reasons: one is to expel the air from the pores, and then to promote the adhesion of the colors; this, however, must be done moderately, or the colors might otherwise suffer in freshness; the moistening must be effected on every spot which has to be painted. The colors are now prepared with the liquid glass, diluted with one-half of its water, which must be applied by means of a syringe, and not by a brush, and with much care, for the reason that these colors adhere but thinly, and, if applied with the least force, would put the colors from their place, or would make them flow together ; the operation of syringing over, the painting must be repeated several times after having become dry, until the colors appear to be so fast that, touching with the fingers, they will not be stained. Many colors require more or less of the liquid glass, which may be learnt by practice, but which may easily be detected.

When the painting is finished, an application of alcohol, after the lapse of a few days, will materially add to fasten the painting and to clear it from any impurities which may have attached themselves, or by the alkali which might have been separated from the liquid glass and have oozed out, and may be worked with mortar free from lime, and it may thus, without any hesitation, be left exposed.

It may be observed that the painting must be guarded against rains during the time of the rubbing up and laying on of the colors. After the exposure of some months, or a year at latest, it is well to examine the painting, in order to ascertain whether the colors have not suffered from rhe condensation of the liquid glass, so as to produce an interruption of the binding or fastening of the colors, so that it may become necessary to apply an additional fixation.

The materials for the upper ground, which is to take up the colors, may be also composed of the following: Pulverized marble, dolomite, slaked lime, and fine quartz, or a sand with the liquid glass combined; the proportion of the liquid glass depends upon the sand which is used in the mixture, so as to form the consistency of mortar. The advantages of this ground work are: it prevents the separation of the lime on the surface after a frequent moistening with water, and, therefore, no lime crust forming, no rubbing off is required before the application of the liquid glass; furthermore, the liquid glass comes in immediate contact with the under ground, producing thereby a good cement with both grounds. This mortar becomes as hard as stone after being dry, and shows its porosity in warm and dry air, which make it very susceptible for absorption.

Stereochromic for Easel Painting.

The basis for this class of painting may be made from plates of burnt, porous clay; it is first impregnated sufficiently with liquid soda glass. These plates may be $\frac{3}{4}$ of an inch thick; after one or two applications they become as hard as any stone ware; they are very suitable for painting ground. The lithographic stone makes a good base for easel painting; a thin coating of liquid glass mortar will produce a good base, and it may be first moistened with phosphoric acid, which assists much to absorb the colors with the liquid glass and to make them fast.

The colors to be used for this class of painting ought hot to be chosen which decomposes the liquid glass, such as contain strong acids, nor those from organic substances. Burnt oxides are better than raw oxides, vermillion becomes brown, and at last black; cobalt blue becomes clearer by the liquid, and the yellow ochre becomes darker.

All colors ought to be properly prepared to make them fit for the silica painting, such as the great variety of oxides, many of which, not containing much oxide of iron, may be suitable, also chrome red, ultramarine, umber, baryta white, cadmium yellow, and many more, purposely made by some chemists, not containing free acid, which enter into a decomposing chemical combination.

The permanent white, or artificial sulphate of baryta, is said to be the proper material for a white paint. It is obtained from the native minerals, heavy spar or sulphate of baryta, and witherite or carbonate of baryta. The manufacture of the new paint is effected by the reduction of the native sulphate to a chloride of barium, or dissolving the native witherite in hydrochloric acid, and then adding either sulphuric acid or glaubersalt, the artificial sulphate of baryta is found in a condition of extreme fineness and purity, possessing a fine lustre, and susceptible for producing a fine white paint, which is the best substitute for white lead and zinc white, is not subject to tarnish or become brown in parlors like white lead, which is attacked by hydrosulphuric acid, and forms, when combined with the liquid glass, a slow but intimate combination, and is likewise used under the name of blancfix for card-makers, paper-stainers and paper collar manufacturers to a very large extent. It may also be considered in point of importance, if compared with that of white lead, not having a dilatory effect upon health as the latter. If mixed with the soluble glass it obviates the odious smell of linseed oil and spirits of turpentine. If it is mixed with dexterine, starch, or other binding material in connection with the liquid silicate of soda, its applications may be multiplied to any extent.

The artificial sulphate of baryta is largely manufactured on the continent of Europe; in the U. S. it has so far been manufactured in New York by a few chemical establishments for card makers, but not yet for the purpose of substituting it to white lead.

SILIFICATION OF WOOD

A Protection against Combustion, Inflammability and Dry Rot.

Wood, and all other organic combustible substances, may to a great extent be preserved against that great element, the fire, by the proper application of the liquid silicates. Still it requires much skill, experience, and proper management to subdue totally this wonderful element when brought to its full power. There are many instances on record to prove either a full, or at least partial success in arresting the progress of a conflagration by the impregnation or coating of combustible bodies with many substances, such as possess incombustibility, whether liquids, gases, or materials which possess the properties of generating gases that will withdraw or suffocate the surrounding atmosphere, such as the oxygen gas, and thereby arrest the progress of the flames. Many chemical agents have been from time to time proposed to effect this object; such as salt, chloride of lime, and latterly carbonic acid in its gaseous form, and many metallic salts have proved but a partial success in the prevention of decay or dry rot of wood. The soluble glass is one of the first materials which have been successfully employed in arresting conflagration, and as far as 1823 this material was recommended in the construction of the Munich Theatre, where 465,000 square feet of timber surface were treated with a coating of the liquid soluble glass, and in 1830,–31 and '32 the author performed many experiments in the Brooklyn Navy Yard, partially as a protecting agent against fire, as also against decay of the woody fibre; small square blocks of wood, after having been impregnated with the soluble glass and sailcloth, writing paper, parchment, etc., were exposed for some time to the flame of a gas lamp. After the lapse of an hour, all these substances were found to be charred, but not consumed. It is proved that the liquid soluble glass produces a perfect adhering, permanent covering which, when properly laid on, suffers no damage from the atmosphere. For coating the wood, etc., a pure solution of the liquid glass is required, otherwise it will peel off, and it is best not to use it first in a concentrated state, as it will not be able to penetrate into the pores, whereby the atmosphere must be expelled, and even five or six applications may be made in intervals of twenty four hours. Although this process renders good services, it may be improved by the addition of other pulverized substances, wherein the soluble glass acts as the binding material, the coating assumes a better body, is stronger and more permanent, and if exposed to the fire a crust is formed such, for instance, are bone dust, clay and chalk mixed together, a lead glass, etc.; common clay $\frac{1}{10}$ was successfnlly used with the liquid glass in the Munich Theatre. If applied on linen or other organic textures, the mere coating, or dipping, is not sufficient, but a surface between rollers must be resorted to in order to produce a full absorption with the pores; these stuffs may then be rolled up, but not folded.

Building timber, rail road sleepers, and other similar materials, have been treated in the manner just described, and were protected fully against fire and dry rot.

The author proposed a combination of the liquid glass with the following substances, intended as decomposing agents by chemical affinity, and producing in the cells of the vegetable fibre the various mineral and metallic salts which are altogether insoluble in water, alkalies and acids, and he extended his experiments on the uses of lime, chalk, gypsum, copperas, etc. His process of treating ship timber, sleepers, cross-ties, roofing shingles, and other wood blocks was the following:

1. The materials to be treated were put in steam-boilers and exposed for four hours to a pressure of

hot steam, (or 300° F) then withdrawn from the kettles and dried. Alkalies and acids, such as hydrochloric, have been since recommended for the purpose of abstracting color and albumen existing in the cells of the woody fibres, which, however, is accomplished by steaming.

2. In a solution of silicate of soda while hot, the materials to be treated are thrown and kept there for twenty-four hours, which will give ample time for the woods to enter into the open cells while hot.

3. A large vat, containing either lime water, solution of copperas, or blue vitriol, white vitriol or gypsum, finely powdered and thrown into hot water, or finely powdered chalk of 1 ℔. to 10 gallons of water: the proportion of metallic salts is but $\frac{1}{4}$ ℔. to the gallon of water. The woods are kept in the vats for another day, and then taken out dried and ready for use.

Coal tar, and the other products of dry distillation from tar and peat, have been recommended by Krieg as far back as 1858, under the name of Kreosote-carbolic acid, which was then considered a waste product, and in its raw state having a spec. grav. of 1.02 to 1.058, and yielded from 20 to 30 % of the tar, it was well known to possess the property of protecting wood against decay.

This chemist combined with the impregnation of woods, etc., the soluble glass that of the kreosote carbolic acid for the reason that the latter precipitates the soluble silica as an insoluble substance while it is soluble in an alkaline lye. He proposed to expose the woods for $\frac{3}{4}$ of an hour to a temperature of 300° F., and then drying them thoroughly.

The woods thus prepared showed an increased weight of 6 %, and a lacquered surface, while in the inside the pores were filled with an insoluble precipitated silica.

For effecting a still more perfect success is to fix the kreosot on the woody fibre from the alkaline solution, by the diluted sulphuric acid or by a solution of copperas (sulphate of iron,) whereby the sulphate of soda thus obtained may either be washed out, or oozed out, and the creosot-carbolic acid combines stronger with the woody fibre, and the impregnated woods may be considered safely protected against fire or rot.

This process just described, deserves the serious attention of the various companies established for the last five years in the preservation of wood by carbolic acid, tar, etc., by combining the soluble glass with their process, as we have described.

Since the introduction of railroads, not quite 50 years, many men have been engaged in chemical experiments upon the cross ties and sleepers, which after being laid down for a few years undergo the decay or rot and have to be renewed, which causes great expenses to the companies. Kyan, Burnett, Boucherie and many other chemists in all countries where this evil existed, proposed remedies; the sublimate, chloride of zinc, pyrolignite of iron, all had their advantages and disadvantages; of late borax, alum, rosin, carbolic acid have been introduced and many articles have been written on the subject.

PRESERVATION OF WOOD, IN DAMP AND WET PLACES.

In 1846, 80,000 sleepers of the most perishable woods, impregnated, by Boucherie's process, with sulphate of copper, were laid down on French railways: after nine years exposure, they were found as perfect as when laid. We would suggest washing out the sap with water, which would not coagulate its albumen: the solution would appropriately follow. Both of the last named processes are comparatively cheap; it costs less than creosoting, but one shilling per sleeper. The unpleasant odor of creosote is greatly against its use for lumber for dwellings; pyrolignite of iron is offensive, and also highly inflammable; the affinity of the chlorides for water keeps the structure into which they are introduced, wet, and they also corrode the iron-work. Sulphate of copper is free from these objections, and is cheaper than the chlorides, and seems preferable for protecting wooden structures against dry rot in damp situations, like mines, vaults, and the basements of buildings.

The surface of all timber exposed to alternations of wetness and dryness gradually wastes away, becoming dark colored or black. This is really a slow combustion, but is commonly called wet rot, or simply rot. Other conditions being the same, the most dense and resinous woods longest resist decomposition. Hence the superior durability of the heart wood, in which the pores have been partly filled with lignin, over open sapwood; and of dense oak and lignumvitæ over light popular and willow. Density and resinousness exclude water; therefore our preservatives should increase those qualities in the timber. Fixed oils fill up the pores and increase the density; the essential oils resinify, and furnish an impermeable coating; but pitch or dead oil possesses advantages over all known substances for the protection of wood against changes of humidity. According to Professor Letheby ("Civil Engineers' Journal," vol. 33), dead oil, 1st, coagulates albuminous substances; 2d, absorbs and appropriates the oxygen in the pores, and so protects from eremacausis; 3d, resinifies in the pores of the wood, and thus shuts out both air and moisture; and 4th, acts as a poison to lower forms of animal and vegetable life, and so protects the wood from all parasities. These properties specially fit it for impregnating timber exposed to alternations of wet and dry states, as, indeed, some of them do for situations constantly damp and wet. Dead oil is distilled from coal tar, of which it constitutes about 30 ℔ cent. and boils between 300° to 470° Fahr. Its antiseptic quality resides in the creosote it contains. One of the components of the latter, carbolic acid, (phenic acid, phenol) $C^{12} H^6 O^2$, the most powerful antiseptic known, is able at once to arrest the decay of every kind of organic matter. Professor Letheby estimates this acid at one half to six per cent. of the oil. Bethell's process subjects the timber and dead oil, enclosed in large iron tanks, to a pressure varying from one hundred to two hundred pounds per square inch, about twelve hours: from eight to twelve pounds of oil are thus injected into each cubic foot of wood. Lumber thus prepared is not affected by exposure to air and water, and requires no painting. Four pence the cubic foot is estimated as the probable expense of this process.

Though we have not to guard against decay, when timber is constantly wet in salt water, the *Toredo-navalis*, a mollusk of the family *Tubicolaria* (Lam.) soon reduces to ruin any unprotected submarine construction of common woods. None of our native timbers are exempt from these inroads. The toledo never porforates below the surface of the sea-bottom. and probably does this little injury below low-water mark; its food is the borings of the wood. Poisoning the timber does not protect from the toledo, the constant motion of sea-water soon diluting and washing away the small quantity of soluble poison with which the wood has been injeted. Thorough creosoting the wood, with ten pounds of dead oil per cubic foot, is a complete protection against the toledo.

Drying Timber by Steam.

Mr. Violitter has lately presented to the Academy of Sciences in Paris, a very able communication on the desiccation or drying of different kinds of wood by steam. He states that steam raised to 482°, Fahrenheit, is capable of taking up a considerable quantity of water; and acting upon this knowledge, he submitted different kinds of oak, elm, pine, and walnut, about eight inches long and half an inch square, to a current of steam at seven and a half pounds pressure to the square inch, but which was afterwards raised to 482°. The wood was exposed thus for two hours. It was weighed before it was exposed to the steam, and afterward put into close-stoppered bottles until cool, when the samples were again weighed, and showed a considerable loss of weight, the loss of which increased with the increase of the temperature of the steam. For elm and oak the decrease in weight was one-half, ash and walnut two-fifths, and pine one-third. The woods underwent a change of color as the heat was rising from 395° to 442°; the walnut became very dark, showing a kind of tar formed in the wood by the process, which was found to have a preserving effect on the wood.

It was found that wood thus heated became stronger, having an increase in the power of resisting fracture. The maximum heat for producing the best fracture-resisting power for elm was between 302 and 347°, and between 257 and 303 degrees for the oak, walnut, and pine. The oak was increased in strength five-ninths, walnut one-half, two-fifths for pine, and more than one-fifth for elm. These are but preliminary experiments, which may lead to very important results, and are, therefore, interesting to architects especially. By this process the fibres of the wood are drawn closer together, and maple and pine treated in the steam, at a temperature of 487°, were rendered far more valuable for musical instruments than by any other process heretofore known. This is valuable information to all musical instrument makers. Who knows but this is a discovery of the Venetian fiddle-makers' great secret.

Wooden Roof Shingles.

One of the most valuable applications of the soluble glass may be recommended for shingles and wooden roofs of farmhouses in the country and near railroads, where the sparks of the locomotives have frequently caused deflagrations and destruction of property.

The operation is quite simple and the expense but trifling; the process has already been described, but it may be still more simplified in the following manner:

After the steaming of the shingles in boilers or in tanks, where steam of 250 to 350° is led into them; they are dried and thrown into a weak solution of liquid silica, standing about 25° B, in which they are left for 24 hours, when they are taken out and exposed to the air. Before they are quite dry, a weak solution of chloride of calcium is thrown over them or sprinkled over them with a broom. When quite dry they are fit for use. They will not burn nor be ignited with the sparks; if exposed to a direct fire, will not light in a surrounding fire. An intense heat of long duration may char them on the surface; they are, however, quite safe from any inflamation.

The Preservation of Wood by Immersion.

The processes for the preservation of wood may be divided into three groups, namely: processes by immersion; processes by pressure in closed vessels, (which are exclusively employed for dry wood,) and processes founded on the displacement of the sap (which are only employed for green wood.) In the present article we shall describe the methods by immersion.

Attempts to impregnate wood by the method of immersion were the first experiments undertaken. As early as 1740, Fagol, a Frenchman, tried to impregnate wood with alum, sulphate of iron, and various other substances, in solutions of which he immersed it for several day. In 1756, Haller recommended vegetable oil for the same purpose. In 1767, Jackson indicated the use of a solution of sea sale, to which sulphate of iron and magnesia, alum, lime, and potassa were to be added. In 1779, Pallas proposed to mineralize wood by dipping it first in a solution of green copperas and afterward in milk of lime. In 1830, Kyan in England, tried to preserve wood by simply immersing it in a solution containing two per cent of bichloride of mercury. Not long since, experiments were made in France and Germany with a large number of railroad ties, by keeping them several hours in a solution containing 1.5 per cent. of sulphate of copper, at a temperature of 160° Fahr. This preparation is, however, altogether insufficient for the preservation of fir or pine wood, and in general for light woods which contain a large amount of nitrogenous substances; but it seems to increase considerably the durability of oak. The wood is thus surrounded by a very thin coating, which is not liable to decay nor to the attacks of insects, and which retards the alteration of the inner parts. These are, however, not impregnated at all by the anticseptic liquid; they preserve their germs of putrefaction, which develop the easier the more the injected surface is removed, whether by friction blows, or the driving in of nails. The decay commences then at the denuded points, and propogates itself toward the central parts.

Baron Champty also indicated a method for preserving wood, by dipping it when green into suet of 200° Fahr. The water and the gases which are inclosed in the vegetable tissue escape, and by the condensation which follows upon cooling, a vacuum is produced, into which, by the pressure of the atmosphere, the suet is made to penetrate. Mr. Payen made use of this experience, substituting for the suet, rosin, heated to 300° Fahr., and in this manner introduced into a small poplar tree three-fifths of its weight of rosin.

Decay of Wood and Processes for Preserving it.

According to the experiments which were made by De Saussure, in the beginning of this century, it would seem that the decay of woody fibre was exclusively caused by the action of air and water. On exposing moist wood to the action of oxygen gas, he found that, for every volume of oxygen absorbed by the wood, one volume of carbonic acid was disengaged. It is now conceded that it is the hydrogen of the fibre which is oxidized at the expense of the oxygen of the atmosphere, while the carbonic acid is solely formed from the elements of the wood, or that the process is simply a separation of a portion of the carbon of the wood by direct oxidation; and it would seem, from the experiment mentioned, that the first and only cause of the decay of vegetable tissue must be ascribed to the affinity of oxygen for the elements of the latter.

Such cases of slow decomposition have indeed also been distinguished by the name *eremacausis*, a term composed of two Greek words, and meaning to burn by degrees.

The above explanation, however, scarcely holds good in all cases, it is now known that, in dry air, woody fibre may be preserved without decaying for thousands of years; and, under water, in certain conditions, it appears to be equally durable. One must, therefore, look for some other cause to explain the transformation of woody fibre. Such a one presents itself in the fact that, when wood is exposed for some weeks to running water, or if it is boiled in water and afterward dried until the original weight is restored, it is rendered therby considerably more durable.

The cause of the transformation in question must, therefore, be sought in a substance which is removed by the dissolving action of water in the experiment mentioned. By further investigation, this substance is found to consist of the albumen of the sap, which is distributed throughout the cellular tissue. Like the animal albumen, as the white of eggs, which it closely resembles both in properties and composition, the vegetable albumen is exceedingly liable to decomposition. In this state, it acts like a ferment, inducing the decay of other bodies, according to the physical law propounded in another application by Laplace and Berthollet, namely, that a molecule set in motion by any power can impart its own motion to another molecule with which it may come in contact.

Among the bodies most prone to decomposition is the sugary element, which is first dissolved. Then the growth of fungi generally begins, and the putrefaction proceeds step by step. It may, therefore, be considered that the spontaneous decomposition of the vegetable albumen is the primary cause of the decay of wood. It is, indeed, found that those kinds of wood which contain the smallest quantity of albuminous matter and amylum are the most durable. Especially is this the case with a certain tree of the acacia tribe, the locust, and the cedar, which resist decomposition in situations where all other kinds of wood soon decay.

In order, then, to find out whether a certain kind of wood is especially fitted for building purposes, the quantity of albumen present in the fibre should be ascertained by analysis. M. Payen recommends, for this purpose, to digest the wood in a dilute solution of caustic alkali—this soda, or potassa—which has no action on the woody fibre, but only dissolves the albumen. Hence, the quantity of the latter may be estimated by washing, drying, and weighing the wood after the experiment has been made.

METHODS OF PRESERVING WOOD.

If the primary cause of the decay of woody fibre be its contact with putrefying albumen, a means of preserving is naturally suggested in the removal of the albumen; or else in so combining it with other substances that it forms a compound which is insoluble in water, and not susceptible to spontaneous decomposition. It would seem that the solubility of the albumen in cold and tepid water would afford a simple means of withdrawing this element of decomposition, and thus of preserving timber; but this process, though effectual, is by far too slow to be practicable.

The most ancient method of guarding wood against decay consists in the application of an external coating of oils and resins or a hot solution of silicate of soda, according to the author of this treatise in connection with that of chloride of calcium and carbolic acid. If the wood is dry, and otherwise in a sound state, and also not exposed to abrasion, a perfect protection may be afforded in this way. A more effectual mode of preserving it, however, consists in its immersion in a hot solution of the respective preservative. This may either serve simply for filling the pores, or for forming a compound with the albuminous matters, which has the property of not being decomposed. Both ends may be arrived at by one and the same substance.

IMPREGNATION OF WOOD BY PRESSURE.

This method was not practiced to any great extent previous to the close of the last century. In the inquiry into the means which have been taken to preserve the British navy, particularly from dry rot, a volume has been produced, which affords a splendid account of all that had been done up to that time in the direction of wood preservation. The author gives a full account of the action of about forty substances, among which may be mentioned, solutions of sulphate of copper, sulphate of iron, alum, borax, lime, corrosive sublimate, and other forms of mercury, preparations of zinc and iron, sea-salt, creosote, linseed-oil, coal and wood tar, and wax. As it is however, not the intention of these articles to do dwell upon things of the past, but upon things of the present, the writer may pass to the description of some modern processes.

The apparatus now used in France for the saturation of timber with preservative agents is described as follows: It consists of a cast-iron cylinder, which is connected by means of a tube with a condenser. Both are placed in a vertical position. The operation is begun by introducing the timber into the cast-iron cylinder, together with the preservative material. The latter, however, is not altogether to rise to the entire height of the stem. The receptacle of the wood is hereupon closed, and connected with the condenser. A vacuum is then produced in the latter, which is accomplished by introducing alternate steam and sprays of water into it. After this the stop-cock of the tube connecting the two cylinders is opened, when the air passes from the receptacle into the condenser. This operation is repeated, until the pressure in the cylinder is less than fifteen decimetres. The same is kept up for several minutes, in order to let the air of the timber have time to escape. The connection between the receptacle and the condenser is finally closed. A pump is then set in motion, by means of which the preservative agent is made to penetrate the pores of the vegetable tissue, until the pressure stands at that of ten atmospheres. This is maintained for various lengths of time, according to the nature of the wood and the liquid, but six hours are generally sufficient. After this the air is gradually allowed to enter, while the preservative liquor is left to run away.

For the relative claims of wood and metal as materials for rails, many facts ought to be considered; wood is exempt from the inconveniences, dangers and expenses incidental to contraction and expansion under variations of atmospheric temperature. Metal at an extreme low point fractures, and most lamentable casualties result; while under the fervid heat of 90 to 170°, the expansion of iron is so great as to displace the work on which the rails repose, and thus render the whole fabric unsteady and unsafe.

From the Report on Wooden Railways the following extract is made:—"The length of the experimental line laid down near Vauxhall bridge was 174 yards, with gradients of 1 in 95, 1 in 22, and 1 in 9, and a curve of 720 feet radius. The speed attainable on so short a line was of course limited; but the power given to the engineer by the bite of the wheel on the wood (for the line was laid with wooden rails) enabled him to drive at the rate of twenty-four miles an hour, and to stop the carriage in a distance of twenty-four yards. In the presence of several engineers the carriage, laden with passengers, ascended an incline of 1 in 9, the rails being in a very bad state at the time from damp weather.

"Since the introduction of wood paving, it may be calculated that a saving of one-half has been effected in the wear and tear of carriages, horses, and harness in those districts where it has been adopted; a saving equally great can be made in the construction of railroads by the substitution of wood for iron rails. The rails may be made of beech or other hard English timber, six or eight inches square, let into wooden sleepers, and secured by wooden wedges, forming one great frame, or wooden grating of longitudinal and cross sleepers.

"An engine weighing ten tons running on wood will have more tractive power than one weighing eighteen tons running on iron; and as the concussion and abrasion on wood is so trifling, carriages built to weigh one and a half tons will be as strong as those having to run on iron weighing three tons. An important question connected with this subject is the durability of the material of which the rails are composed. The engine employed for the experiment weighed about six tons; it passed over the rails during the two months it ran 8,000 times in every variety of weather, which is equal to nearly seven years traffic of twelve engines per day. The rails consisted of Scotch fir, about nine feet long and six inches square; and yet, upon examining them after the severe test to which they had been subjected, they exhibited no appearance of wear from the friction of the wheels on the upper surface, as the saw marks were not effaced.

"The capability of wood to sustain the strain to which it must necessarily be exposed, especially when moving over it at high velocities, has been satisfactorily proved by the experience of the Great Western and other railways, where continuous longitudinal sleepers of wood have been employed, and experience has shown that the solidity of the road is much greater than when the iron rails were attached either to stone locks or transverse wooden sleepers. In proof that wooden rails cut from beech will bear the wear and tear of trains passing over it, it is well known that beech cogs have proven to last eighteen to twenty years when working in gear with an iron wheel. The rails on the Vauxhall line were prepared by Payne's patented process for preventing dry-rot and decay of timber. Scotch fir, if subjected to pressure, will crush at ten tons, while beech (the wood recommended for railways) will bear a pressure of eighty-two tons before it begins to yield.

"Experience having confirmed the capability of Scotch fir to withstand the traffic of twelve engines per day for seven years, without any visible wear, it would be difficult to say how long the rails cut from beech, sustaining eighty-two tons pressure, would last. Some of the impediments with which railroads have to contend are the undulations of the country, and the necessity of diverging from a right line in order to obtain the traffic of important towns. These obstacles can only be overcome by an outlay of capital, in making the required excavations and embankments, or by the oftentimes ruinous system of tunnelling, and after all, inclines of greater or less gradients are unavoidable, and prevent the line working economically. Curves on iron railroads are highly prejudicial, especially if the radius be small, as the wear and tear becomes proportionably increased.

"Now, by the introduction of the proposed plan, the evils arising from the obstacles alluded to would be very materially diminished; for, in the first place, the surface resistance obtained by the elastic character of wooden rails, enables a train to be propelled up inclines with much greater facility and ease than on rails constructed of iron. The advantages of wooden railways thus constructed, in point of economy, comfort, durability, and as feeders to the great and central lines already formed, must be apparent to every one who has given the subject any consideration.

"The result of a series of experiments, made to ascertain the proportionate power of the bite of wood over iron, has fully borne out the assertion of the patentee, that the bite of the driving-wheel on wood is nearly double that on iron. On the surface of an iron wheel four feet in diameter, a lever eight feet long was placed, with a weight of seven pounds attached to the lever, three feet from the centre of the axis of the wheel; the surface of the lever being iron at the tangent of the wheel, it required a weight of twenty-eight pounds attached to the crank to make it revolve. On substituting a wood surface for the iron one; it required a weight of forty-two pounds. Another experiment confirmed the result with the iron surface; a weight of twenty-eight pounds attached to the spoke of the wheel, at a distance of six and three-quarter inches from the centre, made it revolve; whilst with a wooden surface, it required the same weight to be attached to the spoke at a distance of eleven and a half inches from its centre, thus clearly demonstrating the power obtained by the bite of the wood is nearly double the bite of iron.

"Mr. J. M. Mason, (of *Trent* notoriety) when in England, devoted some attention to Prosser's system of wooden rails, with a view to their use in the Southern States during the war, and in a letter to Mr. C. J. Bloomfield, he writes, 'I was most strongly impressed with their *feasibility* and *durability*.'"

Timber Rot and Seasoning.

It is generally supposed that the rotting of timber is merely induced by the action of the oxygen of the air. From analysis made of sound and decayed oak, it has been shown that for every two equivalents of hydrogen oxidized by the air, one equivalent of carbonic acid had separated. It may therefore be inferred that the decay or rot of timber does not arise from fermentation; but is rather a chemical process. Others admit that microscopical parasities of vegetable nature play an important part in the decay of wood; but consider the presence of albuminious matter in the sap as necessary, which, according to them, must also be first in a state of decomposition before it allows the growth of those organisms. In order to throw light upon this most important subject, we propose first to tabulate a number of well-observed facts. Sound timber, when immersed in water, without access of air, will withstand decay for almost an unlimited time. This is proved by the piles upon which the dwellings on the Canaries rest, which were erected in the time of the Conquest in 1402, they being just as sound now as if they had been freshly felled. Roots of trees that have been submerged in marshes are rarely found decomposed. This is stated to be the case with the utensils discovered in the lake dwellings of Switzerland, Bavaria, and Lombardy, which must be at least ten thousand years old. Hartig also describes a cypress-stem with over three thousand rings, representing the same number of years, which, though submerged, had only partially turned into brown coal.

With respect to the action of the atmospheric air, it may be asserted that the same, even when moist, will not produce rot, if the wood has been well steamed, or exposed to the action of running water for a sufficient length of time. In England it is customary to lay the timber destined for threshing-floors and wainscoating in fresh water for several weeks. When again dry and not exposed to damp, such timber will endure for an incredible period of time.

This tends to demonstrate the fact that the substance which induces decay must be foreign to the timber itself. This substance is the juice that is chiefly contained in the vascular tissue, which forms a link between the bark and the wood. The composition of this sap varies according to circumstances, as the variety of the tree, climate, season, ground, etc. The following are analyses of the sap:

In 100 Parts.	Sap of Elm Tree. Vanquelin.	Sap of Cow Tree. Solly.	Dried sap of bark of *Antiaris toxicaria.* Mulder.
Albumen,	....	3.06(*a*)	16.14
Dextrin,	....	4.37(*b*)	12.34
Sugar,	....	....	6.31
Resin,	....	....	20.93
Galactin,	....	30.57	....
Myricin,	....	....	7.02
Antiarin,	....	....	3.56
Organic Substance (not determined),	0.10	....	.....
Potassa with Organic Acid,	0.87	....	.....
Carbonate of Lime,	0.10	....	.....
Extractive Matter and Salts,	....	....	33.70
Water,	98.93	62.00(*c*)	.....
	100.00	100.00	100.00

(*a*) Gluten and Albumen, according to Solly. (*b*) Dextrin and Salt. (*c*) Water and Butyric Acid.

Remarks.—The Cow Tree (*Galactodendron*) is a native of the Cordilleras of Venzuela; it furnishes, by incision, an enormous quantity of a white, thick liquid, which has the taste and some of the qualities of real cow's milk. The *Antiaris toxicaria* belongs to the same family as the former—namely, to the nettle-worts, and it is singular that it furnishes a most deadly poison, which has been the subject of the most harrowing stories. (Jussieu; *Elements of Botany.*)

Unfortunately we possess only one analysis of a tree indigenous to North America; however, the same tends to show that the amount of albumen, if the non-determined organic matter must be considered as such, is exceedingly small, and with respect to the other trees, these analysis prove that the albumen does not constitute the chief part among the ingredients of the juice. How unjustifiable it is, therefore, to attribute, in every instance, the decay of timber to the albumen present in the sap, as if it was the only substance liable to spontaneous decomposition, or affording the vegetation of fungi and lichens! How unfounded is the assertion of Mr. Joseph B. Lyman, who, in an article on the preservation of timber, states that "wood is mainly made up of woody fibre and a substance full of nitrogen"! (*vide Working Farmer*, November 1st, 1868.)

In regard to the amount of sap and air contained in the oak and poplar, we possess the following data from Count Rumford:

	Wood.	Sap.	Air.
Oak	0.39353	0.36122	0.24525
Poplar	0.24289	0.21880	0.53831

The German botanist, Schacht, in all instances of decayed timber, has met with fungi and lichens. The destruction of timber by decay, after the same has been hewn, must, therefore, be considered as being produced by similar causes which brought on the disease of the vine, potato, mulberry trees, and other cultivated plants, which make the years 1845, '48, '53, '57, and others forever painful to the memory.

That the juice should be in a state of decomposition before being capable of generating those organisms seems doubtful, since this has not been found the case in other and well-studied modes of fermentation. The morel, a species of mushroom, will also attack perfectly sound wood. Hand in hand with the spread of the fungi continues the decomposition of the ligneous tissue. Access to moisture and air, as also a certain degree of heat, are necessary. In regard to the air, fungi require oxygen for their generation. When air-dried, steamed, or chemically treated and afterward dried wood commences to rot, it is a sign that moisture has again penetrated; for it is scarcely to be admitted that in all these cases the sap had been entirely removed. Timber decomposes the easier the more sap it contains, and if green trees are hewn when the vessels are overflowing with juice, one may look with certainty for diminished durability of the timber. Timber is not always the more durable the more dense it is, but rather when the even fineness of the grain continues to the pith of the stem.

The Roman historian, Pliny, considers the resiniferous woods as the most durable. Indeed, nature shows that this is frequently the case. The resiniferous red and white pines of Oregon and California are considered first-class ship timber, so much so that entire vessels have been constructed from the denser qualities. The yellow or long-leaved pine, in dry situations, is extremely durable, and is preferred to oak of any kind where a lighter yet solid wood is required. The white or northern pine, which grows abundantly in every northern State of the Union, from Maine to Minnesota, reaching often to an altitude of one hundred and eighty feet, with a diameter of six feet or more, is said to retain its properties as long as the very best description of oak.

The fact that dried timber is, for nearly every purpose, far superior to green, has led to its being dried in the open air, or in confined rooms by means of heated air, or mixtures of air and steam. The first method is termed seasoning. Newly felled wood, in order that it may season properly, should be protected from rain, sun, and strong winds. It should be piled up so that a circulation of air can take place from beneath.

The shed in which the timber is dried should be paved and provided with sewers. Moreover, the relative position of the pieces of timber should be changed from time to time during the seasoning process. The necessary time for seasoning varies from two to four years.

The proportion in which the woody fibre and water are to each other is very different. It varies according to the degree of dryness and the nature of the wood itself. According to Schübler and Neuffer, we have for newly felled woods the following table:

WOOD.	WATER.
Hornbeam	18.6 per cent.
Willow	26.0 "
Sycamore	27.0 "
Ash	28.7 "
Birch	30.8 "
Oak	34.7 "
Pedich Oak	35.4 "
White Fir	37.1 "
Pine	39.7 "
Red Beech	39.7 "
Alder	41.6 "
Asp	43.7 "
Elm	44.5 "
Red Fir	45.2 "
Lime Tree	47.1 "
Italian Poplar	48.2 "
Larch	48.6 "
White Poplar	50.6 "
Black Poplar	51.8 "

The amount of water in wood, after one year's drying in the air, ranges from 20 to 25 per cent., and when perfectly air-dry, as it is called, it still holds from ten to fifteen per cent.

The specific weight of newly felled timber ranges from 0.85 to 1.05; that of air-dried timber from 0.45 to 0.75. The weight of one cubic foot of newly cut native timber would thus range from fifty to sixty-five pounds, while that of seasoned wood would vary from twenty-eight to forty-seven pounds. The total expulsion of moisture by means of air-drying, according to the experiments of Rumford, takes place only at 280° Fahrenheit. But even if thus completely dried, and then exposed again to the atmosphere, it absorbs nearly five per cent. of water during the first three days, and continues to absorb until it contains from fourteen to sixteen per cent., after which it becomes very hygroscopic, losing or absorbing water according to the state of the atmosphere. Indeed, it appears that this property is never entirely removed. According to the author of an article on "Wood" in *Appleton's Dictionary of Mechanics*, some bog oak, supposed to have been buried on the island of Sheppy not less than a thousand years, was dried for a good many months, and then used for the manufacture of furniture. When divided into the small pieces required for the work, it was still found to shrink. With regard to the shrinkage after one year's seasoning, it ranges from five to twenty per cent., and after a seasoning of four years from thirteen to thirty-two per cent.

W. W. Bates, of Chicago, Ill., contributes the following data upon the shrinkage of green North Carolina live oak, cut at different seasons of the year, in the Report of the Commissioner of Agriculture for the year 1866. The shrinkage after one year's seasoning was as follows:

Loss of weight in summer-cut logs, in bark	5 per cent.
Loss of weight in winter-cut logs, in bark	6 “
Difference in favor of summer-cut logs	1 per cent.
Loss of weight in summer-cut squared timber	5 per cent.
Loss of weight in winter-cut squared timber	5 “
Difference	0 per cent.

The shrinkage after four year's seasoning gave:

Loss of weight in summer-cut logs, in bark	23 per cent.
Loss of weight in winter-cut logs, in bark	27 “
Difference in favor of summer-cut logs	4 per cent.
Loss of weight in summer-cut squared timber	23 per cent.
Loss of weight in winter-cut squared timber	22 “
Difference in favor of winter-cut timber	1 per cent.

The drying of lumber in confined rooms by means of hot air, or steam and air alternately, is now largely practiced, and the more on account of the economy of the method than on account of its yielding a superior product. In some cases, the wood, before being exposed to artificial heat, is subjected to a longitudinal pressure, in order to rupture the cells in which the moisture is confined, to the end that it may escape more freely upon the application of heat. It is claimed that the wood is thus rendered more valuable for nearly all the purposes for which it is used, but particularly for the hubs, spokes, and panels of carriages, etc.—*Dr. Ott, in Eng. & Min. Journal.*

PRESERVING WOOD.—ROBBINS'S PROCESS.

The preservation of wood constitutes one of the most important questions with which applied chemistry has to deal. It has been ascertained by careful statistics that the wooden structures alone on the farms of this country cost over one hundred millions of dollars every year, while the sleepers on the railways cost twenty-five millions during the same period of time. If the duration of all this wood could be doubled, it would save the country twelve and a half millions every year in railroad ties, and fifty millions in fence and farm buildings. At the same time, our woodlands are being cut down with fearful rapidity. This fact assumes great importance when we reflect that there exists a most intimate relation between the climate of a country and the extent of its forests. This becomes at once evident when it is known that the springs of rivers do not issue from subterranean reservoirs, but consist chiefly of collections of atmospheric precipitates, rain, dew, and snow, which have percolated from higher levels. Rainless regions are always deficient in woodland, and there are innumerable instances where vast and fertile tracks of land have been changed into barren and unhealthy desserts, simply because they have been stripped of their forests. Therefore, in lengthening the duration of wooden structures, we, at the same time, prevent the destruction of our forests, thus leaving to the coming generations the same resources which we have inherited from our forefathers.

We now propose to examine the process of Mr. Louis S. Robbins, which was patented in 1865, and purchased a year later by the "National Patent Wood-Preserving Company" of New-York. It goes also under the name of the "oleaginous vapor process," and has been described in the daily and weekly press, under the title, "Discovery of one of the Lost Arts of the Egyptians." The process may be briefly described as follows: The wood to be treated is placed in an iron chamber, which is connected with a still containing coal-tar. To the latter heat is applied, until the contents have reached the temperature of 600° Fahr. The inventor not only claims that the thus impregnated wood will be completely protected against the moisture of the atmosphere, but also that it is rendered "nearly as indestructible as granite." In order to comprehend this process, it is necessary that we should examine the nature of the products which are given off in heating coal-tar, and the changes which they produce on entering the pores of the woody fibre. Coal-tar consists, as is well known, of a number of substances—acid, basic and neutral; of the latter, some are liquid, some solid. In subjecting tar to distillation, the first products given off are ammonia and probably also permanent gases; then water is evolved, together with various ammoniacal substances, and a brownish oil of a noxious smell and of less specific gravity than water. The latter is associated with the so-called light oils, the portion in which they are contained being generally gathered separately in tar distilleries. They amount to from five to ten per cent, and when the temperature has reached 320° Fahr., it may be concluded that they have passed over. The oils distilling at a later stage contain large quantities of naphthalin and paranaphthalin, both solid hydrocarbons, of which the first appears at about 400° Fahr. They are often present in such quantities that the condensed distillate assumes the consistency of butter. Carbolic or phenic acid is given off a little earlier, but the giving off of naphthalized oils continues up to 550° Fahr., when a resinous, yellowish product appears, which can be easily kneaded between the fingers. The remainder is the black, pitchy mass, used in the construction of Nicholson's pavement.

Among the various substances here enumerated, the phenic acid alone is that to which any preservative properties can be ascribed. It has been determined that tar from cannel coal contains seven per cent., that of Staffordshire coal four and a half, and tar from Newcastle coal two and a half per cent. of this acid. The average quantity of phenic acid in coal-tar would therefore be less than five per cent; moreover, it is never found in the free state, but always in combination with bases, whereby its efficiency is greatly impaired. Again, being soluble in fresh and salt water, it is easily and rapidly washed out, finally leaving the wood as completely liable to decay, as well as to destruction by insects, as it was before treatment. These facts are sufficient to justify us in drawing the conclusion that the vapors of coal-tar are not efficient preservatives.

This fact was, indeed, particularly reported upon by the Dutch Government Engineers. (See *Dingler's Polytechnic Journal.*) They discovered that after thirteen months' exposure, piles which had been creosotized under Mr. Bethel's special superintendence were found so completely free from the impregnating material that the *teredo navalis* had eaten up and destroyed these to a thickness of one inch and a quarter. The same fact was also reported by Mr. Stevenson, the famous English engineer, in the case of the piles and wood-work on the Woolwich side of the Thames. The dead oil had been completely washed out, and the destruction of the wood by decay and by worms was proceeding at such a rate that Mr. Stevenson expected to see the piles totally destroyed before the expiration of three years from the time when they had been impregnated.

Again, for many very important purposes this process is inapplicable, on account of the intolerably offensive smell of the dead oil and other products of the dry distillation of bituminous substances.

In a pamphlet before us, it is stated that there is no record in the books of any thing like this process having ever been known to the world prior to its discovery by Mr. L. S. Robbins. It is claimed to be as new as was the sewing-machine or the telegraph. We presume that Mr. Robbins did not know of the process patented by Frantz Moll, in England, in 1835, which is as follows: The wood is placed in a close chamber, which is connected with one or more stills. The operation of impregnating is begun by heating the inside of the chamber by a steam pipe to a temperature sufficiently high to maintain the vapors containing the phenic acid in a vaporized state. But before these are introduced, the watery vapor from the damp timber is allowed to escape, after which heat is applied to the still containing the light hydrocarbon oils, or the "eupion," as the mixture was named by Moll. When it is thought that the timber has been sufficiently impregnated with these vapors, the surplus is drawn off, and vapors from another still, containing the heavy oils, are admitted into the chamber.

Finally boiling liquid creosote is introduced into the chamber by a pipe, in a quantity sufficient to cover all the wood therein. It will be seen that this process is substantially that of L. S. Robbins, but was recommended, in 1858, by Dr. Krieg, in connection with soluble glass, for the preservation of all woodwork against fire and rot.—*From the Manufacturer and Builder*, *July*, 1869.

Wooden Roof Shingles.

One of the most valuable applications of the soluble glass may be recommended for shingles and wooden roofs of Farm-houses in the country, and near rail roads, where the sparks of the locomotives have frequently caused deflagrations and destruction of property.

The operation is quite simple and the expense but trifling; the process has already been described, but it may be still more simplified in the following manner:

After the steaming of the shingles in boilers or in tanks where steam of 300 to 350° is led into them for several hours they are dried and thrown into a weak solution of liquid silica, standing about 25° B. from which they are taken out and exposed to the air, before they are quite dry, a weak solution of chloride of calcium is thrown over them or sprinkled over them with a broom, when quite dry they are fit for use. They will not burn, nor be lighted by the sparks, if exposed to a direct fire, will not light in a surrounding fire. An intense heat of long duration may char them on the surface, they are however quite safe against any inflamation.

STREET PAVEMENTS.

As a rule, competent engineers express doubts as to the merits of the Nicolson, and of wooden pavements of all patterns.

In the Nicolson structure the road-bed is of sharp, clean sand, of the proper thickness. A basis is then made by laying common boards, dipped in hot coal-tar, lengthwise on stringers of like material laid from curb to curb. The blocks forming the superstructure are of Southern hard pine, three by four, and are set on end in rows, crosswise of the street—the blocks before setting being dipped to half their length in a bath of coal-tar. Between the rows of blocks intervene pickets of thin board set on edge and leaving an opening between the rows of blocks, of a foot or nearly in depth. This opening is filled with clean screened gravel rammed down with a paver's hammer, and an iron blade made for the purpose, and the surface is covered with hot coal-tar. The gutter exhibits its lowest point half a foot from the curb. The whole surface is covered with coal-tar sufficiently boiled to be tough and fibrous, but not brittle, upon which is sprinkled a layer of fine gravel and common sand. The Stafford pavement differs from the Nicolson in the laying of large blocks prepared after the Seely patent, resting upon stringers, which in their turn may be supported by any specified road-bed. Provided the road-bed is sufficiently secure, say of strong concrete, and the upper deposit is made sufficiently complete, the Stafford pavement cannot but compare favorably with other wooden pavements, and, for simplicity, is quite superior to the Nicolson. The Stafford pavement appears at the present moment to be the favorite one in the city of New York, as a large contract is now carried out for the upper part of the city.

Both obviate certain objections in surface way which pertain to the Belgian, in the wear and tear of vehicles and horses, and the noise or reverberation of wheels; but both are inferior to the asphaltic road in these respects, while the asphaltic has one great superiority valuable as preventive of accident—to wit, the beating of the hoof of the horse is rendered very audible—audible above all other sounds—so as to be measurable by the ear in the matter of distance. This latter advantage can only be estimated by persons who have taken occasion to note the extent to which one falls into the habit of measuring the distance of a vehicle from any given crossing, by the ear; and one of the main liabilities to accident, occurring from wooden pavements, is the muffling or comparative muffling of the hoof-beat. In this respect, in fact, any form of concrete pavement possesses material advantages over either the stone block, which exaggerates the rumble of wheels and obscures the hoof-beat, or the wooden pavement, which reduces both in about equal proportions. In a word, a grave objection to the Nicolson pavement is the fact that in just one respect it is a trifle too noiseless for the safety of pedestrians in crossing, especially in these days when every driver seems to be possessed with the devil to run over some body. Again, in case of extensive conflagration in any part of the city, the wooden pavement might prove a dangerous ally by ignition, an instance of which has recently occurred in Philadelphia. Neither of the wooden pavements, above named command the unqualified admiration of practical engineers as yet, though the test of use is the measure of merit in these matters, and neither has been in use here sufficiently long to warrant the expression of an opinion.

The Parisian system has, since 1854, manifested strong preference for the asphalt road upon the concrete foundation. In 1854, nine hundred and sixty square yards of asphalt road were laid in Paris, and since then the use of the material has steadily increased, until at present it is ranked as well adapted for purposes of heavy traffic on the most frequented thoroughfares. Up to 1866, 96,000 square yards had been put down; in 1867 the surface added was 54,000 in Paris proper, and 84,000 in all in the department of the Seine, making a total in thirteen years of 180,000 square yards. The contract of the Cie Générale des Asphaltes with the city of Paris covered at that date at least 96,000 square yards more, to be put down in 1868 and 1869. The ancient streets of Paris were without sidewalks, and were paved with large square blocks, with grades sloping from the sides to the middle, forming a gutter on the central line. Sidewalks began to appear in 1825, and in the same year the reversal of the surface, bringing the gutter to the sides, was introduced. In 1852 the system of MacAdam was applied to the old boulevards, and in 1858 this method was improved for heavy traffic by introducing margins along the sides, from two to four yards in width, paved with small blocks of Belgian porphyry—the germ of the sidewalk as now used. The whole surface of streets and sidewalks is now constituted as follows:

	SQUARE METRES.
Streets—paved	4,833,643
Macadamized	2,146,005
Of Asphalt	165,164
Total	7,195,302
Sidewalks—of granite	545,939
Paved	14,024
Bituminous	1,192,414
Total	1,752,377

Grand total	8,947,679
Equivalent in square yards to	10,701,416

The relative cost of the three as constructed is worthy of attention, and may be added, together with the annual cost of repairs, to the square yard. The generalization exhibits the following figures:

	COST PER SQ. YD.	ANNUAL REPAIR.
Asphaltic road	$2 50	25
Belgian porphyry pavement	3 00 to 3 67	08½ to 25
Macadamized	1 17	42 to 50

The first cost of asphalt streets is greater than that of macadamized, while the cost of repairs is considerably less; and, again, the first cost of the asphalt is less than that of the Belgian pavement, while the expense of repairing is greater. The asphalt coating, one sixth of a foot thick, is supported upon a roadbed of concrete, composed of ninety parts gravel to forty parts of mortar, about a quarter of a foot in thickness, and rested upon the compacted soil bed beneath. Provided the requisites of thorough surface and under drainage have been observed, the asphalt roofing being utterly impervious to water, the roadbed of concrete waxes harder and drier with age, and, once made, is imperishable. Repairs are easy, and consist simply in cutting away the damaged roofing of asphalt and replacing it with new. As compared with the Belgian pavement, the liability to fall of horses being driven over the asphaltic road is

1 in 1409 to 1 in 1308 on the former, proving the superiority of the asphaltic surface in this respect—that is, in surety of foothold.

The concrete known as *béton Coignet* differs from the ordinary roadbed concrete in being an artificially formed sandstone of great durability and strength, and of extensive application in civil engineering in all its ramifications, from the manufacture of sewers to the construction of aqueducts, from the fabrication of roadbeds to that of underground vaults of the utmost capacity. The best *béton* endures a rushing strength four and three-fourth times that of the best brick, fifty per cent. greater than that of limestone, fifty per cent. greater than that of sandstone, and about forty per cent. less than that of the strongest granite, to thirty-five per cent. more than that of the inferior qualities. For common use a good *béton* is compounded of four parts of sand and one part of fat lime, to which, for extra strength, one half part of Portland cement may be added. It could be manufactured here at an expense of four dollars per cubic yard, and for roadbed, a quarter foot thick, at sixty cents per square yard. The embankment on which runs the Avenue de l'Empereur, at the Trocadere, is supported by a wall of this material forty feet in height, for the distance of a quarter of a mile; and, in general, the subject of its application is now being discussed and experimented upon by the best engineers in France, with a view to extend to the utmost the constructive capacity in engineering of so inexpensive a meterial as that developed by the invention of M. Coignet; while in the sewerage system it is rapidly superseding every thing else. In it no doubt is, at the end, to be sought the solution of the sewerage problem in this city, if the administration thereof ever falls, with the needed powers of discretion, into the hands of a competent board of engineers. What is wanted in the problem is the boldness to break loose from worn out ideas and apply the best invention of the age to the development of a better and more adequate system—a quality which has been startlingly exhibited, with equally startling and successful results, in the administration of the Departments of the Seine and in the construction of public works in Paris for the past ten years.

Most foreigners travelling in France remark the excellence of the macadamized roads, and not unfrequently suppose that there must be something peculiarly favorable in the nature of the soil or something unique in the method of construction. The supposition is not true to fact, however; the quality of the roads in France being attributable to good engineering and care and exactness in all the processes of construction and preservation. In fact, in the system of Trésaquet and Simplon the system introduced into England by MacAdam in 1816 had been anticipated more than half a century. MacAdam copied Simplon in his road-bed, while Telford did nothing more than return to the system founded by Trésaquet in place of the still earlier road-bed of flat stones. The roads of France are simply illustrations of what may be done by good construction rather than of any superiority of facilities; those of the city of New-York are to a great extent examples of the result of slovenly construction with sufficient facilities for the best of work. And this leads to the general principle, that of the several pavements in use any one is practically good enough for all purposes when well constructed. The defect is not in the theory of the pavement itself, but in the defective and slovenly application of it under the contract system. As in railroad-building, with the result of innumerable accidents, so in street-paving defective road-bed is the great sin of the contractor; and, as in railroad-building, the United States cannot be compared with France or England for thoroughness and attention to the details which result in perfection, so, in the matter of pavement and the laying of it, American contractors on the average are slovenly and inefficient. Contracts for street-paving are annually awarded in this city to persons whom a competent European engineer would not trust as workers under a superintendent; and thus, through ignorance in many cases, through greed in many cases, through both together existing in many cases, it is seldom that New York can boast of a section of pavement properly put down with due attention to all details. What is

The Coming Pavement,

or which, of the several kinds now bidding for popular favor, is a question not easily answered. As a rule, competent engineers express doubts as to the merits of the Nicolson, and of wooden pavements of all patterns. In the Nicolson structure the road-bed is of sharp, clean sand, of the proper thickness. A basis is then made by laying common boards, dipped in hot coal-tar, lengthwise on stringers of like material laid from curb to curb. The blocks forming the superstructure are of Southern hard pine, three by four, and are set on end in rows, crosswise of the street—the blocks before setting being dipped to half their length in a bath of hot coal-tar. Between the rows of blocks intervene pickets of thin boards set on edge and leaving an opening between the rows of blocks, of a foot or nearly in depth. This opening is filled with clean screened gravel rammed down with a pavor's rammer, and an iron blade made for the purpose, and the surface is covered with hot coal-tar. The gutter exhibits its lowest point half a foot from the curb. The whole surface is covered with coal-tar sufficiently boiled to be tough and fibrous, but not brittle, upon which is sprinkled a layer of fine gravel and common sand. The Stafford pavement differs from the Nicolson in the laying of large blocks prepared after the Seely patent, resting upon stringers, which in their turn may be supported by any specified road-bed. Provided the road-bed is sufficiently secure, say of strong concrete, and the upper deposit is made sufficiently complete, the Stafford pavement cannot but compare favorably with other wooden pavements, and, for simplicity, is quite superior to the Nicolson. Both obviate certain objections in surface way, which pertain to the Belgian, in the wear and tear of vehicles and horses, and the noise or reverberation of wheels; but both are inferior to the asphaltic road in these respects, while the asphaltic has one great superiority valuable as a preventive of accident—to wit, the beating of the hoof of the horse is rendered very audible—audible above all other sounds—so as to be measurable by the ear in the matter of distance. This latter advantage can only be estimated by persons who have taken occasion to note the extent to which one falls into the habit of measuring the distance of a vehicle from any given crossing by the ear; and one of the main liabilities to accident occuring from wooden pavements is the muffling, or comparative muffling, of the hoof-beat. In this respect, in fact, any form of concrete pavement possesses material advantages over either the stone block, which exaggerates the rumble of wheels and obscures the hoof-beat, or the wooden pavement, which reduces both in about equal proportions. In a word, a grave objection to the Nicolson pavement is the fact, that in just one respect it is a trifle too noiseless for the safety of pedestrians in crossing, especially in these days when every driver seems to be possessed with the devil to run over somebody. Again, in case of extensive conflagration in any part of the city, the wooden pavement might prove a dangerous ally by ignition, an instance of which has recently occurred in Philadelphia. Neither of the wooden pavements above named command the unqualified admiration of practical engineers as yet, though the test of use is the measure of merit in these matters, and neither has been in use here sufficiently long to warrant the expression of an opinion. In the great desideratum of simplicity, as well as in the ease of repair, the Stafford seems to possess advantages over its elder in the field; but there is no likelihood that either will supersede the stone-block to any great extent. The coming pavement, in fact, from all indications included in the survey of the subject, is not to be found in any use of wooden blocks in any form or under any conditions.

If the Belgian (stone-block) is ever superceded—and it will be within the next twenty years—that supersession will have been brought about by invention, in the way of practicable concretes. The asphaltic road in Paris has given an impulse to investigation in this direction which will not stop until some practicable substitute for the stone-block (Belgian) has been developed. The age of block-stone pavements is in its last quarter—to borrow a metaphor from the moon.

The merits of the wooden pavement are its noiselessness, its reduction of the mortality of horses, its reduction of the wear and tear of vehicles, and its effecting a utilization of the utmost percentage of draught force, and these are all merits to an equal degree of the asphaltic road, and may be made merits of any concrete whatsoever. The increased mortality in horses occasioned by the Russ and Belgian and other stone pavements in this city is estimated at 3,500 annually—an item of considerable importance in the discrimination between pavements for thoroughfares. As between the two typical structures, the Belgian and the Nicolson, from data already supplied, it may be estimated that, with the attrition of Broadway, the former would last fifteen years against a last of half that period in the case of the latter, if, indeed, the Nicolson can be regarded as equal to the necessities of Broadway at all. It is seen, therefore, that while the stone block (Belgian or Russ) is open to grave objections on the one hand, the wooden pavements (Nicolson and Stafford) are open to equally serious objections, on the other hand, on the score of lessened durability. The concrete pavement—the value of which has been happily settled in Paris—effects a union of the better qualities of both, without the objections appertaining to either; and, as the minds of engineers and inventors are already beginning to turn in this direction, nothing is hazarded in predicting that the ideal or coming pavement will be developed from the present crude concretes. The asphalt road, one triumph of concretion, the *béton Coignet*, another triumph in a direction of equal practical importance, the attempts at concrete from inexpensive material in this country, all point to the hypothesis that the solution of the long-mooted pavement problem is at hand, in the evolution of a concrete roadway combining the durability of the stone-block with the advantages of the wooden superstructure. Valuable hints as to the constitution of concretes may be found in the reports of Messrs. Beckwith on *béton Coignet*, and asphalt and bitumen as applied to the construction of streets and sidewalks in Paris; and, in the way of American invention, the constitution of the Fiske concrete pavement, under the Hairm Burlew patent, may be studied, but has proved so far a great failure in Fifth avenue, where the concrete had to be taken up again last winter. This pavement is composed of gravel, broken stone, cinders and coal ashes (free from all foreign substances), mixed in definite proportions with tar, rosin, and asphaltum. The road-bed properly prepared, the composition is spread on in layers of moderate thickness, successively rolled with heavy rollers for uniformity and compactness. These layers form a sufficiently strong roadway of from half to three-quarters of a foot in depth, and can be put down at an expense, per square foot, not exceeding the expense of the asphalt road as constructed in Paris. It remains for years and attrition to test the practical value of this concrete; but, in general, it may be remarked, that it is heartily and highly commended by thoughtful engineers as a step in the right direction. The sonorousness of the hoof-beat, as enabling the pedestrian to measure the imminence of passing vehicles, is an element of concretes over wooden pavements, illustrated in an eminent degree by the asphaltic road, the value of which as a preventive of accidents cannot be overestimated. A pavement may be too noiseless as well as too noisy for immunity in this respect, and by all means let the capacity of the concrete be developed to the utmost. The Commissioners of the Park have also developed some excellent roadways in their admirable system of earth roads upon a similar principle; though in relation to the Park, the problem has been less difficult of solution, no necessity existing to provide for the contingency of heavy traffic. In its capacity for the combination of all the qualities which experience has proved to be desirable in a roadway for large cities, the concrete must therefore be ranked as superior to either of its competitors, with some most important and indispensable improvements to be applied, and as embodying in itself the germ of the coming pavement in this city, and the suggested reforms in the sewarage system having been carried out, attention may be directed to the production of an inexpensive concrete, analogous to the asphaltic road.

Discussion on the subject as it relates to the city would be incomplete without due consideration of the

Typical Historical Pavement,

based upon the Roman system, and its susceptibility for improvement; for it is a fact that a large class of conservative engineers still look for the advent of the ideal pave in some modification of the stone-block on the concrete road-bed. The completion, during the past week, of the relay of the Broadway pave, at an expense of nearly $500,000, recalls the fact that no question exists as to the vulue of the substructure of concrete. The question is as to superstructure. Large stone blocks on a road-bed of sand form the major part of the pavement of the city—the large block pave being less expensive than the small. On Broadway the unique feature introduced consists in splitting the blocks by a lateral fissure, leaving them in point of superficial appearance parallelograms a quarter of a foot in width, against a foot or thereabouts in length. This, by quadrupling the number of joints, affords a sure foothold for horses, especially as the blocks are laid traversely—the line of travel crossing the linear of the nave and surface at right angles with the length, with the effect to afford an average of four clinging points for the horseshoe in the new pave to one in the old. This decreases the liability to slip, really dividing it by four, and, with the concrete bed, fulfils the ideal of the old Roman pave. The want of elasticity is, however, in nowise obviated; the difficulty of traction is by no means lessened, the jar and volume of sound are not in the leastwise substracted from. The sanitary purpose is met, and percolation is prevented; but no part of the $10,000,000 annual wear and tear of horses and vehicles is saved; and this is a matter to be considered in the pavement of a city. The important question is to settle upon the desiratum in the way of superstructure. The true method of invention would seem to be to make *béton Coignet* the basis, and to this to superadd some fourth ingredient to develop the needed elasticity, which may be effected by the addition of the liquid silicates. Tar boiled to the point of elastic solidity, or asphaltum, which can be procured at twenty dollars per ton, currency, might be added in small proportions to the *béton;* and in this way, by experiment, a concrete might be developed equal in all respects to the asphaltic road, now so popular with the engineers in Paris. The hugh quarries of trap along the East River render the Russ pavement tolerably inexpensive; and hence, in order practically to supercede it, something must be produced which can be put at $2.50 or less per square yard, and as durable as the block-stone. An able and competent engineer estimates the loss in horses, extra wear of vehicles and extra horseshoeing in the cities of the United States, occasioned by block-stone and cobble-stone pavements, at—

On horses	$15,000,000
On vehicles	20,000,000
On horseshoing	21,000,000
Total	$56,000,000

The province of invention in respect to pavements, is to save this vast amount by the substitution of a concrete upper structure as inexpensive and durable as the Belgian, and as elastic and easy as the wooden, which has failed in the respect of durability as well as over-expensiveness, and can never be generally adopted.

Most roadway surfaces, it is clear, should afford, in the first place, certain and firm foothold for horses; secondly, as little resistance to wheels as possible; thirdly, permanence, as regards structure and firmness; fourthly, such qualities as will ensure ease in draining and cleaning; and fifthly, facility for removal and replacement. There can be no difference of opinion about these conditions. No matter how thoroughly excellent a pavement may be otherwise, if it only affords a slippery and unstable footing for horses, it is worthless, and its perfection in other points wasted. The greater the amount of strength the horse has to exert the more increased is his liability to slip. This arises from the fact that his hoof always strikes the pavement toe first, the point of contact then becoming the fulcrum about which his leg moves as a lever, so that the greater the load the greater the pressure on this fulcrum, with resulting increased tendency to slip. Hence, no pavement is at all perfect which presents a smooth, hard, unbroken surface, or that has any great longitudinal or transverse slope. A pavement, to offer as little resistance to wheels as possible, must have great hardness, smoothness, evenness, and no elasticity. As to permanence as regards surface and structure, any pavement requiring frequent renewals is an expensive one, no matter how small its original cost. True economy will allow a most liberal original outlay for a pavement which, if satisfactory in other respects, affords permanence. The cost of frequent renewals and repairs is not only a large item of direct expense, but while the pavement is settling and wearing smooth the draught and the wear and tear of vehicles are increased, and the necessary blocking up of the roadway while the repairs of construction are actually in progress, causes delay and time-consuming detours, unavoidably crowding the adjacent streets, while greatly inconveniencing warehouse owners by preventing the delivery and loading of goods immediately at the warehouses. To secure permanence we must consider locality, material, construction and surface. As to the locality, it is essential to examine the nature of its traffic and transportation, the nature of the soil on which the pavement must rest, and the climate to which it will be exposed. The nature of the traffic should be specially studied, as it would be manifestly injudicious and wasteful to place a stone block or iron pavement on the roads of pleasure grounds, or, *vice versa*, to transfer a park gravel road to a crowded business street. We should note the character of the soil, whether it be properly drained by nature or artificially; whether it is composed of homogeneous, dry and incompressible material, like sand, or is soft and spongy, as it invariably is when the street has been much used without pavement, or has been filled in with building or street rubbish. The climate of the locality must be considered, as some pavements lasting well under certain conditions of moisture and temperature become speedily perishable when these conditions are changed. This, perhaps, is particularly noticeable in the use of wooden or macadamized pavements. Pavement material should be thoroughly examined with regard to its tendency to decay and disintegration, to tearing to pieces or grinding up. With regard to construction, we must separately look to the foundation and the upper part, or pavement proper. Without proper foundation or bed no pavement can attain much longevity. It must be thoroughly dry, rigid or incompressible, and when uniformly thick pavement blocks are used, even-surfaced. A clean pavement is not only healthy and sightly, but economical. The pavement surface should be so graded as to clean itself to a great extent during every rain-fall. This may be most efficiently accomplished by the longitudinal slope of the street, very slight lateral slopes being needed.

VARIOUS SYSTEMS ADOPTED FOR BROADWAY PAVEMENTS.

A great variety of systems have been adopted for roadway pavements. The most convenient classification of them is into gravel compositions, broken stone, plank, wooden block, cobble stone or pebble stone block and iron block pavements and tramways. The first attempts at pavements generally commence with the use of gravel. Roads thus made possess the advantages of cheapness of material and construction. In the Park, where there are probably the most perfect roads in this country, they have shown better endurance than those made on the macadam plan. Gravel roads, when properly constructed and maintained, are comparatively smooth and noiseless, besides affording excellent foothold for horses. The great objections to them are that they cannot be kept firm enough to afford easy draught for heavy traffic; that they lack, in a high degree, permanence, and are constantly requiring repairs; that they are difficult to keep clean and to drain properly; the rapidly grinding and crushing to powder tending greatly to cause dust in dry weather and mud in wet weather; and, lastly, that the best construction yet attained has failed to prevent them from washing into gullies. Under the head of second composition pavements may properly be included pavements formed by the combinations of several materials, such as the famous asphalt pavement of Paris, concrete, *béton*, gutta percha, slag, cinder, and other pavements; also, those formed according to the experiments of McNeil, partly of broken stone and partly of pieces of cast metal, laid on a sub-pavement of rubble stone. The asphalt pavement of Paris, so often recommended in newspaper articles, is really quite an imperfect pavement. It is generally formed on a foundation of macadamized road. Powdered asphalt is placed on the foundation and stamped with hot rammers until it is very hard and has a thickness of one or two inches. It is very pleasant and smooth to ride over, but requires most constant watching and repairing. It is slippery in wet weather, and excessively so at a freezing temperature.

PAVEMENTS OF GRANITE.

Granite blocks, considered in every respect, form one of the most perfect pavements known. They are preferred, and almost exclusively adopted, in London. The Russ pavement, the nearest approach to a perfect pavement yet constructed in this city, has, in imitation of the Roman pavement, a *béton* foundation of six inches thick. The *béton* is composed of one part cement to two and a half parts of broken stone and two parts of gravel. On this foundation are laid hard granite blocks ten inches deep, ten to eighteen inches long, and from five to twelve inches wide. It is very durable, and yet, as shown in Broadway, this excellent pavement has most signally failed, the surface of the granite used polishing and affording dangerous foothold. What is required, and this would give a perfect pavement, is the adoption of the kind of stone blocks used in London, which do not polish by wear, and present joints about every four inches. Another pavement is now being substituted here in an imperfect manner. The blocks now used are of a coarser granite, twelve inches long, nine inches deep, and four inches wide, the courses running at right angles with the line of the street. What is known as the Belgian pavement was, until recently, the principal one in use in the old streets of Paris, and, as is well known, has been quite extensively adopted in this city. This pavement has the advantage of cheapness, and, if well laid, of economy, the necessary and actual cost being a little over one-half that of the Nicolson pavement. The final trouble, however, is their becoming polished and slippery, and hence they should not be laid in streets where they are subject to constant use.

Iron Block Pavements.

Several attempts have been made, with more or less success, to cast iron in blocks suitable for pavements. The chief objection is the cost of iron, but if properly laid there can be no doubt of its being cheaper in the end than most other pavements. It has failed here on account of its inadequate and defective foundation, and on account of the principle employed of keying. The rings pressing on the sand foundation gave too little bearing surface, and any weight tended greatly to displace or overturn the block, which occurring, all the neighboring ones keying into it were released, and unless quickly repaired, the ruin of the whole pavement soon followed. It has stood much better in Boston, and for the simple reason of its being better laid. It has stood there admirably, and shows no material signs of surface wear after ten or twelve years of constant use. It can be cast in such form as to give the best foothold for horses drawing heavy loads. It can be kept perfectly even and made smooth as the Nicolson pavement, and by its extreme hardness will give much less resistance to wheels. Being of uniform quality, all parts will wear equally, and as perfect a face will always be presented as when new. Its smoothness tends greatly to lessen the noise, as this nuisance is caused principally by the boxes of the wheels striking against the collars on the axles, and of course increases with roughness of pavement surface. Iron, furthermore, loses but little from oxidation. It can be kept as clean as the Nicolson pavement, with the advantage of non-absorption. It has one great advantage in being made so as to be easily and readily removed and replaced, the blocks formed from the same pattern, being exact counterparts.

The Fisk Concrete Pavement.

This pavement is composed of seventy per cent. in bulk of broken stone, coal or gravel, clean coal or iron cinders not over three inches in any dimensions. These are passed over a screen with meshes one quarter inch square. The coarser portion is then coated by mixing with tar, warm or cold, and then spread on the roadbed and heavily rolled until a depth of four inches is attained. The finer portion is then mixed with clean sharp sand, warmed, and then thoroughly mixed with tar, to which has been added rosin, carbojapanis or pitch. This is placed on the first layer of coarse material and rolled until a depth or two inches is attained, after which the surface is covered with an excess of clean sharp sand and again rolled.

THE NICOLSON PAVEMENT.

We now come to the subject of wooden pavements. The first general attempt to use wooden blocks for pavements took place some thirty years ago both in this country and Europe. They are generally made in the form of hexagonal prisms of hard wood, laid directly on sand or earth. Leading off in the list of wooden pavements adopted in this city is the Nicolson pavement. In laying this pavement, the street is first prepared by a sufficient covering of sand, which is brought to the proper crown with a straight edge made for that purpose. This surface is then covered with common round inch boards, laid lengthwise with the line of the street. The ends of these boards rest on stringers of the same material laid from curb to curb.

Both sides of these boards are covered with hot coal tar. The blocks are of Southern pine, three inches wide and six inches deep, and are set on end in rows crosswise of the street. Before setting, the blocks are dipped to half their height in hot coal tar. Between each row of blocks, and at their base, pickets one inch thick and three inches wide are nailed on edge. The opening thus formed between the rows is filled with clean screened gravel rammed with a pavor's rammer an iron blade made for that purpose, and then covered with hot coal tar. The whole of the upper surface of the pavement, when laid, is covered with hot coal tar, boiled to a consistency, which, when cold, is to be tough, fibrous and not brittle, and then covered with fine gravel and common sand. After the top gravel has become packed on the surface and in the grooves, the street is swept.

The M'Gonegal Pavement.

This pavement, claimed to be an improvement on the Nicolson, to which it is similar, consists of a foundation of two inches of *béton*, on which are placed wooden blocks six inches deep, two and three-quarter inches wide, and from four to sixteen inches in length. Holes of one and a half inches in diameter, and three and a half inches deep, are bored in each block, and then triangular grooves formed on each side of the blocks, so that when two blocks are placed together, there will be a square opening one and a quarter inch square to receive a wooden dowel or key. The wood used for blocks and keys is prepared for preservation by Robbins' process. In laying, the blocks and keys are dipped in hot coal tar. The perforations in the blocks are filled with clean roofing sand. The pavement is finished by a coating three-quarters of an inch in thickness of coal tar and fine sand. These are the specifications as we have described them; but where this pavement has been laid in this city, a foundation of flooring of tarred boards has been substituted for that of *béton*.

The Stowe Pavement.

In constructing this pavement, which is also wooden, and a cheap form of the Nicolson, the street is first filled with sand, loam or loose earth, free from stones, to within about six inches of the desired street grade, but smoothed off so as to conform to the desired arch or crown of the street; then blocks of sound pine or spruce wood three inches in thickness, and six inches in length, are set on their ends in a tier across the street, these blocks being cut square at both ends. A tier of blocks made wedge-shape at their ends by beveling on one side is set across the street close against the first tier of square-ended blocks, which are set up as before, and so on alternate tiers of square and wedge-shaped blocks are placed until a space of ten feet or more is covered, then the wedge-shaped blocks are driven down into the sand or earth with rammer and swage until the foundation is of the required compactness. The cells or spaces between the three-inch blocks are filled with clean coarse gravel, not exceeding three-fourths of an inch in diameter, thoroughly driven with rammer and swage, then the gravel saturated with hot coal tar, and the whole surface covered with hot coal tar, and lastly, the pavement covered with fine gravel or sand.

The Brown and Miller Pavement.

This pavement is also similar to the Nicolson, only that its blocks are not set vertically, but at an angle of forty-five degrees, and rest on sills of a prismatic form, which, in turn, rest on boards placed five feet apart and parallel with the line of the street.

The Robbins' Pavement.

This is another of the multifarious wooden pavements recently introduced in this city. It is very similar to the Nicolson, only the wood used is first prepared by Robbins' patent wood preserving process.

The Stafford Pavement

is only another imitation of the great original Nicolson. The blocks are dressed to a uniform thickness, grooved in the middle with a double dovetail, two and one-half by three-fourth inches, each side of the block bevelled at one end, and running to an edge so as to form a groove on the upper surface.

SEELEY'S CONCRETE PAVEMENT

now being put down in Eleventh street, near University place, consists of sulphur, three parts; gas tar, twelve parts; silica (pebbles) sixty parts, by weight. The pebbles are heated 230° Fahrenheit before being mixed with the melted sulphur and tar.

WOODEN PAVEMENTS, *versus* STONE AND CEMENT.

The failure of the concrete in Fifth Avenue for which the citizens were mulcted in the sum of half a million of dollars, and which was taken up during the winter on account of its uselessness. The various stone pavements, which have from time to time been brought forward by the patentees and speculating companies, have all brought the unbiased and practical men to the conclusion that for comfort a wooden pavement in such streets as Fifth Avenue, would prove by far preferable to any other, provided it is made durable, at the same time a proper concrete as mentioned in these pages in connection with silicates may with great propriety be employed as a base but not as a capping for either stone or wooden pavement; whether this shall be a concrete or whether the base shall be of planks properly prepared and silicified so as to construct the blocks upon it, is a matter of great importance, and is well worth a reflection and experiment upon a small scale, but not hazarding an outlay of perhaps a million of dollars, and the experiment to prove again a failure.

The following method of application is recommended by the author:

The planks and wooden blocks, intended as pavement, the size of the planks being from 10 to 12 feet in length and 1 inch in thickness, and the blocks from 10 to 12 inches square and in the first place exposed the iron boilers to a temperature of 300° F. for several hours, or kept for 4–6 hours in boiling water, containing 2 per cent. of soda ash, which possesses the property of dissolving the albumen and sap contained in the cells of the wood and by the boiling the coloring matter is extracted from the wood; when taken from the boilers, they are brought in drying chambers of high temperature, and then removed to vats containing crude carbolic acid and tar water standing for 6–8° B. which will enter into the pores, left open by the previous process and a large portion of the liquid will be absorbed; from thence they are thrown in vats containing hot silicate of soda, standing 20° B. and left therein for 4–6 hours; they are then removed and dried either in air or hot chambers. When perfectly dry they are suitable for being put on a smooth ground, which may consist of a cement of silicated hydraulic lime or cement. The interstices of the ends of the blocks may likewise be made tight by applying a silica cement between each.

The Mode of Application.

The frequent enquiries how to apply the soluble glass, and how much is required for spreading over certain surfaces, may herewith be recommended in the following manner; application for hardening stones as a mortar between bricks, or any cement or composition for wall, cistern, cellar, or roofing.

In all cases the liquid soluble glass, either the silicate of soda or potash, or both combined, are diluted with equal quantities of water so as to stand 25° B. If strong cements, or lutes, where various other substances along with the dry silicate and metallic oxides are to be employed, the soluble glass is not diluted but employed from 30–35° B, sufficiently to make a plastic composition; but where it is intended for mending or filling cracks or holes either in stoves or iron castings, discretion of the consistency of the mass must be used, as it may be more advantageous for the cement to dry slowly, so as to prevent too sudden a contraction.

For painting or coating on stone, it is useful to apply the dilute by a syringe, and if necessary, repeat the operation 2–3 times after each drying. For preserving monuments, tombstones, marble columns, etc., the dilute silicate of soda may be used as a wash with or without the addition of baryta (the precipitated sulphate of baryta is always preferred although expensive), lead, zinc, or limewash, by means of a paint brush and according to the condition of the stone as to porosity. If the chloride of calcium, chloride of iron, or dilute hydrofluoric acid are applied upon the surface of the stone, cement or paint, they are thrown over the silicated surface uniformly, so as to cover every part of the material to be treated. In all cases it is understood that the silicate application is to be applied on new stone, for it will not adhere on old paint; therefore, if it is to be used, it is indispensible that it be first removed by soap, caustic alkali, spirits of turpentine, or even acids, and when perfectly clean and dry, the operation of silicating may take place. In all cases where the substances are to be painted or undergo a silification, it may be repeated 2-3 times at each interval of at least 12 hours; a weak hydrofluoric acid may in all cases be used as a wash over the silicated stones; 1,000 square feet of wall covering can be executed with 200 gallons of dilute silicate of either soda or potash. In diluting the silicate, it is well to employ 3 applications of various qualities, such as for instance, the first coat may consist of part of silica to 2 parts of water, and another of equal quantities of water, and the last coat the dilution to be 1 part of water.

Wood and timber of every description may be treated with the concentrated silicates.

For Preservation of Walls.

It is well known that brick absorbs its weight of moisture and requires much attention. The external surfaces of the walls to be protected are first washed with a silicate of soda, which is applied again and again, until the bricks are saturated, and the silicate ceases to be absorbed. The strength of the solution is regulated by the character of the bricks upon which it is to be applied, a heavier mixture being used upon porous walls, and a lighter one on those of denser texture. After the silicate has become thoroughly absorbed,and none is visible upon the surface, a solution of chloride of calcium is applied, which, immediately combining with the silicate of soda, forms a perfectly insoluble compound, which completely fills up all the interstices in the brick or stone, without in any way altering its original appearance. By this operation the wall is rendered perfectly watertight, and, as the pores of the bricks are thoroughly filled for a considerable depth from the surface with the insoluble compound, which is entirely unaffected by atmospheric influences, no subsequent process is necessary.

THE PROTECTION OF RAIL ROAD SLEEPERS, CROSS TIES, FRAME HOUSES, TELEGRAPH POLES, TIMBER, STAVES, SHINGLES, LATHS, TANKS, TUBS, CASKS, BARRELS (Petroleum, Naptha, Spirits Turpentine, Alcohol, Linseed Oil), CISTERNS, AND EVERY DESCRIPTION OF WOOD, AGAINST FIRE, DRY ROT AND LEAKAGE.

The seasoning or initiatory preparation of the lumber, so as to destroy the organic or nitrogenized matters enclosed in all the cells of vegetable matters, are dissolved and washed out of it, or, in other words, the removal of all the albumen, sap and coloring matter, is effected by exposing for from four to six hours to boiling water, containing about one per cent. of soda ash in solution. They are then withdrawn and dried in hot rooms, and then thrown into tanks containing the tar and carbolic acid water, and left for a few hours, then dried again and thrown into a hot solution of silicate of soda standing 20° B., in which they are left for ten or twelve hours. When removed from here a weak limewash is applied with a brush or sponge, consisting of 10 lbs. slacked lime to 40 gallons of water, when likewise they are removed to a dry or hot air; after that a weak wash of chloride of calcium is thrown or brushed over them when nearly dry. The process is then finished, and the articles so prepared will resist the elements as above stated. They increase in weight by this process about 6 per cent. After this treatment, they assume upon the first drying a glazed appearance, and the pores are filled with insoluble silicas precipitated by the action of the tar liquor upon the alkali of the silicate of soda. Barrels which have been treated may be rendered perfectly impervious by filling up the chimes (the inside of those barrels having been treated with the silicate of soda and chloride calcium) with a thin silicated cement applied on the interstices. No air nor any liquid will then have any effect; the lightest liquid may then be kept in those prepared barrels without escaping—flour, butter, lard, and many other perishable substances may be kept for a length of time in barrels so prepared. Spirits of turpentine, linseed oil, alcohol, and other spirituous liquors may safely be transported and kept for a length of time without evaporation or loss in the contents of the barrels. *Telegraph poles*, which are from twenty to thirty feet long, require a different treatment for their seasoning before they undergo the silification. They are steeped first in the tar carbolic liquid, in holes dug in the ground with tanks built in the same, and left in there for several days, then taken out and undergoing the other process of silicate of soda, limewash and chloride of calcium, as described, will render them proof against fire and dry rot.

The following Cements, Whitewash and Concretes have all been tested, and deserve a general introduction:

THE SILICA CEMENT A PRESERVATIVE TO THE BOTTOM OF IRON SHIPS.

It is well known that iron ships have produced many disasters from rusting after long voyages; the experiments tried for preventing the adherence of barnacles and the rusting have been very numerous. The author feels quite confident of success by the proper application of a silica cement prepared by a hot solution of asphaltum and fine sand, manganese, and liquid silicate of soda, and putting it on the bottom of the iron ships by means of a brush, and before becoming quite dry to dust over the paint more powdered manganese.

THE MOST ADHESIVE INSOLUBLE CEMENT.

Blacklead, 6 lbs., are mixed with 3 lbs. slacked lime, 8 lbs. sulphate of raryta are mixed with 7 lbs. of linseed oil; the whole mass is well mixed together to a uniform consistency, and the entire mass made more plastic with concentrated solution of silicate of soda. This cement may be used for numerous purposes, where hardness and adhesiveness are the desired objects, uniting at the same time steam and hot water. The *cheapest Lubricator* for locomotives, engines and machinery is prepared from a mixture of silicate of soda liquid at 25° B. added to fine plumbago, talc and aspestos in equal quantities, so as to retain the thin plastic condition, and capable of dropping it on the journals in very small portions.

The *Cheapest Whitewash*, which is very durable for indoor and outdoor work, is prepared by the following composition: To 1 lb. slacked lime and 1 lb. sulphate baryta, add 1 pint of silicate of soda and 1 pailful of hot water; stir the materials well together, and use it at once. If the color is intended for a yellow wash, add a quarter of a lb. chrome yellow; if for a blue wash, use instead of the latter a quarter of a lb. of ultramarine (worth six cents); and if the paint is intended to coat iron railing, stoves, steamboat chimneys, and to obtain a brown or black fire proof paint, add half a pound of manganite, an oxide of manganese, or the pyrolusite, which is the black or gray peroxide of manganese.

The white wash or yellow wash just quoted is extremely durable and cheap for wooden fences along railroad tracks, canal boats, farm houses, and other wooden structures.

THE MOST DURABLE AQUARIUM CEMENT.

The materials of a water-resisting composition are prepared by mixing finely powdered dry silicate of soda, powdered chalk, and fine sand in equal quantities, made plastic with the liquid silicate, and applied at the joints, and worked over with fluid chloride of calcium, and when quite dry let some weak hydrofluoric acid pass over the cemented joints. This cement will be permanently impervious to water, and will not crack. The same composition is quite suitable for brewries, malt houses, linings for water-tanks, and cellars into which water flows.

The author considers it advisable to show, also, the advantages of concrete by quoting Tall's system, applied in Paris, and the description of the concrete bridge at London, and will state that the addition of silicate of soda to the concrete will undoubtedly ensure a great saving.

Tall's system has been used in the construction of a large number of houses in Paris, erected under the directions of the emperor, who takes great interest in the improvement of the working classes. This con- has also been applied in other parts of Europe, and to some extent in the United States.

The work can be performed by ordinary laborers, who, after four or five days' experience, acquire all the requisite expertness. Even boys have been successfully employed in this kind of building. The only skilled workman necessary is a common carpenter, whose duty is to adjust the framework or apparatus to receive the successive courses of material, and place joists, doors, and window-frames properly. The apparatus is designed to construct eighteen inches in height daily over the entire extent in hand. what is done in the evening of one day is hard next morning, and quite strong, the best proof of which is that the wall itself, as it rises in height, supports the necessary scaffolds. A double curb, entirely surrounding the upper part of the walls, serves to hold the plastic material in place, until it acquires sufficient hardness to support itself.

The material consists of one part of Portland cement to eight parts of coarse gravel. The cement and gravel are first well mixed together in a dry state, and when this is done it is damped by means of a large watering-pot, containing some hot silicate of soda and again mixed by a pronged drag, such as is used for dragging dung out of a cart, until the entire heap has been wetted and mixed together. It is then put in iron or zinc pails and poured into the frame, where it is leveled by men stationed for the purpose. In order to save concrete, large lumps of stones or brickbats are put into the centre of the wall, and covered over and about with concrete. Frost does not affect the concrete after it has once set, which, with good cement, will be in about five or six hours. Nor do heavy rains appear to injure it in the slightest degree, though they may chance to fall ere the concrete has hardened. The walls can be made straight and even as it is possible for walls to be, and the corners as sharp and neat as if they had been formed of the most carefully dressed stone.

Concrete makes excellent floors, and the walls and floors are quite impervious to vermin of all kinds, and also to wet. Many kinds of building bricks will absorb water; hence, brick houses, when the walls are saturated with water, are cold. This is not the case with houses constructed of concrete, as it is non-absorbent of moisture, and such houses must be, therefore, more healthy.

This novel mode of building houses has excited great interest in the neighborhood of Runnamoat, Ireland, and the proceedings have daily attracted numbers of people from all parts.

While concrete may be used in constructing buildings of every description, it is peculiarly adapted, from it cheapness, for the construction of cottages for laborers, and also for farm buildings. Its cost is not more than half that of brick-work; almost any material can be used along with the cement, and as we have already shown, the most ordinary class of country laborers are quite competent to carry out the details of the system. With reference to its adaptability for large buildings, we may mention that a warehouse seventy feet long, fifty feet wide, and sixty feet high, five stories in all, has been erected on Mr.

Tall's system for Mr. H. Goodwin, Great Guilford street, Southwark, England, and that gentleman testifies in the warmest terms to its satisfactory character, and is making arrangements at the present time for the construction of another similar building. The warehouse already erected has attracted universal admiration from the practical and scientific gentlemen who witnessed its erection.

The chief element of success, when the cement is of good quality, seems to be the thorough mixture of the dry materials, to secure uniform strength.

Concrete Bridge.

The tests applied to the experimental bridge of concrete, set in cement, erected over that branch of the Metropolitan District Railway which forms one of the junctions between the circular line and the West London Extension, prove conclusively the reliable character of concrete exposed to compressive strains. The structure experimented upon spans the open cutting between Gloucester-road Station and Earle's Court Road. It is a flat arch of 75 feet span, and 7 feet 6 inches rise in the centre, where the concrete is 3 feet 6 inches in thickness, increasing towards the haunches, which abut upon the concrete skewbacks. The material of which the bridge is made is formed of gravel and Portland cement, blended in the proportions of six to one, carefully laid in mass upon close boarding set upon the centring, and enclosed at the sides. In testing the bridge rails were laid upon sleepers over the arch, which brought a load of two seventy-fifths of a ton per foot upon the structure. Seven trucks, weighing, together with their loads, forty-nine tons, were formed into a train, having a wheel base of fifty-seven feet; hence the rolling load amounted to forty-nine-fifty-sevenths of a ton per foot run. The deflection produced by the passage to and fro of this train four times was noted upon a standard, cemented to the side of the arch, at a distance of one-third the span from the abutments. When one side of the bridge was loaded, the extreme rise of the branch on the opposite side was about one-sixteenth of an inch, which was produced by a maximum strain of 10 tons 14 cwt. per square foot. At a subseqnent trial, a mass of gravel 10 feet wide and 3 feet thick at the crown, and 6 feet deep at the haunches, was laid over the bridge, and upon this ballast was placed the permanent way. After an interval of a few days, the trucks, loaded as before, were passed over the bridge, at first in pairs, and finally all together. In this test the strain upon the concrete was as follows:

The weight of the arch, as before	7 tons 17 cwt.
170 tons of ballast	4 tons 8 cwt.
Strain per square foot from dead load	12 tons 5 cwt.
Strain per square foot from passing load	2 tons 17 cwt.
Total strain per foot	15 tons 2 cwt.

After repeated transit, the load was left upon the bridge all night, and the arch, upon examination, showed no signs of failure or distress under the severe strains to which it had been exposed.

THE SOLUBLE GLASS AS MANURE FOR GRAPEVINES.

By putting the dry silicate of soda at the roots of grapevines, with or without the addition of phosphate of lime, has by experiments proved of immense benefit to the thriving of the vines to a proper thickness, and the grapes of uncommon size.

SOLUBLE GLASS A SUBSTITUTE FOR SOAP.

A chemical compound is effected by the combination of an alkali with silica, which possesses a greater affinity to the first than the acid of either grease or stearic and oleia acids have in coarser soap. On account of the soap which generally contains the caustic lime, that compound prepared by the admixture of soluble glass possesses less caustic properties, and acts therefore less injurious on the texture of cotton, linen and woolen fabrics. As examples of this property may serve the treatment of lyes with wool or silk, which are actually dissolved by the same, while the soluble glass removes but externally the adhering dirt without any injurious action. The slippery and adhesive consistency of soluble glass acts likewise beneficial in the easy washings and rinsing with water of the impurities.

There are many advantages in its applications on wool, silk, cotton and leather; it is stronger than common soap, requires a less quantity, and either hard, soft, cold, or lukewarm water may be employed.

The labor and saving of fuel is an advantageous economy; it preserves also many colors, which are not fast, much better than common soap; it resists, in fact, almost all colors. From one to four pounds liquid glass is sufficient for 100 pounds of water; as that used for wool is quite sufficient for a menstruum, it is employed quite extensively in Europe for washing and fulling of wool, and it has been used long before the soluble glass was known by dissolving flints in caustic lye prepared from wood ashes.

The Prussian Government has found it advisable, for the introduction of the soluble glass in the military and other royal institutions and prisons, and also for the paper manufacturers, and their extensive linen establishments; and instituted experiments as to practicability of a general economical application.

In the cotton mills it has proved a saving of 50 per cent by substituting it for starch and flour, which was so indispensable for fastening the colors; and in England, thousands of pounds sterling have been economized by its application. In our late war the consumption of the soluble glass in that branch of industry of the United States was very extensive.

The soap manufacturer, who formerly did use rosin for an adulteration or admixture, the cost of which was formerly but two dollars, but rose to 25 and 30 dollars per bbl. of 180 ℔s., was obliged to resort to the use of soluble glass in its various forms either as liquid or jelly.

Rosin is now again more employed than the soluble glass; not however for the reason that it is better as a sophisticator, but because the soap maker has an idea that the soap formed from rosin with fat suited better, and is more time saving; he does not consider all the circumstances: such as the smell and touch produced in the handling or washing with rosin soap, and that the admixture of soluble glass is no adulteration, but an improvement, and that it is as economical as rosin soap.

THE SOLUBLE GLASS A SUBSTITUTE FOR GLUE.

It has proved quite useful in applying the liquid glass for glueing wood and paper together, instead of the common glue, and it is sold in the trade as mucilage, and is applied on paste board instead of emery or corundum paper, used by cabinet makers and other mechanics for polishing. As a paste for bookbinders instead of glue, starch or dexterine it has proved quite useful. Earthenware may be kept more durable by lining them with a weak solution. It is likewise used on leather, provided the same is not exposed to much bending.

The *glazing or enamelling of culinary vessels*, made either for iron or stone ware, the soluble glass is usefully applied in the following manner :—

The silicate solution of soda and potash is mixed with thick lime water, to 100 parts of the silicate add 1 part of lime water, made for 1 part caustic lime to 6 parts of water. The mixture is then evaporated to dryness and reduced to fine powder. By dipping first the objects to be glazed in the liquid silica, the powder is then sifted over them ; when dry, the operation is repeated again ; when dry, the coating becomes so hard that it cannot be rubbed off by the hands ; they are then treated like other ware by putting them in a furnace, requiring however, not a very great heat.

A similar process is to prepare a mass from 100 parts powdered quartz, 80 parts pure potash, 10 parts saltpetre, and 20 parts slacked lime, which mixture is made into a thin paste with the liquid silicate, and then burnt. This glazing is very durable and resists both vegetable and mineral acids like common glass. It requires no great skill to execute the operation, and the expense to prepare such a glazing is but a trifle.

SOLUBLE GLASS APPLICATION FOR VARIOUS CEMENTS.

Porcelain, Glass and Metals are fastened together when broken, either by the liquid or gelatinous silicate by the following method: Heat the object to be fastened together to that of boiling water, and apply the soluble glass on both sides of the fracture, press them together and leave them in a warm place for a fortnight, when they will be fit for use. Fluorspar finely ground, black oxide of manganese, oxide of iron (crocus,) finely powdered soluble glass, and many more refractory substances are suitable articles to mix with the liquid silica for the various cements in use; a cement for fastening iron in stone, glass or wood is recommended, consisting in 1 part prepared chalk, 1 part marble dust, and made plastic with the liquid silica, or 1 part powdered soluble glass, 2 parts powdered fluorspar made into a paste with the liquid, silica, and this is for pasting labels on glass bottles.

Caseine or metamorphosed milk is also mixed with the liquid silica, and makes an excellent paste.

Fireproof Cement is composed of the various oxides of iron, and formed into paste with the liquid silica.

The Athens Marble Cement is composed of carbonate of lime, carbonate of magnesia and silica with oxide of iron, and made into a thin liquid and applied to the stone, which, on drying, is permanently fastened to the surface, and protects it from smoke, dust, and atmospheric agents.

Common and fire brick acquire great strength if the silicate of soda has been employed in the manufacture, and become indestructible, they are then particularly fit for baker ovens, wall and well foundations and furnace beds.

Glazed paper for apothecarie's use, may likewise be prepared with the soluble glass.

Metallic Cement is formed when a mixture of equal parts of oxide of zinc, per oxyde of manganese and litharge, and made up with liquid silica and marble dust, and applied between the metals to be cemented.

AN IMPERMEABLE CEMENT RESISTING STEAM.

It is prepared by mixing six parts finely powdered blacklead, 3 parts slacked lime, and 8 parts of plaster of paris, made into consistency by the liquid silica.

Zinc Cement for stopping cracks in metallic apparatus and other materials is made by mixing equal weights of zinc white and finly powdered soluble glass with a solution of chloride of zinc of the density of 126; it sets rapidly and resists the action of most agents. The simple mixture of oxide of zinc with a solution of the chloride of zinc, has also been recommended.

Cement for any foundation wall is made by mixing 1 part of good slacked lime with 3 parts of fine sand, and $\frac{3}{4}$ of its weight of finely powdered quick lime is added, and made into a paste with the liquid silica; this mass becomes so hard in 4 days that a piece of sharp iron would not attack it.

THE GYPSUM AND CLAY CEMENT.

This cement is very hard, and is prepared by an intimate mixture with liquid silica, after the gypsum has been calcined, and it is preferred to lime cement for the reason that by the action of fire, it becomes reconverted into lime, which, when the waters from fire engines is brought to bear upon it, expands much and forces out the walls to the destruction of the walls.

HARD ADHESIVE CEMENT.

It consists in mixing 5 parts powdered clay, 2 parts iron fillings, and 1 part of black oxide of manganese, and ½ part borax made into paste with liquid silica, when dry is very hard, and withstands water. Also a *mixture of manganese and zinc white* with plaster of paris forms a very hard cement, and has great adhesive capacity.

Drain and Gaspipes for conducting to sewers and houses, may be made as permanent as iron pipes by using a hard cement consisting of hydraulic lime, clay and sand, mixed with fine powdered fluorspar and soluble glass, all made plastic by the liquid silica; this mass when dry and burnt, will resist a pressure of 600 ℔s. to the square inch, while iron pipes burst under a pressure of 400 ℔s. to the square inch.

CEMENT FOR CLOSING CRACKS IN STOVES, &c.

A useful cement for closing up cracks in stove plates, stove doors, etc., is according to a notice of the *Scientific American*, March 12th, 1870, prepared by mixing finely pulverized iron, such as can be procured at the druggists, with liquid water glass, to a thick paste, and then coating the cracks with it. The hotter the fire then becomes the more does the cement melt with its metallic ingredients, and the more completely will the crack become closed.

CEMENT FOR A CISTERN.

Take 10 parts of Plaster of Paris.
" 2 " Glauber Salts.
" 4 " Clay.
" 4 " Slacked Lime.

Made in a plastic cement with the liquid silicate of soda, and before it hardens, add liquid chloride of calcium.

For sweetening the water in cisterns, which is found to be hard, may be made soft by one gallon of silicate of soda in the cistern, and repeat the operation once a month.

The best iron cement is composed of calcined plaster and iron filings, from each 10 parts, 4 parts oxide manganese, 2 parts slacked lime, made plastic with the liquid silicate of soda.

The most refractory cement is formed from silica, asbestos, plumbago, and soapstone. These materials mixed in certain proportions and made plastic by the liquid silica, form a most valuable cement for locomotive journals and other lubricating purposes, for lining of steam boilers as well as coating, for filling up airholes in iron castings. By the addition of peroxide of manganese, it may be much improved, and serve as a permanent paint, which is fire and waterproof.

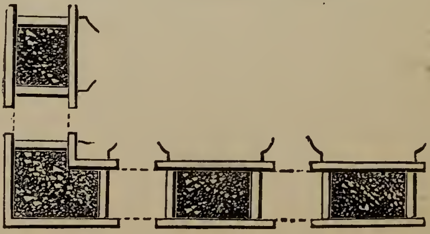
Besides the cements, such as the Portland, Roman, Keene's, Parion and Martin's, and those obtained from the Puzzuolanas and Trass, as obtained near Naples, and from the extinct volcanic districts, such as Vivarais in Central France, at Brihl, near Andernach on the Rhine, and also near Edinburgh in Scotland, and the Rosendale, all of which when mixed with coal cinders, slags and scoria and wood ashes, contain more or less soluble alkali, and have a considerable effect in hastening the absorption of the moisture, and facilitating the setting of the lime and sand. There are also the burnt clays or terra cotta, and are frequently used as artificial stone, but from their great and unequal contraction, and the facility with which they are acted on by frost, are rarely satisfactory, except treated with soluble glass as has been described.

There are also many varieties of concrete now manufactured in vast blocks and a perfectly solid mass, which replace now the accumulations of rubbish and loosely aggregated stones, once thought sufficient for filling up intervals between walls of solid masonry, especially in piers, harbors, and other important works, and to which the name concrete has been given, and means a species of rough masonry, consisting of gravel or broken stone mixed with lime, the latter being slaked and immediately put in contact with the gravel. When lime is used that has previously been worked into a paste, it passes by the name of Beton, and the Beton Coignet Building has of late been introduced into this country, and to a great extent substituted for brick and stone.

Beton Building.

Of all the compositions which in late days have been introduced as a substitute for brick or stone-work, there is not one that presents more attractions as a material than béton. But the use of it is limited to those localities where water-lime can be had at a reasonable price. For, although that admirable cement is about the only one of its component parts that is expensive, yet the proportion used makes the béton more costly than could be wished, notwithstanding its many merits as a building material. There need not be any stone or stone chips used in the making of béton. All that is required to make a quick-setting and very durable material is, sand three parts; water-lime, one part; broken brick, six parts. The water-lime and sand should be well mixed together, dry. Then have as much water thrown on as will make a moderately stiff mass, when it is to be instantly transferred to the moulds, which are already in their positions on the walls, and the centre to be packed with the broken brick, which, being very porous, will receive the moist cement readily on its broken faces, and help to set the whole. The mode of proceeding to construct the courses is by means of moulds easily adjusted and taken apart. They are to be calculated so as to inclose a block of béton of the required thickness of the wall, and of, say, half again that thickness in length. Their height may be ten inches. Thus, if the wall be twelve inches, the block will be the same, and also eighteen inches long by ten inches high.

We will proceed to describe the operation of building as carried out in the construction of a béton house at Black Rock, near Buffalo, New York, some years ago. The lines being laid out, the basement was excavated to a depth of six feet, and the trenches for the foundation walls dug out one foot and a half below the bottom of the basement. These trenches were two feet and a half wide, that is, three inches on each side wider than the basement wall above them. The basement was, therefore, dug just three inches wider than the plan, all around, and this was done to leave room for the placing of the moulding-boxes with their rods. The bottom of the trenches was made level, and these were filled with concrete composed of gravel, six parts; sand, four parts; and quick-lime, one and a half part, with sufficient quantity of silicate of soda, so as to make the composition plastic. When this mass was well mixed and turned over three or four times, it was thrown into the trenches in layers or courses of, say, four inches in depth. Each course was spread over the whole of the foundation trenches, until they were all, including those of the foundations of cross-walls, filled. When the surface of the basement or cellar bottom was reached, then the whole area was gone over with a coat of gravel; and over this was poured a creamy mixture of water-lime and sharp river sand, in equal proportions, until the whole was flush. This was done on Saturday, and on the following Monday the floor was hard enough to walk upon. The basement walls were now commenced in the manner here described. The lines of the walls were carefully laid out, and angle-moulds placed at each corner, with straight moulds set at equal distances all along.



A corner mould and three or four straight moulds are sufficient to work with: but the greater the number of moulds the more expeditiously the operation of building goes on. When all was ready, the corner moulds were filled first, and then the other moulds regularly in turn. When all were filled, the moulds were taken apart and set up at other points along the walls; but sufficient time was given for the béton to become hard enough to admit of being uncovered. The walls being thus gone around, the next operation was to inclose the spaces between the béton blocks, and this was done by using the sides of the moulds, without the ends, and holding them in place by the following means: Two pair of pieces of scantling, say two by three inches each, and two feet long, were set upright at each end of the side-boards, and bearing them against the béton blocks. At the middle of their length they were held by the rods and screws used in the moulds; and their upper ends being kept apart by sticks of the necessary length, the boards were thus clutched and kept in place. These inclosed spaces were now up flush, in the same manner as the moulds, and, by packing and tamping, the connections were made so complete as to render the whole a uniform mass. As each course was in this manner completed, the moulds were laid for a new one, taking care to break joint, although no joint was visible, yet this precaution was taken to avoid any continuous joint or point of imperfect connection. Where doors or windows occurred, the moulds were placed correspondingly, on either side of such opening; for it may be observed that there is no necessity for the fixing in of the frames until the work is all sufficiently set. However, it is necessary to insert in these moulds, at doors and windows, at the ends which will form the jambs of such, pieces of scantling, called stops, say, four inches thick, and in width, sufficient to permit the future frame to rest five or six inches back from the outer face of the wall. Of course, the frame can be set up and these jambs worked up to it, but it is more troublesome and will scarcely make as good a job. The window-sills and caps were provided for in like manner; and there was a *splay* left in the window jambs, by means of angular pieces being added to the above-mentioned stops, which gave the required mold to the béton. When the level of the ceiling was attained, the flooring joists were all set up in their places, and temporary bridgings of plank fixed between every pair, so as to hold the béton, which was thus continued up, making a compact bed for the joists, and effectually preventing the lodgment of vermin. The short boards or pieces here used may be removed when the work is set, as they will be wanted again on the next floor. In the building we describe they were left in, but it is not at all necessary.

The joists being all flushed up with béton, the floor boards were nailed down and the béton again flushed up to the surface of the floor. The moulds were now placed for the walls of the principal story, which being six inches less than those of the basement, the ends of the moulds were made in accordance with the new thickness, namely twelve inches, and the work went on as before, with the exception of the corners of the main walls, which were rounded by means of blocks of the necessary shape being set in the angle. This rounding off of the walls on the outer corners gives a very neat appearance, without adding to the cost. On the contrary, it economizes the material; for the thickness at these corners, instead of being greater on the diagonal, is exactly the same as that of the straight walls throughout. In the manipulation of the béton for the walls of the superstructure, it was deemed advisable to pack the front of each mould with a purer or finer coat of cement than that used at the heart, or even at the back, so as to give one uniform face to the outside. This face was carefully troweled into the bed made for it in the mould by working back the coarser béton in which the broken brick was packed. In the top of the first tier of blocks forming the course, an angle mould was laid along and pressed into the fine béton forming the outside face. And on the bottom of the next tier of moulds a corresponding angle-mould was laid and the béton cast firmly around it. And thus every course was treated. The consequence was that the > cincture left on the removal of these moulds produced an effect on the exterior, remarkably like coursed masonry, the course lines being of the > shape, and about two inches wide and one inch and a half deep. Any other section of cincture can be moulded in to suit another design of building. After each course was uncovered, these sunken mouldings were finished smooth by working a whole mould of the > shape along them, backward and forward. Perpendicular moulds of like shape might have been made to mark out each block, and no doubt would have much improved the appearance of the building. The sunken horizontal courses were carried all around the house and produced a good effect. The next floor was flushed up at the joists precisely in the same manner as the first, or principal floor. The windows and doors were all set in and worked up to. But this, as was before observed, is not the better way. The sills and lintels were of oak, but the latter did not show on the outside. It would be much better to have stone sills and lintels. The partition walls were six inches thick, and were cast in unbroken courses, with the exception of openings for doors. The door-cases were set in and worked up to. Blocks were nailed to the floor at the walls and partitions to receive the base-boards of the apartments, and these blocks were covered up in the béton. In like manner, there were blocks inserted for nailing finishings of windows and doors to, and for holding the horizontal slats from which to hang pictures. The roof was a gabled one, of a fourth pitch; but a Mansard would at this day be a great improvement. The walls were skim-coated on the inside of the house, and the best rooms were hard finished. Nothing can be easier for the plasterer to make a truly workmanlike job with, for his material is sure to adhere to it. There is little more to add, save that the chimney-flues were all cast round by means of stove-pipes used as moulds, and left in. This is not a good plan, as the stove-pipe will corrode after a time, and it is very difficult, if not impossible, to remove it. It would be better to use a movable cylinder mould with a handle, and have the flue finished smooth in béton. The chimney shafts can be very ornamentally finished with terra cotta caps. To those who can procure water-lime at anything like a reasonable price, we would strongly recommend béton as a particularly applicable material. It is warm in winter, cool in summer, and at all times dry and healthful. In mixing common lime with it—of course for economy's sake alone—it will be well to bear in mind that, while quicklime swells in slacking, say one-fourth, water-lime, on the contrary, shrinks about a fifth. By experiment on the limes to be used, exactness can be obtained. And by thus calculating, the two may be, so to speak, dovetailed into each other. — *Manufacturer and Builder.*

Essays Relating to this Treatise.

The following essays on the origin as well as functions of carbonic acid, limestones, alkalies, silica, etc., follow herewith in order to explain, in the first place, what a powerful influence carbonic acid exercises in the application of soluble or water glass for all purposes of domestic economy, how carbonic acid acts in the sedimentary rocks, and whether derived directly from the atmosphere or from subterranean decomposition, produce the disintegration of carbonate of lime from siliceous substances.

The sources of limestones from the ocean bed and coral reefs, and the subsequent formation of various limestone rocks, and application of the same for our purposes; the origin of the alkalies as are employed in the manufacture of soluble glass.

The silica in all its applications for domestic purposes, explaining the immense variety of forms as found in nature, and uses in the manufacture for soluble and every other species of glass, and forms an interesting guide for the production of plain and colored glass, and the green sand formation of New Jersey.

I. *Essay on Carbonic Acid.*—By Dr. Lewis Feuchtwanger.

" Carbonic acid, the pabulum of the organic and inorganic world."

According to the ancient philosophers, the simple bodies or elementary principles from which all the varieties of matter are composed, were but four, namely: fire, air, water and earth. This notion, after having for ages formed a part of the creed of the learned, has been completely explained by the light of modern science, though it is not yet extinct among the vulgar. The alchemical writers of the middle ages added to these principles some others, as salt, sulphur and mercury, to which terms, however, they attached ideas very different from those that belong to them at present, and into the nature of which it is not necessary to inquire. Some of the alleged elements of the olden chemists are now known only to exist in imagination, and others are ascertained to be by no means simple substances. Thus air is found to consist of two different elastic fluids or gaseous bodies, which may be separated by various processes, and exhibited apart from each other. Water, also, has been ascertained to be a compound, which may be analyzed or decomposed so as to produce two distinct kinds of gases, which may be separately collected, and when again mixed together in proportions, they may be made to form water by their union.

Other bodies formerly esteemed simple have yielded to the analytical processes of modern chemistry; but there is a certain number of substances which, either in the state in which they are presented to us by nature, or as they are procured in various operations by art, have resisted all attempts at further decomposition, and which, therefore, as before stated, must be regarded as simple substances. Their number is not very great, amounting to about sixty-three, and it is not unlikely that the future researches of chemists may demonstrate some of these bodies to be compounds, as we have the latest example in the discovery of Graham, who converted the hydrogen from its gaseous form into a metal *hydrogenium.* At the same time it is probable that additions may be made to the class of elementary substances in consequence of future discoveries, several of those now admitted into this class having become known to us but very recently.

Some of those elementary bodies are widely and abundantly disposed throughout the three kingdoms of nature, either alone or in a state of composition, while those appear to be of very rare occurrence, or at least, they have hitherto been met with only in small quantities and in a few situations. The whole of the elementary substances may be arranged in two divisions: the first comprehending those which are not of a metallic nature, and those which are regarded as metals, although many exhibit properties differing considerably from those, which are well defined as such, like gold, silver, mercury, iron, lead, &c. The accompanying table shows all the elements. The non-metals are in large capitals, and the metals in small type:

NAME.	DISCOVERER.	Date.	SYMBOL.	AT. WT.	SP. GR.
Aluminium	Wœhler, Germany	1828	Al	27.4	2.6
Antimony	Basil Valentine	1450	Sb	122	6.7
Arsenic	Paracelsus knew it in XVI. century; George Brandt, Sweden.	1733	As	75	3.7
Barium	Sir H. Davy, England	1808	Ba	137	
Bismuth	Agricola	1530	Bi	210	9.7
BORON	Sir H. Davy, England.	1807	B	11	1.47
BROMINE	Ballard, France	1826	Br	80	5.54
Cadmium	Stromeyer	1817	Cd	112	8.6
Caesium	Bunsen	1861	Cs	133	
Calcium	Sir H. Davy	1808	Ca	40	1.58
CARBON	Lavoisier established the diamond as carbon	1775	C	12	3.5
Cerium	Hisinger, Sweden	1804	Ce	92	
CHLORINE	Scheele, Sweden	1774	Cl	35.5	.2454
Chromium	Vauquelin. France	1797	Cr	52.2	
Cobalt	Brandt, Sweden	1733	Co	58.7	7.7
Copper	Known by the ancients.	——	Cu	63.5	8.9
Didymium	Mosander	1843	D	95	
Erbium		——	E	112.6	
FLUORINE	Shecle investigated and discovered, but never separated it	——	F	19	1.060
Glucinum	Oxide, by Vauquelin, 1797; metal by Wœhler	1828	Gl	9.3	
Gold	Known by the ancients	——	Au	197	12.
HYDROGEN	As gas, by Cavendish, England	1766	H	1	.69
Hydrogenium (metallic)	Graham	1869	H		1.708
Indium	Reich found in zinc ore	1861	In	35.91	
IODINE	Courtoise, France	1801	I	127	4.95
Iridium	Tenant	1803	Ir	198	
Iron	Known from early time	——	Fe	56	7.79
Lanthanum	Mosander	1839	La	92	
Lead	Known by the ancients	——	Pb	207	11.4
Lithium	Oxide, by Arfvedson, Sweden, 1818; metal by Brand	1820	Li	7	.59
Mercury	Known to the ancients	——	Hg	200	13.5
Magnesium	Bussy, France	1829	Mg	24	1.74
Manganese	Gahn, Sweden	1774	Mn	55	7.
Molybdenum	Shecle, Sweden	1782	Mo	96	8.6
Nickel	Bergman, Sweden	1775	Ni	58.7	8.2
Niobium	Hatchett	——	Nb	94	
NITROGEN	Dr. Rutherford, Scotland.	1772	N	14	.972
Osmium	Tenant	1803	Os	199.2	21.
OXYGEN	Dr. Priestly, England	1774	O	16	
Palladium	Dr. Wollaston, England	1803	Pa	106.6	11.3
PHOSPHORUS	Brandt, Hamburg	1669	P	31	2.0
Pelopium	H. Rose	1846			
Platinum	Charles Wood, Jamaica	1741	Pt	197.5	21.
Potassium	Sir H. Davy, England	1807	K	39.1	865
Rhodium	Dr. Wollaston, England	1804	Rh	104.4	11.
Rubidium	Bnnsen	1861	Rb	85.4	
Ruthenium	Clauss	——	Ru	104.4	
SELENIUM	Berzelius, Sweden	1818	Se	79.5	4.3
Silver	Known to the ancients	——	Ag	108	10.4
SILICON	Berzelius, Sweden	1824	Si	28	2.49
Sodium	Sir H. Davy	1807	Na	23	.15
Strontium	Sir H. Davy	1808	Sr	87.5	2.53
SULPHUR	Natural product	——	S	32	2.0

NAME.	DISCOVERER.	Date.	SYMBOL.	AT. WT.	SP. GR.
Tantalium (Columbium)	Hatchet and Eckeberge, 1801; reduced by Berzelius	1824	Ta	182	
Tellurium	Klaproth, Berlin	1797	Te	128	6.2
Thallium	Crookes and Lane	1861	Tl	203	
Thorium	Berzelius, Sweden	——	Th	115.7	
Tin	Known by the ancients	——	Sn	118	7.29
Tintanium	Vauquelin	1796	Ti	50	4.3
Tungsten	M. M. D'Elhuyard, Spain	1781	W	184	17.5
Uranium	Klaproth, Berlin	1789	U	120	
Vanadium	Sefstrom, Berzelius, and Del Rio	1830	V	51.3	
Yttrium	Gadolin, Sweden	1794	Y	18.6	
Zinc	Henkel	1721	Zn	65.2	6.9
Zirconium	Berzelius, Sweden	1824	Zr	89.6	4.3

Carbon, one of these elementary bodies, is the most remarkable substance in nature, and enters largely into the composition of most substances belonging to the animal and vegetable kingdom, and forms also the basis of many of the combustible minerals, as bitumen, coal, plumbago, amber. In the form of charcoal, procured by charring or distilling without the access of air, wood, animal, and some other substances, carbon is obtained in a separate state or merely intermixed with small portions of earths or salts. The charcoal used in the various arts and manufactures is commonly prepared on an extensive scale by the imperfect combustion of wood, built up in large piles and covered with turf, or by the distillation of wood in cast-iron cylinders. Lamp-black is also chiefly composed of charcoal, consisting of soot collected from the combustion of the refuse resin obtained in making turpentine. Ivory black is another carbonaceous substance, which results from the burning of bones in close vessels. Coke is chiefly composed of charcoal, arising from the distillation of coal, as in the coal gas manufactories. Pure carbon is, however, represented in the *diamond.* Chemical investigation has proved that the diamond, when exposed to a very high temperature, and especially if confined in oxygen gas, will burn like charcoal and exhibiting the same product. This splendid gem, in its natural state, is composed of octahedral crystals, and Sir Isaac Newton ascertained from observing, that it was possessed of high refractive powers and an inflamable substance. It is brittle, but appears to be harder than any other substance. Hence the powder of the diamond is used for cutting and polishing the hardest gems, and the diamond itself, as the most ornamental article of jewelry. How diamond was formed is a matter of enquiry. It certainly could not have been produced at a high temperature, because when strongly heated, apart of the air or oxygen, the diamond swells up, and is converted into a black mass resembling coke.

Carbon, as commonly procured by distilling wood, is a good conductor of electricity, though a bad conductor of heat. It remains unchanged by air or water at common temperature, but when highly heated readily burns in oxygen gas or common air.

It has the property of destroying the smell and taste of many animal and vegetable substances, and it powerfully resists putrefaction; so that tainted meat, if covered with new burnt charcoal for a few hours, becomes perfectly sweet. The colors of vegetable substances are also effected by charcoal; hence it is sometimes added to port wine for the purpose of giving it a tawny hue. Vinegar boiled with it becomes colorless, and it is largely used in refining sugar, particularly the animal charcoal. Freshly prepared charcoal largely absorbs various gases. This property, however, depends on the texture of the charcoal, and the dïfferent kinds absorb, in various proportions, aqueous vapors contained in the air.

Carbon unites with oxygen to form three or more compounds, an oxide and various acids. The carbonic oxide is a gaseous body, and was discovered by Dr. Priestley, and this is produced from the decomposition of the compounds containing carbonic acid, as by the heating in an iron retort a mixture of chalk and charcoal, or of equal weights of chalk and iron or iron filings. The gas resulting from either of these operations may be collected in a jar inverted and filled with water, and then purified by agitating it with lime water. It is destitute of color and taste and has a disagreeable smell, and is highly injurious to animals, producing giddiness and fainting if respired when mixed with atmospheric airs. We have many instances where many families were found suffocated in the morning, the cause being that they had a coal fire burning, in close apartments, before retiring to bed.

Carbonic acid, or called fixed air.—It is obtained when the carbonic oxide is mixed with half its volume of oxygen, and exposed in a detonating tube to the electric spark, when an explosion takes place, and carbonic acid is formed equal in bulk to the carbonic oxide. It is a compound gas, and is formed both by art and nature in a variety of processes. An abundant production of this gas takes place in the combustion of animal and vegetable substances in general; but the most interesting example of the formation of carbonic acid occurs when the diamond is intensely heated in common air or oxygen gas. This extremely dense and apparently permanent substance under these circumstances becomes wholly converted into carbonic acid, a result which plainly demonstrates it to consist of carbon alone. Carbonic acid, when wanted for the purpose of experiment, may, however, be most readily obtained by decomposing the combinations of this acid with alkalies or earths. Thus chalk or marble, when dropped in small fragments into dilute sulphuric or hydrochloric acids, will give out abundance of this gas, which may be collected over water; they, however, absorb a large portion of it, even at common pressures and temperatures.

Carbonic acid gas is destitute of color or smell, but like other acids, it has a sour taste. It is much heavier than common air, and is uninflammable, extinguishing burning bodies which are plunged into it. Owing to its great specific gravity, it may be poured from one vessel to another, like a liquid, and will remain for some time at the bottom of an open jar without mixing with the atmospheric air above it. It is poisonous to animals, and cannot be breathed without the utmost danger. The famous Poison Valley in the Island of Java, has been visited by travelers, who relate that they took with them two dogs and some fowls to try experiments in the poisonous valley. When arriving at the foot of the mountain, and when within a few yards of the valley, they experienced a strong, nauseous, suffocating smell. The valley is about half a mile in circumference, and a depth of 30–35 feet, flat bottom, and no vegetation, strewed with some large sized stones, and the whole covered with the skeletons of human beings, tigers, pigs, deer, peacocks, and all sorts of birds. Did not perceive any vapors or any opening in the ground, which appeared to be of a hard, sandy substance. They descended, after lighting a cigar, and assisted by a bamboo, within eighteen feet of the bottom, where they did not experience any difficulty in breathing, nor did any offensive smell annoy them. They then fastened a dog to the end of a bamboo, and after the lapse of fourteen seconds he fell on his back; did not move his limbs, but continued to breathe eighteen minutes. Another one was sent in, and he fell in ten minutes on his face, and continued to breathe for seven minutes longer. A fowl was then tried, which died in one minute and a half. On the opposite side, near a large stone, was the skeleton of a human being, who must have perished on his back with the right hand under his head.

It is for this reason that the proportion of this gas contained in the air is so very small. Were this proportion much greater than it is, animals, as they are now constituted, could not breathe the air without much injury. On the other hand, that growing plants may be able to obtain a sufficient large and rapid supply of carbonic acid from a gaseous mixture which contains so little, they are made to hang out their many waving leaves into the atmosphere. Over the surface of these leaves are sprinkled countless pores or mouths, which are continually employed in separating and drinking in carbonic acid gas. The millions of leaves which a single tree spreads out, and the constant renewal of the morning air in which they are suspended, enables the living plant to draw an abundant supply for all its wants from an atmosphere already adjusted to the constitution of living animals.

(A common lilac tree, with a million of leaves, has about 400,000,000 of pores or mouths at work sucking in carbonic acid; and on a single oak tree as many as 7,000,000 of leaves have been counted.)

This constant action of the leaves of plants is one of the natural agencies by which the proportion of carbonic acid in the lower regions of the atmosphere is rendered less than it is in the higher regions.

As water readily takes up this gas, so it may be made by pressure to absorb a large quantity of it, so is the soda water of the shops, and such is also found in the bowels of the earth, as the mineral springs of all countries which contain also small quantities of saline matters.

Carbonic acid has been reduced from a state of gas into that of liquid by compression, Faraday obtained it in this form, by disengaging it from carbonate of ammonia by means of sulphuric acid in a glass tube hermetically sealed, one end of which was immersed in a freezing mixture, and the pressure under which the fluid was formed was estimated to be equal to 36 atmospheres.

Carbonic acid may be decomposed by the action of the metal potassium, which having a stronger attraction for oxygen than the carbon has, when heated in carbonic acid, it forms with great splendor, charcoal is deposited and an oxide of potassium is formed. It may also be decomposed by hydrogen and other bodies.

It is one-half heavier than common air. A constituent of our atmosphere, which is known to consist, in 100 gallons, of 79 gallons of nitrogen and 21 gallons of oxygen, while the carbonic acid is in very small proportion.

At ordinary elevations, there are only about two gallons of carbonic acid gas in 5,000 gallons of air, or 1-2500 part of the whole. It increases, however, as we ascend, so that at heights of 8,000 or 10,000 feet, the proportion of carbonic acid is nearly doubled. Even this increased quantity is very small, and yet its presence is essential to the existence of vegetable life on the surface of the earth. This dependance appears more striking the more precise our ideas become as to the absolute quantity of the carbonic acid which the entire air contains. The whole weight of the atmosphere is about fifteen pounds to the square inch, and at this the carbonic forms somewhat less than 120 grains, containing about 33 grains of carbon. Notwithstanding plants are continually sucking in this gas by their leaves, and the operation goes on so rapidly, that were the entire surface of the earth dry land, and under cultivation, crops as we generally reap from it, would contract and fix the whole of the carbon in the form of vegetable matters in the short space of twenty-two years. Were this to happen, vegetation would cease. Such a catastrophe is prevented by the constant restoration of carbonic acid to the air through the increasing operation of preservation causes, which may be summed up under the following heads:

1. The trees of the forest yearly shed their leaves, and, in some countries, their bark. Through the influence of the weather, these waste portions decay and disappear, restoring again to the atmosphere a portion of the same carbon which the living tree had previously detracted from it during the period of their growth. The yearly ripening herbage, also, and every plant that naturally withers on plain or hill, the grass of the burning prairie, and the timber of inflamed forests, with all that man consumes for fuel and burns for other uses, every form of vegetable matter, in short, when exposed to the action of air or fire, returns more or less quickly to the state of carbonic acid, and disappears in the invisible atmosphere. Thus what is yearly withdrawn from the air by living plants is so far restored again by those which naturally perish, or which are destroyed by the intervention of man.

2. But man himself and other animals assist in the same chemical conversion. They consume vegetable food with the same final result as when it perishes by natural decay or is destroyed by the agency of fire. It is conveyed into the stomach in the form in which the plant yields it. The green herb, the perfect seed, and the ripe fruit are eaten and digested. Then

forthwith they are breathed out again from the lungs and skin in the form of carbonic acid and water. Let us follow the operation more closely.

The leaf of the living plant sucks in carbonic acid from the air, and gives off the oxygen contained in this gas. It retains only the carbon. The roots drink in water from the soil, and out of this carbon and water, the plant forms starch, sugar, and other substances. The animal introduces this starch sugar into its stomach, and draws in oxygen from the atmosphere by its lungs. With these materials it undoes the previous labor of the living plant, delivering back again from the lungs and the skin both the starch and the oxygen in the form of carbonic acid and water. The circle begins with carbonic acid and water, and ends with the same substances, the same materials. The same carbon, for example, circulates over and over again, now floating in the invisible air, now forming the substance of the growing plant, now of the moving animal, and now again dissolving into the air, ready to begin anew the same endless revolution. It forms part of a vegetable to-day, it may be built into the body of a man to-morrow, and a week hence it may have passed through another plant into another animal. What is mine this week is yours the next. There is, in truth, no private property in ever-moving matters.

3. Yet all the carbonic acid which is removed from

the air by the agency of plants is not immediately restored by the circulation above described. Two larger wheels revolve to make up the deficiency.

4. It has been shown that when plants die and decay, are burned in the air, or are eaten by animals, the carbon they contain is delivered back again to the atmosphere in the form of carbonic acid. But all the plants produced yearly over the whole earth are not so resolved into gaseous substances in any given time. In all parts of the world, and during all time, some portions of vegetable matter have escaped this total destruction, and have been buried beneath the surface of the earth to be preserved in the solid form for an indefinite period. With such comparatively indestructible forms of vegetable matters we are familiar, in the peat bogs of Scotland and Ireland, sometimes from 50 to 100 feet deep, and in the submarine forests which are seen in so many parts of our inland shores. We are still better acquainted with them, however, in the vast deposits of coal which a kind Providence long ago brought together and covered up. What is and has been thus collected and gradually buried would necessarily cause a constant diminution in the small quantity of carbonic acid contained in the air were there no natural means in operation for making up the yearly loss. The means we are most familiar with for repairing this loss are those which man himself brings into operation. At

a certain period in his history, half-civilized man discovered the use of coal. At a more advanced period, he found out how to dig deep and hollow out mines in search of it; and at a still later period, how to employ it for a thousand beneficial purposes. In burning coal, we cause its carbon to unite with the oxygen of the air, and to disappear in the state of carbonic acid.

We restore it to the atmosphere again in the state in which it existed there, perhaps, a million of years ago, when it was sucked in by the growing plants, and, in the form of vegetable matter, afterwards buried beneath the earth's surface. In raising and consuming coal, therefore, we are, to a certain extent, undoing and counteracting the yearly lessening of the carbon in the air, which appears to come from the yearly covering up of a portion of vegetable matter. The 200,000,000 tons of coal which are now yearly consumed throughout the globe, produce about 600,000,000 of tons of carbonic acid. How far this quantity serves to compensate for what is constantly buried up again, it is impossible to estimate. It must be acknowledged, however, that the coal fires we burn are an important subsidiary agent in promoting the circulation of carbon on the globe.

5. Again, within the bosom of the great seas tiny insects are at work, upon which nature has imposed, in addition to the search for food and the care of

their offspring, the perpetual labor of building new houses. The common shell-fish of our coasts toil continually for defence as well as for shelter, repairing, enlarging and renewing their own dwelling places; and as they die, each drops its shell as a feeble contribution to the beds of shelly limestone, which are everywhere forming at the bottom of our deep seas. In more southern waters, again, still humbler insects build up massive coral walls, thousands of miles in extent, which now skirting along coast lines, and now encircling solitary islands, bid defiance to the angriest storms. And then, too, as they die, generation after generation, leave in rocky beds of coralline limestone an imperishable memorial of their exhaustless labors. These rocks contain, chained down in a seemingly everlasting imprisonment, two-fifths of their weight of carbonic acid. This has been all withdrawn, either directly or indirectly, from the atmosphere, and thus, through the rock, forming living things it contains, the sea must ever be drinking in and storing up the carbonic acid of the air.

The same process has been going on almost continuously since the world began. Vast coral reefs lie buried beneath our beds of coal and mountains of thick ribbed shelly limestone have been lifted from ancient seas before these other reefs were formed. The labours of marine animals, therefore, like the burying of vegetable matter must throughout all time have been causing a daily lessening of the absolute quantity of carbonic acid in the atmosphere, which some other natural operation has meanwhile been making compensation for this constant removal. But the earth herself breathes for this purpose. From cracks and fissures, which occur in vast numbers over the surface of the earth, carbonic acid issues in large quantities, sometimes alone and sometimes along with springing waters, and daily mingles itself with the ambient air. It sparkles in the springs of Carlsbad and Selzer, rushes as if from subterranean bellows on the table land of Paderborn, astonishes travellers in the Grotto del cane, interests the geologist in the caves of Pyrmont and among the old caves of the Eifel and is terrible to man and beast in the fatal "Valley of Death", the most wonderful of the wonders of Java, and besides, it doubtless issues still more abundantly from the unknown bottom of the expanded waters which occupy so large a proportion of the surface of the globe. From these many sources, continually flowing into the sea, carbonic acid is and has been daily supplied in place of that, which is daily withdrawn to be buried in the solid limestones of the globe. Did we know after what lapse of time the earth would again breathe out what is thus daily entombed, we should be able to express in words how long this slovely revolving secular wheel requires fully to perform one of its immense gyrations.

Carbonic acid gas rises from the earth in an elastic form, or assumes many successive varieties of plant and animal forms, is finally buried in the earth again in a state of blackened fossil plants or beds of solid limestone.

Carbonic acid, as has already been stated, is very plentifully disengaged from springs in almost all countries. (The writer drank, in California, in a fissure of the celebrated marble quarry at Suisan City, 1,000 feet above the level, ten cups of water, in which the carbonic acid gas was so abundant and free that the water was unable to take up any more.) It is, however, particularly abundant near active or extinct volcanoes. This elastic fluid has the property of decomposing many of the hardest rocks with which it comes in contact, particularly that numerous class in the composition of which felspar is an ingredient. It renders the oxide of iron soluble in water, and contributes to the solution of calcareous matter. In volcanic districts these gaseous emanations are not confined to springs, but rise up in the state of pure gas from the soil in various places, as already observed in the Grotto del Cane, near Naples, and the prodigious quantities now annually disengaging from many parts of the Limagna d'Auvergne, where it appears to have been developed in equal quantity from time immemorial. As the acid is invisible, it is not observed except an excavation be made, wherein it immediately accumulates, so that it will extinguish a candle. There are some springs in this district where the water is seen bubbling and boiling up with much noise in consequence of the abundant disengagement of this gas. The whole vegetation is affected, and many trees, such as walnut, flourish more luxuriantly than they would otherwise do in the same soil and climate, the leaves no doubt absorbing the carbonic acid. It is found in springs rising through the granite near Claremont, as well as in the tertiary limestone of the Limagne.

Near Claremont, a rock belonging to the gneiss formation in which lead mines are worked, has been found to be quite saturated with carbonic acid gas, which is constantly disengaged. The carbonates of iron, lime and manganese are so dissolved that the rock is rendered soft and the quartz alone remains unattacked. Not far off is the small volcanic cone of Chaluzet, which once broke up through the gneiss and sent forth a lava stream.

The effect of carbonic acid as a chemical agent, both as commonly present in atmospheric air and as more abundantly occurring in such localities as those above described, must depend on the nature of the rocks and other bodies with which it may come in contact. It may thus cause the decomposition of granite, gneiss, and other feldpathic and micaceous substances by combining with the potash, soda and lithia which enter into their constitution. On the contrary, when it encounters lime or magnesia it may contribute to the production of new rocks.

The disintegration of granite is a striking feature of large districts in Auvergne, especially in the neighborhood of Claremont. Dolomieu called this decay "la malady du granite," and the rock may with propriety be said to have the rot, for it crumbles to pieces in the hand. The phonomenon may, without doubt, be ascribed to the continual disengagement of carbonic acid gas from numerous fissures. The chemical action of carbonic acid, as it exists in the usual state of the atmosphere near the earth's surface, though much more gradual, and, therefore, less noticed than were it copiously evolved from the water or soil as in volcanic countries, is yet sufficiently powerful to produce a manifest effect on the structure of large masses of granite and rocks of analogous composition. In the western parts of Great Britain, where primitive formations prevail, granite masses frequently occur, which, from their peculiar forms, received the celto cymric appellations af lagon, talmon and kistoaers, and were by the antiquarians long regarded as works of art of Druidical origin; but there rocking stones, rock basins, cheese-rings, and altars are now generally admitted to be blocks of granite which have acquired their respective forms in consequence of superficial decomposition or disintegration. Devonshire is the locality for these odd figures, which, Dela Beche remarked, looked more like the remains of some huge building or battlement than the effect of cleavage and decomposition, which it is.

Granite is not generally regarded as a stratified rock, like gneiss and mica slate; but it is a fact well known to the workmen who are employed in quarrying and cutting it, that it has what they term a *grain*, or that it will split in one or more directions more easily than in others. This, doubtless, is owing to the arrangement of the mineral bodies of which it is composed, and especially the feldspar, the decomposition of which must essentially aid the process of disintegration, and determine in a great degree the direction in which it takes place.

The protracted action of atmospheric air, and also of water, appear to act jointly as a destructive and formative or constructive power; likewise the more rapid and violent operation of streams and torrents assist in dissolving and wearing away solid surfaces in the situation, and depositing beds of transported matter in another; and the detritus of rocks and of organic bodies have been removed by the agency of water from the higher parts of a country, and serving to form new tracts of land. Such catastrophas are common to most countries, and if a rock so detached or weathered be limestone, there is not unfrequently a reconsolidation of the parts by means of calcareous matter deposited by the water that percolates through the fragments, and which dissolves a portion of them. At Nice, the fractured surface thus reunited is so hard, that if it occur on a line of road, it must be blasted by gunpowder for removal. The same reconsolidation gives ample example upon the limestone hills of Jamaica, and at the cliffs of Milk river at that place.

The feldpar contained in granite is often easily decomposed, and when this is effected, the surface frequently presents a quartzose gravel. D'Aubuisson mentions that in a hollow way which had been only six years blasted through granite, the rock was entirely decomposed to the depth of three inches, and the granite country of Auvergne and Eastern Pyrenees, felspar is frequently so much decomposed that the traveller may imagine himself on large tracts of gravel. The most striking example of the detrition of solid rock by the agency of water is exhibited at the Falls of Niagara. The water at these falls is divided by a small island, which separates the river into two cataracts, one of which is 600 yards, and the other 750 yards wide. The height of the fall is from 150 to 160 feet. It is estimated that 670,000 tons of water are dashed with inconceivable force against the bottom, wearing down the adjacent rocks. Since the banks of the cataract were inhabited by Europeans, they have observed that it is progressively shortening the distance of the falls from Lake Erie. When it has worn down the intervening calcareous rocks, the upper lake will become dry land, and form one extensive plain or valley, surrounded by rising ground, and watered by a river or small lake, which will occupy the lowest part. In this plain, future geologists may trace successive strata of fresh water formation covering the subjacent ancient limestone. The gradual deposition of minute earthy particles, or the more rapid subsidence of mud from sudden inundations, will form distinct beds in which will be found the remains of fresh water fish, vegetables and quadrupeds. Prof. Henry says: "The descent of the country from Lake Erie to Ontario is principally by a step, not at the falls, but at Lewistown, several miles below. In reviewing the position of the Falls, and the features of the country around, it is impossible not to be impressed with the idea that this great natural race-way has been formed by the continued action of the irresistable current of the Niagara, and that the falls, beginning at Lewiston, have, in the course of ages, worn back the rocky strata to their present site. The deep chasm through which the Niagara passes below the falls is nearly a mile wide, with almost perfect mutual sides. The bed of the river below the falls is strewed with huge fragments of rocks hurled down by the cataract.

The retrogration of the waterfall, owing to the destruction of the surface over which it takes its course, is said to have amounted to nearly fifty yards during the last forty years. If the excavation always proceeded at the same rate, it must have required about 10,000 years for the formation of the whole ravine; and it would take up more than 30,000 years from the present time before the channel would be worn backward to Lake Erie; but if it retroceded 1 inch a year, which would make 8¾ feet a century, 380,000 years."

The great gorge of the Colorado, which is 300 miles long and 3–6000 feet deep, and hundreds of feet of the depth being much of the distance through granite, has probably taken the same length of time as the Niagara retrocession, and at the close of the mesozoic period or reptilian age, which was the era of the culmination and incipient decline of two great types in the animal kingdom, the reptilian and molluscan, and remarkable as the era of the first mamals, birds and fishes.

Before proceeding further of the functions of carbonic acid in the inorganic world, let us make a few remarks respecting the distinctions between animals and plants, in order to show how near the organic bodies are related to the inorganic, and that carbonic acid may probably have an important agency in this all important work. Since the discovery that the spores (or seed cells) of some algae have locomotion like animalcules, and that there are unicellular locomotive plants (the diatoms, etc.) Some have thought that the two kingdoms of life were blended together through their inferior species. But the fact is that they are diverse throughout; the opposite but mutually dependent sides or parts of one system of life. The following are some of their distinctions:

1. Plants excrete oxygen, a gas essential to animal life; animals excrete, in respiration, carbonic acid, a gas essential to vegetable life.

2. Plants take inorganic material as food and turn it into organic; animals take this organic material thus prepared (plants) or other organic materials made from it (animals), finding no nutriment in inorganic matter.

3. Plants passing from the unicellular state by growth lose in power, becoming usually fixed; animals, in the same change or in development from a germ, increase in power, augmenting in muscular force; and also in the case of species above the lowest grade in nervous force, like an ant is a one ant-power, a horse a one horse-power, whence an animal is a self-propogating piece of enginery, of various power, according to the species.

4. The vegetable kingdom is a provision for the storing away or magazining of force for the animal kingdom. This force is acquired through the sun's

influence or forces acting on the plant, and so promoting growth. That of starch, vegetable fibre and sugar is a state of concentrated or accumulated force, and there is also a magazining of force in a still more concentrated or condensed state. There are thus five states of stored force in nature—three in inorganic, the *solid*, *liquid* and *gaseous*; and two in organic, the *vegetable* and *animal*. The animal type differs from the vegetable, (though not all animals from plants,) in this, that while the latter has the superior and inferior polarity of single growth—the stem growing upward and the root downward—the former has the anterior and posterior or cephalic and anticephalic polarity connected with a well developed nervous system. The radiates among animals are allied in this respect to plants, being animal representatives of the vegetable radiate type; and this is the ground of the subdivision of the animal kingdom.

The following are the two grand subdivisions in groups in nature, the first mentioned being the inferior, the other the superior. The latter is also the more typical group, or that in which the idea of the type is more fully represented:

a. Life in general—1, vegetable; 2, animal kingdom.

b. Vegetable kingdom—1, cryptogams or flowerless plants; 2, phanerogams or flowering plants.

c. Animal kingdom—1, the flower-like type, including radiates; 2, the true animal type or cephalized species, that is, those having a head or anterior and posterior polarity with bilateral symmetry, including mollosks, articulates and vertebrates.

d. Sub-kingdom of mollusks—1, the flower-like type, including the bryozoans closely like flowers, the brachiopods generally attached by stem or pedicles, and ascidians, also often attached; 2, the true molluscan type, including acephals, cephalates and cephalopods.

e. Sub-kingdom of vertebrates—1, water vertebrates, including fishes; 2, land vertebrates, including reptiles, birds and animals.

f. Class of crustaceons—1, entomostroceons; 2, malacostroceons.

g. Class of reptiles—1, amphibious; 2, true reptiles.

h. Class of mammals—1, marsupials or semioviparans; 2, nonmarsuphial or typical mammals.

The great question of the day is, where can we draw a strait line between organic and inorganic bodies, for if we ever succeed to produce these organic matters, fat, starch, or fibrine from inorganic substances, the problem would be solved.

From a lecture by Dr. Loew, of the College of the City of New York, referring to this great difficulty, and to the important place carbonic acid assumes in the organisms, the following extract must be highly interesting:

"Confessing that we cannot state positively how the first organic being was formed from inorganic matter, nevertheless we must conclude from consequence that it was formed by *natural forces.* When we see that the vegetable can produce organic matter from inorganic substance; when we see the animal being taking this organic matter of the vegetable up, and during the process of its life connecting in the very same inorganic combinations from which the vegetable builds up its body; when we see this infinite construction, destruction, and reconstruction, we remark, as one of the first conditions, that the vegetable world existed previous to the animal world. Hence arises the question, How was the first organized vegetable world formed? There are possibilities directly from inorganic matter or from previously formed organic matter. Above all, let me ask here attention to the difference between the words 'organic' and 'organized.' The chief part of an organism consists of carbon, hydrogen, oxygen, and nitrogen; water and mineral salts form the remainder. These four most important elements combine in an infinite number of proportions, and these combinations are of such an extremely complex order as are never to be found in the inorganic world. An organic combination is the first condition for an organized body, and organic combinations form the step from inorganic matter to organized beings. Two possibilities may have existed: either organic matter was formed from inorganic by natural forces, previous to the formation of the first cell, or in the other case, the cell, during its formation, formed also the organic combination necessary for its life from mineral salts, carbonic acid, and water. In the first case, the spontaneous generation has the same plasmogony; in the second, autogeny. Theodore Saussure was the first who stated the fact that the carbonic compounds in the vegetables derive their carbon from the carbonic acid contained in the air, and their hydrogen from the matter. Liebig then stated that the nitrogen of the plants comes from the ammonia contained in the soil and in the atmosphere. We see, therefore, the body of the vegetable, no matter how complicated its structure and its organization may be, is built up chiefly from carbonic acid and water—three inorganic combinations of a simple constitution. By a process of reduction, complicated organic radicals are formed, combining themselves to numerous bodies. Among these are sugar, fat and albumen. As organic chemistry must be considered as an offspring of this century, it was, of course, considering its tender age, not possible until a few decades ago to prepare an organic body synthetically from its elements; therefore the hypothesis came in vogue that there exists an especial power, the *vital* power. It was long considered as an *impossibility* to prepare artificially, from inorganic matter, such combinations as may occur in the vegetable and animal body. The death-knell of the dogma of vital force was tolled in the year 1828. In this year the German chemist, Wœhler, prepared, synthetically, the first organic combination. Wœhler, in attempting to prepare eganate of ammonia, got, in evaporating a mixture of eganate of potassium and sulphate of ammonia, a body of an entirely different character to the salt he was seeking for. The atoms arranged themselves in another form, and this body presented itself exactly the same as that which is found in animal urine, named urea. This was the first step on a new road, and so rapid was the progress of organic chemistry, so rapidly was it advancing, that now we can count them by the hundreds. Dr. Loew then gave instances of some of these combinations. Thus hydrogen and carbon, united in the voltaic curve, produce the hydrocarbon acetyline—the root of numerous organic combinations—until, with hydrogen, it produces olefiant gas; the cyanide of this gas, boiled with potassa, gives succinic acid; this treated with brimstone, and then with potassa, gives malic and tartaric acid; malic acid heated gives fumaric. But malic, tartaric and fumaric are organic acids occurring in a great number of vegetables; they can thus be artificially prepared from the elements. From acetyline benzol may be produced; from benzol, benzoic acid, the root of a great number of organic combinations, which can all be artificially prepared from benzoic acid, as oil of bitter almonds, gallic acid, hypuric acid, &c. Sulphur and carbon may be united; the bisulphide of carbon, treated with iron filings and water, gives formic acid, which occurs in the ant and in the nettle; formic acid, treated with potassa, yields oxalic acid, which is found in many plants. By treating oxalic ether with sodium amalgam, we obtain disoxalic and malic acid and a kind of sugar, all organic substances. Dr. Loew added to these instances numerous others, in which organic substances, such as fat, sugar, and alcohol, were formed by chemical processes from inorganic bodies. He then continued: These organic bodies which I have mentioned here form only a small part of the numerous organic combinations which can be prepared artificially from the elements in the laboratory; but, simultaneously, I must confess that there is much more to do than has been done. For example, gum-starch, quinine, strychnine, cannot yet be artificially prepared, but there is not the slightest doubt that chemistry will solve all these problems in coming time. Further, it must be mentioned that the ways of the chemist in the laboratories are different from the ways of nature. The chemist has strong acids at his disposition; not so with nature, for she works only with the reducing power of the sunlight. That cannot as yet be imitated, although we can often reach the same result in a laboratory. The history of chemistry, however, bids us to hope that this problem will yet be solved. When this great problem finds its solution, we will obtain, probably some light, as to how, from carbonic acid, water and ammonia, organic matter was formed hundreds of thousands of years ago, when the first cell became endowed with life. In every case we had different conditions in those infinitely remote ages—conditions more favorable for spontaneous generation, as there was a very warm and wet atmosphere rich in carbonic acid, with a mineral surface more liable to change, and different in appearance to what it is now-a-days. Therefore, it is probable that those first cells had quite a different character, as we imagine very liable to change and to different developments. Many experiments have been made to produce, artificially, cells, infusories, or fungi, and this question seems to be satisfactorily solved."

In regard to the chemical relations of our globe, Dr. T. Sterry Hunt, in his lecture on primeval chemistry, throws much light on the functions of carbonic acid exercised upon our globe, and cannot do better than to make an extract of his remarks:

After explaining the astronomical parts and solar system, he says, in reference to the history of this earth, that there were no chemists who had an eye, except the eye of its great All Seeing One, to investigate the marvellous phenomena; but the chemist of the present day has to look to the rocks, water and air, and to their origin.

Our earth was once a luminous mass of vapor, passing through a stage in which it was self-luminous like the sun, until it finally became cool to such a point that it liquified and became at last solid. The next question is, did the earth become solid first at the circumference or at the center? This is important from more than one point of view, and has been investigated by astronomers, physicists, and chemists, and it seems pretty clearly proved that the earth, if not solid to the center, must have a crust several hundred miles in thickness. And it is probable that if the cooling commenced at the center, that at least the surface would be covered with a thin layer of liquid matter, which, on cooling, would give an uneven surface to the primeval globe. So far as the chemistry of our planet is concerned, we have to deal only with this outer layer, all the various elements of which must have existed either in that crust or in the atmosphere which then snrrounded it. We form a good idea of this primeval crust, if we suppose the elements, rocks, air and ocean to be brought together at the intense heat which then existed. Under such conditions the lime, magnesia, alkalies—would all unite into combination with silica and alumina, while the atmosphere would contain chlorine, sulphur, carbon and hydrogen, together with oxygen and nitrogen. This would form on the one hand a slag-like siliceous mass, and on the other hand an atmosphere charged with acid vapors, yielding all the chlorine, sulphur and carbon in the form of acids, and the water in the form of steam mixed with nitrogen and oxygen. The weight of the atmosphere would be immense, and under its pressure water and the less volatile acids would be liquified at the high temperature, and these acid waters would collect in the depressions of the earth's crust, where they would immediately decompose the silicates, separating the silica and forming sulphates and chlorates of the alkalies—lime and magnesia. This solution would form first, sea water, and the action would continue till these affinities were satisfied. Then commenced a new chemical process, the action of air and water upon the exposed portions of the earth's crust, converting the silica into clay, with carbonates of lime, magnesia, and soda through the action of the carbonic acid of the atmosphere. The soda carried by rains to the sea, decomposes the lime salts, forming carbonate of lime and sea salt. The process is still going on, though more slowly, from the small amount of carbonic acid in the air, and causing the decay in the hearts of granite rocks. We have thus explained the generation of silica or quartz of clay and of limestones, the principle elements of sedimentary rocks. Every clod of clay represents granite rocks decomposed, and an amount of limestone and sea salt, formed from the waters of the ocean. In this way the air was freed from carbonic acid, and fitted for the support of animal life. Besides this, the vegetation removed large portions of carbonic acid, replacing it by oxygen, and the formation of limestone directly diverted still greater amounts of carbonic acid, whose presence must have rendered the early atmosphere unfit for the higher forms of life. The presence of carbonic acid in the early atmosphere serves to explain the higher temperature then prevailing, which permitted the growth of tropical plants within polar circles. We know that a portion of carbonic acid, such as then existed in the air, while it would not prevent the passage of the sun's rays would impede the radiation of obscure heat from the earth's surface, and thus tend to keep up a summer temperature. The effect of this carbonic acid would be like the glass of an orchard-house in preventing the escape of heat. Thus carbonic acid exerted also an important part in many other chemical processes then active at the earth's surface. Besides deposits formed by chemical processes, mechanical operations were forming at the earth's surface a great amount of sandy and clayey rocks, which make up the bulk of the stratified forms. Although the interior of the earth has been regarded as solid, it is notwithstanding doubtless intensely heated, and thus is explained the increase of temperature as we go below the surface. The cooling of this center, once rapid, is now very slow indeed from the thickness of the overlying sediment. The effect of this heat upon the deeply buried sediment has been to crystallize them, and convert them into metamorphic rocks. To this class belongs granite, once looked upon as a primitive rock. We have now evidence that granite is in all cases a secondary rock, derived from sediments crystallized through the agency of water and heat. In the quartz of granite are often found small cavities, partly filled with water, which are so many small thermometers showing the temperature at which the granite was crystallized. Pressure, which increases the melting point of rock when exposed to fires, greatly favors the dissolving power of heated water, so that we may snppose that the lowest strata of sediment and often adjacent portions of the primal nucleus being permeated with water, under great heat and pressure, became softened and yielding. From this softened zone came all eruptive rocks, and in it are to be found the causes of volcanoes whose various products are generated by the action of heat upon the varied elements of deeply buried sedementary strata. The theory which ascribes volcanic products to the supposed uncooled liquid center, fails entirely to account for the great diversity in composition of these products, all of which, wherever found, are represented in rocks of aqueous origin. The distribution of modern vocanoes shows them to be intimately connected with comparatively recent accumulations of sedimentary rocks; entire absence of volcanic phenomena over the eastern part of this continent is thus explained.

II. *On Limestones: their Origin and Functions.*

The early geologists were impressed with the theory of the origin of all limestones; that is, was due to organized beings or substances, and the reason advanced by them was because the quantity of limestone in the primary strata bore a much smaller proportion to the silicious and argillaceous rock in the secondary, and because testaceous animals were so rarely found in the ancient ocean, and furthermore that the quantity of calvareous earth deposited in the form of mud or stone is always increasing, and that as the secondary series far exceeds the primary in this respect, so a third series may hereafter arise from the depth of the sea, which will exceed the last in the proportion of its calcaceous strata. Some conclusions were drawn from this assertion that lime may probably be an animal product combined by the powers of vitality from some simple elements, and that every particle of lime that now enters into the crust of the globe, may possibly in its turn have been subservient to the purposes of life by entering into the composition of organized bodies.

Lime is contained in the ocean and is plentifully secreted by the testacea and corals of the Pacific, and must have derived either from springs rising up in the bed of the ocean or from rivers fed by calcareous springs or impregnated with lime, derived from disintegrated rocks, both volcanic and hypogene and the greater proportion of limestone in the more modern formations, or compared to the most ancient may be explained, for springs in general hold no argillaceous and but a small quantity of siliceous matter in solution, but they are continually substracting calcareous matter from the inferior rocks. The constant transfer therefore of carbonate of lime from the lower or older portions of the earths' crust to the surface must cause at all periods and throughout an indefinite succession of geological epochs a preponderance of calcareous matter in the newer or contrasted with the older formations. It has been urged that we discover in the ancient rocks the signs of an epoch, when the planet was uninhabited and when its surface was in a chaotic condition. The opinion however that the oldest of the rocks now visible may be the last monuments of an antecedent era in which living beings may already have peopled the land and water, has been declared to be equivalent to the assumption that there never was a beginning to the present order of things, no argument can be drawn from premises in favor of the infinity of the space that has been filled with worlds, and if the material universe has any limits, it then follows, that it must occupy a minute and infinitessimal point in infinite space. So if in tracing back the earth's history, we arrive at the monuments of events which may have happened millions of ages before our time, and if we still find no decided evidence of a commencement, yet the arguments from analogy in support of the probability of a beginning remains unshaken, and if the past elevation of the earth be finite, then the aggregate of geological epochs, however numerous, must constitute a mere movement of the past, a mere infinitesimaal portion of eternity!

We know that it is not only the present condition of the globe, which has been suited to the accommodation of myriads of living creatures, but that many former states also have been adapted to the organization and habits of prior races of beings. The disposition of the seas, continents and islands, and the climates, have varied, the species likewise have been changed; yet they have all been so modelled on types analogous to those of existing plants and animals, as to indicate throughout a perfect harmony of design and unity of purpose. To assume that the evidence of the beginning or end of so vast a scheme lies within the reach of our philosophical inquiries, or even of our speculations, appears to be inconsistent with a just estimate of the relations which subsist between the finite powers of man and the attributes of an infinite and eternal being. The peculiar position of lime in the system of nature, is that of a medium between the organic and inorganic world. Carbonate of lime is soluble in water which holds a little carbonic acid in solution, and is found in river, marine and well waters. It is made into shells, corals, and partly into bone, by animals, and then turned over to the inorganic world to make rocks. Lime is therefore the medium by which organic beings aid in the inorganic progress of the globe; for the greater part of limestones have been made through the agency of life, either vegetable or animal. Lime, which is the oxide of the metal calcium, is commonly called quicklime, forms compounds with silica or silicate, with carbonic acid, the carbonate or carbonate of lime, which is the material of limestones, with sulphuric acid the sulphate of lime or gypsum.

Lime also unites with phosphoric acid, forming phosphate of lime, the essential material of bones, a constituent also of other animal tissues. Like the carbonate, this phosphate is afterwards contributed to the rock material of the globe, and is one source of mineral phosphates. Calcium is one of the nine elements which are the prominent constituents of rocks, viz., oxygen, silicon, aluminium, magnesium, calcium, potassium, sodium, and carbon, making up 977-1000 of the whole crust. The limestones of the siluric and later ages have nearly all been made through the wear and accumulation of shells, crinoids and corals, or the calcareous relics of whatever life occupied the seas. The great limestone formations of existing coral seas are modern examples of the process. It has been the subject of curious speculation whence the coral polypifers and testaceous mollusca can obtain the vast quantities of carbonate of lime which they secrete to form the envelopes by which they are preserved. It has been considered more than probable that they have the extraordinary faculty of producing lime from simple elements. Some seem disposed to impute its origin in the same manner to the influence of vital energy in combining elementary bodies, and it follows that the quantity of lime on the surface of the earth must be progressively increasing, unless it be supposed that other natural processes are regularly taking place for the decomposition of calcareous earth, or rather of the metallic base calcium.

Mr. Lyell, however, sees no reason for supposing that the lime now on the surface or in the crust of the earth may not, as the silex and aluminum, or any other mineral substance, have existed before the first organic beings were created, if it be assumed that the arrangement of the inorganic materials of our planet proceeded in the order of time, the introduction of the first organic inhabitants, and adds, in reference to the abundance of carbonate of lime furnished by springs which rise through granite, that if the carbonate of lime, secreted by the testaceous corals of the Pacific, be chiefly derived from below, and if it be a very general effect of the action of subterranean heat to subtract calcareous matters from the inferior rocks, and to cause it to ascend to the surface, no argument can be derived in favor of the unaggressive increase of limestone from the magnitude of coral reefs, or the greater proportion of calcareous strata in the more modern formations. A constant transfer of carbonate of lime from the inferior parts of the earth's crust to its surface, would cause throughout all future time, and for an indefinite succession of geological epochs, a preponderance of calcareous matter in the newer as contrasted with the older formations.

The rock, formed under the surface of the sea originated either from depositions or from chemical precipitation; those of the former class are numerous, including most of the stratified rocks which inclose sea-shells, fragments of corals, and other exuviæ of bones of marine animals. Among those of the better class, some geologists have reckoned even granite, and Deluc states in that respect that the strata of granite were evidently produced by chemical decompositions from a liquid, and form the most ancient monument of the action of physical causes on our globe; however the origin of granite as well as that of all other unstratified rocks, has been ascribed mostly to igneous fusion and consolidation. Most of the calcareous rocks containing marine shells must have been produced under the influence of chemical affinity, and of this nature are the formations which are occasionally observed to take place on the sea coasts. Collections of perfect and broken shells and corals are sometimes consolidated by the precipitation of calcareous and ferruginous matter, constituting banks or beds of considerable extent. Such masses, containing shells, occur in various parts of the shores of Great Britain. Similar conglomerates, including both shells and corals, are not uncommon around some of the islands in the West Indies. At Guadaloupe human bones have been found imbedded in a rock of this kind, whence were obtained two imperfect human skeletons, one preserved at the British Museum, and the other in the Paris Museum, and from the occurrence of these bones, and other circumstances, may be inferred the comparatively modern origin of the rock in question. The Florida Keys abound in deposits of shells in various states of disintegration and subsequent union by cement.

Among the marine formations there are few more curious or interesting than coral reefs and islands, which to a certain extent are constructed by different kinds of polypiferous zoophytes ; and they are very numerous, mostly belonging to the genera Meandrina, Coryaphillia, and Astrea, particularly the latter. All of them are minute animals, for which the coral tubes serve as habitations. It has been supposed that the coral rocks descend in perpendicular columns to the bed of the ocean, and cover millions of acres of the Pacific. So great is the extent, that the inhabitants of Disappointment Islands and those of Duff's Group pay visits to each other by passing over long lines of reefs from island to island, a distance of six hundred miles.

Many islands which were visited by Capt. Kotzebue have several groups of coral islands arranged in a circular or oval form, with openings among them which afforded access to the interior basin. These islands seemed to be only the upper portion of ridges of unequal height, on the inside of which, toward the basin or lagoon, where there is still water, the smaller and more delicate kinds of polypes carry on their operations, while the stronger species live and work on the exterior margin of the bank, against which a great surf usually breaks. These creatures leave off building as soon as their structures reach such a height as to be left almost dry at the lowest ebb of the tide. A mass of solid stone is seen, composed of shells of molluscs, and when with them broken off prickles, and fragments of coral cemented by calcareous matter. The ridge is raised by fragments of corals thrown up by the waves, till it becomes so high as to be covered only by high tides at certain seasons. Masses of the stone thus formed are sometimes separated and thrown upon the surface of the reefs, so as gradually to augment its elevation. The rate of growth of the common branching Madrepore is not over one and a half inches a year. Other branches are open. This would not be equivalent to more than half an inch in height of solid coral for the whole surface covered by the Madrepore; and as they are also porous, to not cover over three-eighths of an inch of solid limestone. But a coral plantation has large bare patches without corals, and the coral sands are widely distributed by currents, part of them to depths over one hundred feet, where there are no living corals. Not more than one-sixth of the surface of a reef region is in fact covered with growing species, which reduces the three-eighths to one-sixteenth. Shells and other organic relics may contribute one-quarter as much as corals. At the outside the average upward increase of the whole reefground per year would not exceed one-eighth of an inch. Now some reefs are at least two thousand feet thick, which at one-eighth of an inch a year corresponds to 190,000 years. If the progressing subsidence essential to the increasing thickness were slower than the most rapid rate at which the upward progress might take place, the time would be proportionally longer. Coral formations are most abundant in the tropical Pacific, where there are two hundred and ninety coral islands, too numerous to mention. A distinction exists between coral islands and coral reefs; the first are isolated coral formations in the open sea, and the second are banks of coral bordering other lands or islands. It has been already stated that the tropics are the hotbed for coral formations; the limiting temperature of reef forming corals is 68° F. They do not flourish where the mean temperature of any month of the year is below that degree. Certain tropical coasts are exempt from coral reefs, for the following reasons: the cold extra-tropical oceanic currents, as in Western South America; muddy or alluvial shores, or the emptying of large rivers; for coral polyps require clear sea water and generally a solid foundation to build upon. Also the process of volcanic action destroys the life of a coast; also the depth of water on precipitous shores, for the reef corals do not grow where the depth exceeds one hundred feet. Beyond that depth there are no growing corals, except some kinds that enter but sparingly into the structure of reefs, the largest of which are the dendrophylliae.

The rock forming the coral platform and other parts of the solid reef, is a white limestone, made out of corals and shells: its ramification is like that of ordinary limestones. In some parts it contains the corals imbedded, but in others it is perfectly compact, without a fossil of any kind, only an occasional shell. In no case is it chalk. The compact, non-fossiliferous kinds are found in the lagoons or sheltered channels, the kind made of broken corals on the sea shore side, in the face of the waves; those made of corals standing as they grow in sheltered waters, where the sea has free access. The principal kinds of coral rock consist in,

1. A fine grained, compact, and clinking limestone, solid and flint-like in fracture as any Silurian limestone, and with rarely a shell or fragment of coral. This is a calcium variety, and when coral reefs and islands have been elevated, it often makes up the mass of the rock exposed to view, it is a puzzle how to account for the absence of the fossils.

2. A compact colite consisting of rounded concretionary grains, and generally without any distinct fossils.

3. A rock equally compact and hard with No. 1, but containing imbedded fragments of corals and some shells.

4. A conglomerate of broken corals and shells, with little else, very firm and solid; many of the corals several cubic feet in size.

5. A rock consisting of corals standing on the solid earth, the interstices filled in with coral sand, shells and fragments. In general, the rock is exceedingly solid, but in some instances the interstices are but loosely filled.

All these corals, when alive in water, are covered throughout with expanded polyps, emulating in beauty of form and colors the flowers of the land. Besides corals and shells, there are also some kinds of calcareous vegetation called nullipores, both branching and incrusting in form, which add to the accumulation. They grow well over the edge of the reef, in the face of the breakers, and attain considerable thickness.

The waves in their heavier movements, sweeping over the coral plantations, may be as destructive as winds over forests. They tear up the corals, and by incessant perturbation reduce the fragments to a great extent in to sand, and the debris thus made, and ever making, are scattered over the bottom or piled upon the coast by the tide, or swept over the lower parts of the reef into the lagoon. The corals keep growing, and this sand and the fragments go on accumulating, the consolidation of the fragmental material makes the ordinary reef rock. Thus, by the help of the waves, a solid reef structure is formed from the sparsely growing corals.

Where the corals are protected from the waves, they grow up bodily to the surface, and make a weak open structure instead of the solid reef rock, or, if it be a closely branching species, so as to be firm, it still wants the compactness of the reef that has been formed amid the waves. According to their position, there are fringing or barrier reefs, the first are attached directly to the shore, while the others are like artificial moles, separated from the shore by a channel of water. The thickness of a coral formation is very great, sometimes thousands of feet; the instances are quoted that no bottom was found at 6,000 feet; at the Fejees, 2 to 3,000 feet. Fringe reefs form the origin for the Atolls, like the Menchikoff, as explained by Darwin, which are high islands consisting of two clusters of summits, like Mani and Oahee in the Hawaian group. It has been stated that one of the principal sources of the limestone formation is formed. Shells and corals, which form extensive beds and acquire a texture as firm as any marble, and by watching the process of accumulation, from the growth of corals and the wear of the waves, that the remains of these corals form a compact bed; and we infer from this great phenomenon that if we meet with a limestone over this continent containing remains of corals or shells, that the ancient limestone was as much a slowly formed rock made of corals or shells as the limestone of coral seas.

From Hirsch's new Journal "The Arts" the following Extract is made with reference to the reef-building coral.

The variety of compact and branching corals far exceeds description: 120 species are inhabitants of the Red Sea alone, and an enormous area of the Tropical Pacific is everywhere crowded with the stupendous works of these minute agents, destined to change the present geological features of the globe, as their predecessors have done in the remote ages of its existence.

Four distinctly different formations are due to the coral-building polypes in the Pacific and Indian Oceans, namely: lagoon islands or atolls, encircling reefs, barrier reefs, and coral fringes—all nearly confined to the torrid zone.

An atoll is a ring or chaplet of coral, enclosing a lagoon or portion of the ocean in its centre. The average breadth of that part of the ring which rises above the surface of the sea is about a quarter of a mile, often less, and it is seldom more than from six to ten or twelve feet above the waves; hence the lagoon islands are not visible, even at a very small distance, unless covered by the cocoanut, the palm, or the pandanus, which is frequently the case. On the outside, the ring or circlet slopes down for a distance of one or two hundred yards from its edge, so that the sea gradually deepens to about twenty-five fathoms, beyond which the sides of the ringe plunge at once into the unfathomable depths of the ocean, with a more rapid descent than the cone of any volcano. Even at the small distance of some hundred yards, no bottom has been reached with a sounding-line a mile and a half long.

All the coral in the exterior of the ring, to a moderate depth below the surface of the water, is alive; all above it is dead, being the detritus of the living part washed up by the surf, which is so heavy on the windward side of the tropical islands of the Pacific and Indian oceans, that it is often heard miles off, and is frequently the first warning to seamen of their approach to an atoll.

The outer margins of Maldave atolls, consisting chiefly of nullipores and porites, are beaten by a surf so tremendous that even ships have been thrown, by a single upheaval of the sea, high and dry on the reef. The waves give innate vigor to the polypes by bringing an ever-renewed supply of food to nourish them, and oxygen to support life; besides, uncommon energy is given and maintained by the heat of the tropical sun, which gives them power to abstract enormous quantities of solid matter from the water to build their strong homes — a power that is efficient in proportion to the energy of the breakers which furnish the supply.

On the margin of the atolls, close within the line, where the coral is washed by the tide, three species of nullipores flourish; they are beautiful little plants, very common in the coral islands. One species grows in thin spreading sheets, like a lichen; the second, in strong knobs as thick, as a man's finger, radiating from a common centre; and the third species, which has the color of peach blossoms, is a recticulated mass of stiff branches, about the thickness of a crow's quill. The three species either grow mixed or separately, and although they can exist above the line of the corals, they require to be bathed the greater part of each tide; hence a layer two or three feet thick, and about twenty yards broad, formed by the growth of the nullipores, fringes the circlet of the atolls and protects the coral below.

The lagoon in the centre of these islands is supplied with water from the exterior, by openings in the lee-side of the ring, but as the water has been deprived of the greater part of its nutritious particles and inorganic matter by the corals on the outside, the harder kinds are no longer produced, and species of more delicate forms take their place. The depth of the lagoon varies from fifty to seventy fathom or less, the bottom being partly detritus, partly live coral. In these calm, limpid waters, the corals are of the most varied and delicate structures, and the most charming and dazzling hues.

When the shades of evening come on, the lagoon shines like the milky way, with millions of brilliant sparks. The microscopic medusa and crustacea, invisible during the day, form the beauty of the night, and the sea-feather, vermillion in day-light, now waves with green phosphorescent light. This gorgeous character of the sea-bed is not peculiar to the lagoons of the atolls—it prevails in shallow water throughont the whole coral-bearing regions.

We have other materials of organic origin which have been formed into rocks, and which are generally divided in four groups, such as,

1. The calcareous rocks from which the limestones have been formed, namely, corals, shells, crinoids, which have a specific group of 2,428.

2. The silicious, or those which have contributed to the silica of rocks, and may have originated flints, such as, *a*, the microscopic siliceous shields of the infusoria called diatoms, which are now regarded as plants; *b*, the microscopic siliceous spicula of sponges.

3. The phosphatic, or those which have contributed phosphates, especially the phosphate of lime, as

bones, excrements, and a few shells related to the lingula. Such excrements are called coprolites, as those of birds, when in large accumulations guano.

4. The carbonaceous, or those which have afforded coal and series of plants.

Among the calcareous rocks, we have also an uncrystalline limestone and a crystalline.

1. The massive, which, as has previously been mentioned, as being formed from shells and corals, ground up by the action of the sea and afterwards consolidated.

The colors are dull gray, bluish, brownish to black, its composition is usually the same as that of calcite, carbonate of lime, except that impurities, as clay or sand, are often present. They vary in texture, from an earthy looking limestone to a very compact semi crystalline one, and passes gradually into a crystalline.

2. Magnesian or Dolomitic Limestone, which consists of carbonate of lime and magnesia, but it is not distinguishable in color or texture from ordinary limestone. Most of our American limestones are magnesian.

3. Hydraulic Limestone. It is an impure or earthy limestone, containing some clay, and affording quicklime, and thence the water cement is formed.

4. Ooietic Limestone, a rock consisting of minute concretionary spherules, and looking like the petrified row of fish.

5. Chalk is a white earthy limestone, which leaves a trace on a board.

6. Marl, a clay, composed of a large proportion of carbonate of lime; and it is called shell marl if it consists largely of shells or corals.

7. Shell Limestone is a rock consisting entirely of shells or corals.

8. The Birdseye Limestone is a compact limestone which has crystalline points disseminated through it.

9. The Travertin is a massive but porous limestone formed by depositions from springs or streams, holding carbonate of lime in solution, or bi-carbonate. Such a rock abounds on the river Avino, near Tivoli, and is used there as building material.

10. Stalagmite, Stalactite, depositions from water trickling through the roofs of limestone caverns, from pendent calcareous cones and cylinders from the roofs, which are called stalactite, and incrustations on the floors which are called stalagmite; they are usually translucent. The crystalline limestone comprehends the granular limestone, such as the statuary marble, which has a granular texture from white to gray color. The calcareous deposits in the thermal springs have been mentioned, and have furnished food for speculation as to their origin and cause of their deposit. We find some hot springs which deposit siliceous matter, and some calcareous. The Geysers of Iceland contain siliceous earths in solution

and deposit them on cooling; these deposits extend over an area of about half a mile in diameter, and from the depth of a cleft near the great Geyser, the siliceous matter appears to be more than twelve feet in thickness. The hot springs of Furnas, in the volcanic district of St. Michael, one of the Azores, large quantities of silex, enveloping grass, leaves and other vegetable bodies, some of which are still flowering, in the island are seen, frequently forming horizontal strata, siliceous stalactites two inches long, and covered with small brilliant quartz crystals. The hot springs of Arkansas, in the Ozark Mountains, form a district of extinct volcanoes; they have furnished the author most exquisite specimens of quartz crystals in groups for his own cabinet, and excited the admiration of the scientific and curious world when he exhibited them at the London Exhibition in 1851, and the variety of forms, as well as the sizes and particular appearance, cannot be excelled.

The thermal springs of Primarkoon and Loorgoothe, in the East Indies, contain besides silica various salts of soda.

The Travertin is by no means confined to locations where limestone districts are known, but occurs indiscriminately in all rock formations. In Auvergne in France, where the primary rocks are destitute of limestone, springs abundantly charged with carbonate of lime rise up through the granite and grass. In the valley of the Elsa, which skirts the Appenines in Italy, are innumerable springs which have thrown down such calcareous precipitates that the whole ground in some parts of Tuscany is coated with Travertin, and sounds hollow under foot. A most striking instance of the rapid deposit of carbonate of lime from thermal waters may be observed in the hill of San Vignone, on the high road between Sienna and Rome, a large mass of Travertin descends the hill, from the point whence the spring issues to the bank of the River Orcia, a distance of 250 feet, forming a mass of varying thickness, but sometimes 200 feet in depth, and on the other side of the hill a similar deposit extends about half a mile, in parallel strata, one of which is fifteen feet thick and constitutes excellent building stone.

The hot springs of Wachita, before mentioned, have likewise large deposits of travertin, forming escarpments along the borders of the stream, into which the hot springs descend.

Among the beds of the Potsdam period, the magnesian limestone strata of the Quebec group contain numerous fossils, and thus show that they are marine and that they have the origin of whatever life occupied the seas. The extensive magnesian limestones of the Mississippi Valley have the same composition and are similar in compactness; the natural inference is that they were also of organic origin. But over extensive regions they do not contain a single fossil. Yet it is to be remembered that the sea, which grinds pebbles and sand and makes fine sandstones, may also grind shells and make an impalpable limestone. This is abundantly exemplified in coral regions, for a large part of the limestone there made of corals and shells is as compact and unfossiliferous as the magnesian limestone in question.

The only other mode of origin is by chemical deposition. This could not have taken place in the open seas, for, owing to the oceanic currents, the waters have a remarkable uniformity of composition, and no local deposition can take place. It requires, therefore, an elevation above the sea and the existence of calcareous mineral springs, and springs on a wonderfully vast scale, for a formation as extensive as the magnesian limestone of the Potsdam period. Such a condition of things is improbable. Moreover, the depositions would have a structure wholly unlike that of the magnesian limestone. Whoever has seen the travertin beds of Tivoli, which are the largest of the chemical calcareous deposits formed in the present era, will appreciate the wide distinction between the mass made up of a series of incrustations, curving with all sorts of fantastic irregularities, and the dense even-grained limestone of the calciferous epoch. The oolitic structure of part of this limestone has a parallel in the oolitic coral rock of Key West, which is also without imbedded corals or shells.

It is curious to reflect that if the bottom of the equatorial seas, where atolls abound, were upraised and laid dry, we should behold mountain peaks and ridges composed fundamentally of volcanic, granitic and other rocks, on which tabular masses of limestone would repose. Some of these calcareous cappings would be continuous over an area three miles, others above 300 miles in circumference, while their thickness might vary from 1,000 to 10,000 feet or more. They would consist principally of corals and shells—in some places entire, in others broken. In the lower regions of the same continent, and between the high table lands or mountain ridges, there would often be no contemporary deposits, or where exceptions occurred to this rule the calcareous strata would differ in their nature as much as in the species of fossils which they enclosed from the tabular masses of coral. It has been observed that the softer corals, when they decompose in the lagoon, are resolved into a white mud, which, when dry, is undistinguishable from common chalk; and inference may be drawn that a recent cretacrous formation may now be in progress in many parts of the Pacific and Indian oceans.

It is, however, more than probable that lime, which is generally contained in sea water and secreted so plentifully by the testacea and corals of the Pacific, may have been derived either from springs rising up in the bed of the ocean, or from rivers fed by calcareous springs, or impregnated with lime derived from disintegrated rocks, both volcanic and hypogene; and if this be admitted, the greater proportion of limestone in the more modern formations, as compared to the most ancient, will be explained, for springs in general hold no argillaceous, and but a small quantity of siliceous matter in solution, but they are continually substracting calcareous matter from the inferior rocks. The constant transfer, therefore, of carbonate of lime from the lower or older portions of the earth's crust to the surface, must cause at all periods, and throughout an indefinite succession of geological epochs, a preponderance of calcareous matters in the newer, as contrasted with the older, formations.

The chalk of which allusion has just been made, having their origin likewise in the lagoons where the corals have been converted into mud, belongs to the tertiary strata called the cretaceous or chalky group and is but a limestone or carbonate of lime. Although usually soft, this substance passes in many localities by a gradual change into a solid stone used for building, the stratification is often obscure, except where rendered distinctly alternating layers of flint. These layers are from 2 to 4 feet distant from each other and from 3 to 6 inches in thickness, occasionally in continuous beds, but more frequently in nodules.

No doubt exists but what the chalk was formed in an open sea of some depth, but how so large a quantity of this peculiar white substance could have accumulated over an erea many hundred miles in diameter and some of the extreme points of which are distant more than 1000 geographical miles from each other, is of the greatest interest and its derivation from the decay of corals and shells has given rise to many philosophical investigations. The most difficult problem is the origin of the flint in the chalk, whether it occurs in isolated nodules or continuous layers. It seems that there was originally siliceous as well as calcareous earth in the muddy bottom of the cretaceous sea, at least when the upper chalk was deposited. Whether both these earths could have been alike supplied by the decay of organic bodies, may be a matter of speculation. The flints which is contained as nodules in the chalk are distributed in layers through it like the hornstone in the earlier limestones; they are more or less rounded and often assume fantastic shapes; sometimes they resemble rolled stones, but in fact all are of concretionary origin. The exterior of the nodules for a little depth is frequently white and penetrated by chalk, proving that they are not introduced boulders or stone but have originated where they now lie, and we attribute the parallel disposition of the flints layers to successive deposition. The distances between the layers must have been regulated by the intervals of precipitation, each new mass forming at the bottom of the ocean a bed of pulpy fluid, which did not penetrate the preceeding bed on which it rested, because the consolidation of the last has so far advanced as to prevent such intermixture; it remains, therefore, a singular phenomenon not yet satisfactorily accounted for. Perhaps, as the specific gravity of the siliceous exceeds that of the calcareous particles, the heavier flint may have sunk to the bottom of each stratum of soft mud. How far and wide this mud has been scattered by oceanic currents may be seen by the area over which the white chalk preserves a homogenous aspect, that we can hardly find an analogous deposit of recent date; chalk is found from the north of Ireland to the Crimea, a distance of 1,140 geographical miles, and from the south of Sweden to Bordeaux, about 840 geographical miles. The chalk cliffs of the English Channel form one great continuous mass on both sides, in the neighborhood of London and Paris basin.

Chalk forms one of the rocks of the cretacious period. It is not found in America, but the cretacious limestone of this formation comprises very extensive beds, and is divided into two great epochs —1, that of the earlier cretaceous, and 2, the epoch of the later cretaceous; they extend from New Jersey to South Carolina, along the Gulf borders, and through a large part of the Western Interior region, over the slopes of the Rocky Mountains, from Texas northward and far into the Colorado region, on the west of British America and Arctic Sea, but they are unknown on the Atlantic borders north of New York. The rocks comprise beds of sand, marl, clay, loosely aggregated shell limestone, and compact limestone, and the sandy layers are predominating, and are of various colors; white, gray, reddish and dark green, and though sometimes solid, they are often so loose that they may be rubbed to pieces in the hand, or worked out by a pick and shovel. Layers of potters' clay occur in the series.

The marl of New Jersey and elsewhere, which is a dark green sandy variety and forms very extensive beds, is called *Greensand*; is a green silicate of iron and potash, with a trace of phosphate of lime, and this makes it highly valuable for fertilizing purposes. The cretaceous formation has a thickness in New Jersey of 400 to 500 feet; in Alabama, 500 to 600 feet; in Texas, about 800 feet; and in the region of the upper Missouri, 2,000 to 2,500 feet.

The upper or later cretaceous period, comprises the beds on the Atlantic and Gulf borders and in New Jersey, while the lower are represented in the Western Interior region, including Texas.

The cretaceous beds of Europe have been divided into:

1. The lower cretaceous, including—England, the lower greensand, 800 to 900 feet thick, and in other regions beds of clay and limestone, sometimes chalky.

2. The middle cretaceous, including in England—*a*, the clayey beds or marls called gault, 150 feet thick; and *b*, the upper greensand, 100 feet thick.

3. The upper cretaceous, including in England the beds of chalk, in all about 1,200 feet. It consists of —*a*, the lower or gray chalk or chalk marl without flint; *b*, the white chalk containing flint; *c*, the Maestricht beds, rough friable limestone at Maestricht, Denmark, 100 feet thick.

The life of the cretaceous period in Europe resembled that of America, but was far more abundant. Nearly 6,000 species of animals have been described, more than half of them molluscs; whereas, in America the whole number does not exceed 2,000.

The great Interior Continental basin, which had been a limestone-making region, for the most part, from the earliest period of the Siluvian, was still in its southern part, as in Texas, continuing the same work, for limestones 80 feet thick were there formed. To the north of Texas, where the waters were shallower, there appears to have been none of the echinoderms, corals, orbitolinae, &c., which were common in Texas.

Having stated of the extent of the cretaceous or chalk formation as of a recent origin or mesozoic time, we find before our doors the limestones in large deposits on the verge of the azoic time.

New York Island, which is about 13 miles long, consists of eight different formations of metamorphic rocks, (a term first proposed by Lyell, of the altered strata of the sedimentary rocks,) among which the limestone represents a very conspicuous part; they are, according to Cozzens, as follows:

1. Granite, beginning at 28th Street, a little east of 8th Avenue; running to North River at 32d Street, up to 60th Street; crops out at 86th Street, near the Croton Water Works Receiving Reservoir.

2. Syenite crops out at the north edge of the Serpentine, probably but a boulder of greenstone.

3. Serpentine.—Between 54th and 62d Streets, the shore and 10th Avenue, four or more small knolls of black serpentine are visible, with scales of silvery and golden talc, accompanied by a vein about 12 feet wide, of anthophyllite. This vein is in a vertical position, and actinolite is found embedded in the serpentine. At the south end there is a vein of carbonate of lime, resembling much a verde antique, on account of containing small specks of serpentine diffused through it.

4. Gneiss.—This rock is more abundant on the Island than any other; beginning at the Battery,

which it underlies, may be seen at East 14th Street, and 18 feet below the surface in 8th Street. It underlies Governor's Island at its most southern extent, passing through New York Island, and running through the greater part of Westchester County; forms the rock at the straits called Hell-Gate, and then underlying Long Island. The gneiss of New York Island is a peculiar variety; has more mica than common.

5. Hornblende Slate.—This rock is associated with the gneiss in many parts of the Island—at Spuyten Devil bluff, at the north end of the Island, and at Manhattanville.

6. Quartz Rock.—On the 10th Avenue, near 60th Street, veins of quartz of various thicknesses, gray and granular.

7. Primitive (so-called) Limestone, of Kingsbridge, is a dolomite, and has all the varieties of white, gray and light blue, granular and coarse marble. It begins at the south end ot Dykeman Farm, and runs through the middle of the Island to Spuyten Devil Creek; the formation rests on granite.

8. Diluvium.—This formation covers almost all the Island; it is 100 feet in depth on the lower end of the Island; there are found types of all the rocks of the valley of the Hudson.

Dr. R. P. Stevens states that no where on the face of the globe could such numerous sections of metamorphic rocks be seen in so easy and accessible a manner as on the upper end of our Island. We find gneiss forming the main mass of the Island; then comes the granite, hornblende, anthophyllite and other masses. The limestone is found independent of the large deposit at Kingsbridge, at 132d Street, east of 6th Avenue, reposing conformably upon gneiss, which is a continuation southward of the limestone of Westchester County. Between 4th and 3d Avenues, East 123d Street, another bed of limestone, always the gneiss either on the eastern and western flanks. In the excavation of a culvert in East 50th Street, between 3d and 4th Avenues, the axis of limestone, 18 feet beneath the street, was visible. This fold of limestone has been cut through at the Montauk Steel Works, on the mainland at Mott Haven, where its base is 100 feet wide and 20 feet high, and large masses of limestone were seen thrust into the solid gneiss. At Melrose, another bed of limestone, traceable to the Harlem River, as well as at Hastings; the large bed underlies the Harlem River, continuing southwards.

Dr. Stevens has good geological reasons for inferring that the North River flows through fractures and abrasions of folds of gneiss and limestone, from Haverstraw Bay to the Narrows.

Limestones increase with extreme slowless; from five to ten feet of fragmental deposits will accumulate while one of limestone is forming. This conclusion is sustained by the ratio in any given period between the fragmental rocks of the Apalachians and the limestones of the interior basin. It may well be here noticed that the different kinds of rocks have been conveniently divided into fragmental and crystalline rocks. The first are made up of pebbles, sand or clay, either deposited as the sediment of moving waters as formed and accumulated through other means—as ordinary conglomerated sandstones, clay rocks, tufas and some limestones. The larger part of the rocks here included are made of sedimentary material, and are commonly called sedimentary rocks. They are stratified rocks, that is, consist of layers spread out one over another. Many of them are fossiliferous rocks, or contain fossils. The crystalline rocks have a crystalline instead of a fragmentary character. The grains, when large enough to be visible, are crystalline grains, and not waterworn particles or fragments of other rocks, such as granite, micaschist, basalt. They may have been crystallized either from fusion like lava or basalt, when they are called igneous rocks, or from solution or with some limestones, or through long-continued heat without fusion. By this method sedimentary beds have been altered into granite, gneiss, micaschist, and compact limetone into statuary marble. When a bed originally sedimentary has been metamorphosed into a crystalline one, rocks of this kind are called, metamorphic rocks. The former division of the rocks in aqueous, volcanic, plutonic and metamorphic was made in the infancy of science, when all formations, whether stratified or unstratified, earthy or crystalline, with or without fossils, were alike regarded as of aqueous origin.

A separate subdivision is made of the calcareous rocks or limestone, which are mostly sedimentary in original accumulation, but generally lose that appearance as they solidify. The rock masses of the globe, occur under three conditions: 1st, the stratified; 2d, the unstratified; and 3d, the vein condition. The first may be considered in the—1, the nature of stratification; 2, the structure of layers; 3, the positions of strata, their natural positions and dislocations; 4th, the general arrangement of strata or their chronological order.

By chronological order is understood the arrangement of the rocks of the different continents in a chronological series.

We found that North America has some large blanks in the series, which in Europe are full; and in this way various countries are contributing to its perfection. The series has been divided in ages, based on the progress of life:

I., The Azoic age, containing no traces of animal life.

II., The Silurian age, or age of mollusks, the mollusks being the dominant race.

III., The Devonian age, or age of fishes, where fishes form the dominant race.

IV., The Carboniferous age, or age of aerogens, characterized by coal plants or aerogens.

V., The Reptilian age, reptiles the dominant race.

VI., The Mammalian age, mammals the dominant race.

VII., The age of man.

In order to explain these divisions more fully, we will state of the thickness of the stratified rocks. The whole thickness of the rocks in the series is fifteen or sixteen miles; but this includes the sum of the whole grouped in one pile. As the series is nowhere complete, this cannot be the thickness observed in any one region. The rocks of New York down to the azoic, counting all as one series, are about 13,000 feet in thickness. They include only the Silurian and Devonian (excepting the triassic in the southeast). To the north they thin out to a few feet, while they thicken southward towards Pensylvania. The rocks in Pennsylvania include the carboniferous, and the whole thickness is at least 40,000 feet. In Virginia the thickness is still greater, but no exact estimate has been made. In Indiana and the other States west it is only 4,000, although extending to the top of the carboniferous. The greater part of the continent of North America, east of the Mississippi, is destitute of rocks above the carboniferous.

In Europe the rocks of the later periods are far more complete than in North America, while the older also, according to the estimates stated, exceed the American.

In Great Britain the thickness to the top of the carboniferous is over 60,000 feet, and from the carboniferous to the top of this series little less than 10,000 feet more. This amount is the sum of the thickest deposits of the several formations and not the thickness observed in any particular place.

The ages above referred to belonging to rocks such as the age of mollusks or silurian and the age of fishes, &c., we have another signification in them, subdivision of geological time, such as:

I., Azoic time or age, meaning absence of life.

II., Polæozoic time, or ancient life—
  1. The age of mollusks, or Silurian,
  2. " " " fishes, or Devonian,
  3. " " " coal plants, or carboniferous.

III., Mesozoic time, or mediæval age,
  4. The age of reptiles.

IV., Cenozoic time, or recent life,
  5. The age of mammals.

V., Era of mind,
  6. The age of Man.

We have also the subdivisions into periods, epochs, and, according to Lyell, also the Eocene, Miocene and Pliocene subdivisions of the age belonging to the Tertiary period.

How long or how far apart time was required of the creation and extinction of these periods we have no definite data to show; but all the facts of geology tend to dictate an antiquity of which we are beginning to form but a dim idea. Take for instance one single formation, the chalk of the English coast, which consists entirely of shells and fragments of shells deposited at the bottom of an ancient sea, far away from any continent, and take the rate of deposition at 10 inches in a century; the chalk is more than 1,000 feet in thickness, and would have required therefore more than 120,000 years for its formation. The fossiliferous beds of Great Brittain, as a whole, are more than 7,000 feet in thickness, and many which within the United States measure only a few inches, on the continent expand into strata of immense depth, while others of great importance elsewhere are wholly wanting with us (many epochs in the Jurassic period); for it is evident, that during all the different periods in which Great Brittain has been dry land, strata have been forming elsewhere, not with us. Many strata now existing have been formed at the expense of older ones; thus all the flint gravels in the southeast ot England have been produced by the destruction of chalk. This again is a very slow process. A cliff 500 feet high will be worn away at the rate of an inch in a century. When a fall of cliff has taken place the fragments serve as a protection to the coast, until they have been gradually removed by the wave. The Wealden Valley is twenty-two miles in breadth; on these data it has been calculated, that the denudation of the Weald must have required more than 150,000,000 of years.

But preceding the appearance of animal life, we only know that our globe was at one time in a state of universal fusion, and that the crystaline rocks underwent a process in which sand, clay, and limestone were deposited, and these materials formed the original crust.

The Origin of the Alkalies Contained in Soluble Glass.

The two alkalies employed in the manufacture of silicate are potash and soda, the oxides of the metals potassium and sodium; both of which were discovered in 1807 by Sir HUMPHREY DAVY. They were decomposed by him by means of a powerful galvanic current. Before that time all alkalies and alkaline earths were supposed to be elementary bodies. The metals have since been prepared by heating in an iron retort either the potash or soda, with charcoal, at a high temperature. By this process, the carbon, at the high temperature, is able to take the oxygen from the potash or soda, forming a carbon monoxide, which escapes as a gas, while the metal, either potassium or sodium, being volatile at a red heat, distills over. The preparation of these metals is attended with many difficulties, and requires special precautions, as the vapors of these metals not only take fire when brought in contact with the air, but decompose water, combining with the oxygen, and liberating hydrogen; hence the metallic vapors must be cooled with naptha or petroleum, which do not contain any oxygen. It is indispensably necessary to distill the metals a second time for purifying them and freeing them from a black explosive compound, which invariably forms in the original preparation and has caused several fatal accidents.

Potassium.—Is a bright, silver white metal, which can easily be cut with a knife at the ordinary temperature, is brittle at 0°, melts at 62°.5 Fahrenheit, and does not become pasty before melting. When heated to a temperature somewhat below red heat, potassium sublimes, yielding a fine, green-colored vapor. This metal rapidly absorbs oxygen, when exposed to the air, and becomes converted into a white oxide. Thrown into water, one atom of potassium displaces one of hydrogen from the water, forming potassium hydroxide, or potash. This takes place with such force, that the heat developed is sufficient to ignite the hydrogen thus set free, and the flame becomes tinged with the peculiar purple that is characteristic of the potassa compounds, whilst the water attains an alkaline reation from the potash which is formed. Potassium also combines directly with chlorine, sulphur, and many other non-metals, evolving heat and light.

The original source of potassium compounds is the felspar of the granite rocks, containing from ten to twelve per cent., and mica, containing from five to six per cent. of potash. Up to the present time this source has not been used for the manufacture of the potassium salts, for the reason that no cheap and easy mode has yet made available for separating the potash from the silicic acid, with which it is combined in felspar and mica. The grand natural source from which the supply of potash is obtained is the ashes of wood and other vegetable matter. The potassium exists in the plants previous to combustion, having been absorbed by them from the soils in which they grow; the soils obtain the potash from the decomposition of rocks, clay, etc. It is also found, combined with other substances, in sea water. Potash is now generally obtained from the ashes of plants, from which it is leached out, or by filtering water through them and boiling down the clear liquid, which, on evaporation, produces the crude potash, which is then purified. It used to be manufactured to a great extent in the States of New York, Ohio and Michigan, and was called pearl ash, and when perfectly refined, pearl or pot tartar. Some of the other potassium salts, such as the nitrate and chloride, are found in large quantities in various localities as deposits on the surface, or in the interior of the earth. The sources of nitrate of potash, or saltpetre, have been sufficiently well known. The chloride of potassium occurs in beds, together with rock salt, in Stassfurth, near Halle, in Prussia, in considerable quantities, and is largely employed by gunpowder manufacturers for the conversion of nitrate of soda into that of potash. There have been already described thirteen varieties, all containing the chloride with the salt. The utilization of sea water for the extraction of potash salts is about to be tried in Europe on a large scale. All potassium salts are soluble in water, and impart a violet color to flame, The spectrum of this flame is distinguished by two bright lines, one red, and one violet.

Sodium.—This metal resembles in external appearance the metal potassium. It is, however, procured more easily than the latter, by reducing the carbonate of soda in the presence of carbon. It is now manufactured in large quantities for the preparation of other metals, especially magnesium and aluminum, as potassium was formerly used for the same purpose.

The metal distills over, and is condensed in petroleum. It is a silver-white metal, soft at ordinary temperature, melting at 95.6° and volatilizing below a red heat. When thrown upon water it floats and rapidly decomposes the same with disengagement of hydrogen, soda being formed. If the water be hot, or be thickened with starch, the globule of the metal becomes so much heated as to enable the hydrogen to take fire.

THE COMPOUNDS OF SODIUM are very widely diffused, being contained in enormous quantities in the primitive granitic rocks. They are readily obtained from sea-water, which contains nearly three per cent. of chloride of sodium or the common salt of the kitchen. There are large deposits of salt in Galicia, Prussia, England, and this country, (as is the case in Louisiana and Nevada and on the island of San Domingo) and it was formerly obtained from the ashes of sea plants, or kelp, in the same manner as potash was prepared from land plants. At present, however, the carbonate of soda is manufactured on an enormously large scale from the sea-salt, especially in England, and is known in commerce as soda-ash, which is indispensable in glass-making, soap-manufacture, bleaching, and for various other purposes in the arts. No less than two hundred thousand tons of salt are annually consumed in the alkali works of Great Britain.

Soda-ash is prepared from sea-salt by a series of chemical operations, such as that of the production of the sulphate or salt-cake, and the reduction of that to soda-ash. The first is obtained by heating oil of vitriol with common salt, in a reverberatory furnace, whereby the sodium is separated from the chlorine with which it is combined, and uites with oxygen and sulphuric acid to form sulphate of soda, or anhydrous glauber salt. The liberated chlorine combines with the hydrogen of the water contained in the sulphuric acid, to form hydrochloric acid, which is collected as a commercial article. The sulphate of soda then undergoes the second process of pulverizing the same (salt-cake) and heating it with pulverized chalk and charcoal. The product is called black-ash. By lixiviation and evaporating down the solution (the heated air passing over a leaden pan containing the liquid) and calcining afterwards the residue, the soda-ash of commerce is obtained. It contains from from forty-eight to fifty-six per cent. of pure caustic soda, combined as carbonate and hydrate, the remainder being impurities, consisting generally of sulphate, sulphite and chloride. If soda-ash be dissolved and the saturated solution allowed to stand, large transparent crystals of the hydrated carbonate, known as soda crystals, are obtained. These are used to soften water for washing purposes.

Carbonate of soda also occurs in certain localities as an efflorescence on the soil and in the beds of dried up lakes.

SILICA OR SAND, GEOLOGICALLY, CHEMICALLY AND TECHNICALLY CONSIDERED.

[Read before the Polytechnic Institute.]

Sand is the term generally applied to all powdered stone, but pure sand consists of particles of quartz, silex or silica, which is composed of silicon and oxygen; and its chemical symbol, under the new atomic weight given to silicon, is Si, O_2. These particles, which are more or less rounded, are of a white, gray or grayish red color, and are unquestionably derived originally from a compact rock, called the sandstone formation. Sand may, however, be granitic, containing particles of felspar. This is the case when it has not been exposed to atmospheric agents long enough to decompose it. Sand consisting of angular grains is mostly employed for mortar or building purposes. The rock called sandstone is made up of agglutinated sand or pebbles and fragments of the same. It may be a siliceous, granitic, porphyritic, basaltic or calcareous sandstone, according to the material which occurs with it in nature: and it may be a compact, friable, ferruginous or concretionary sandstone, according to its structure. Again, if the sandstone glistens with scales of mica, it is called a micaceous sandstone; if much clay is mixed with the sand, it is called an argillaceous sandstone; and if this contains lime, it is called marly sandstone. If the quartz or sand peebles are rounded, and are held together in a conglomerate, the result is called a pudding-stone; and if they are angular, a breccia.

The flexible sandstone, or itacolumite, is a schistose quartz rock.

Buhrstone is a cellular siliceous rock.

The millstone, or gritrock, is composed of siliceous pebbles.

Siliceous schist is a flinty quartz rock.

Jasper rock is likewise a flinty siliceous rock.

Obsidian volcanic glass, or pumicestone, pitchstone, pearlstone, are all siliceous or sandy rocks, having a volcanic origin.

Sand, if transparent, bears the name of quartz, the constituent of a great many rocks, of both the primitive and newer formations. Quartz crystallizes in six sided prisms, with no apparent cleavage, of all degrees of transparency and opacity, and of all colors, from white and yellow green to black, with intermediate amethystine, rose and smoky tints. Pure pellucid quartz is called rock crystal, or pure silica.

Quartz is infusible before the blow-pipe, but when heated with soda, fuses easily to a glass. If quartz has colored bands, it is called agate, and without bands or clouds, it is chalcedony. When massive, of dark and dull color, with translucent edges, it is called flint; if with a splintery fracture, it is hornstone, like the Arkansas whetstone. When it is still more opaque, or black, it is the Lydian stone or basanite; of a dull red, yellow or brown color, and opaque, it is jasper; when in aggregated grains, it is called quartzite, and when in loose, incoherent grains, it is the ordinary sand, which is frequently transparent. Sandstone belongs to all ages, from the lower silurian to the most recent period, but the azoic rocks, which are nearly all crystalline, contain some sandstone; and the metamorphic, which are the most ancient rocks, and comprise granite, gneiss and syenite, consists largely of quartz. Certain dark red sandstone known as the freestone of New Jersey and Connecticut, and the general term, new red sandstone is applied to this formation, which is more recent than coal, while the old red sandstone lies below the coal, and above the great laurentian formation. Freestone is an excellent building material; in New York it is used more than any other stone. Trinity church, in Broadway, and many other public and private buildings, serve as examples; also the greater part of the flagstones which are brought to this city from Connecticut.

The green sand of New Jersey, which has for the last thirty years enhanced the agricultural prosperity of the lands of that State, and which belongs to the cretaceous formation, is a sandstone containing iron and potash.

A short description may prove interesting:

Ages and ages ago, in the mists of geological antiquity, an ocean lapped the margin of the land that extends from the first to the second city of this continent. The line that connects New York and Philadelphia, when straight drawn, will be seen to cross the Delaware River at its easternmost angle, just south of Trenton. In the period referred to, such a line would have stretched mostly on dry land; but for a part of the distance it would have crossed friths and arms of the sea, and broad marine swamps and meadows and lagoons, then growing rank with strange flora. It would have passed over broad reaches of warm shoal water, in which huge saurian reptiles disported, and along oozy and slimy beds, where great turtles were sleeping. Enormous sharks, also, darted after their prey through waters that teemed with scaly life. Down at the bottom of this ancient sea there were myriads of minute creatures, of shape and in size not unlike a tobacco seed, only a step advanced from vegetable life in their development and habits. So low were they in the scale of being that the naturalist still expresses a doubt whether they had higher than a vegetable life. But minute, humble and beyond the ken of any eye but the All-seeing, as were these microscopic atoms,—these tiny animalcules—these many chambered organisms, they were in their way vastly more useful than the giant reptiles that swam over them, and sprawled in the mud through which these little shells were dispersed. For now that all this dim and ancient life is exhumed from its geological grave, now when the spade of the laborer throws up clay, and shell, and mud, and claw and tooth from the cool, sunless depths where they have slumbered, heaven knows how long, we find that these mites and pin-heads of the old ocean have left us a broad, deep and exhaustless bed of material, as valuable in its way as the vein of silver in the hill, or the stratum of coal in the mountain side. The greatest of the natural laws are few and simple. The sun is, and ever has been, the grand source of light. Afar back in those cycles, compared with which the period of human history is as the span of a man's hand in contrast with the breadth of a continent, sunlight was drawing carbon from the air, and building, cell by cell and foot by foot, great tropical forests, rich in every form of vegetable life. By crashes and earthquakes, the date and extent of which can never be estimated by human geology, these forests with all the opulence of their vegetable glory were plunged into fathomless pits, overwhelmed with mountains of earth and stone, and deluged with vast avalanches of mud. Compressed by the mass above and roasted by the central fires, these ancient forests were converted into coal measures, and now we drive our millions of spindles, we speed across oceans, we span continents, we drive printing presses, and light our studies with carbon separated so long ago by the great Alchemist, and stored in this mysterious way for the use of unborn millions of men. In the same way great magazines of plant-food have been prepared by the action of obscure animal life, and by similar convulsions or slow upheavals, garnered up for a future agriculture.

Long and careful research may eventually disclose the precise contour of this ancient sea-shore. All we now know, is that a substance we call greensand occurs throughout the cretaceous belt of New Jersey. Draw a line from the shore just south of Long Branch to New Brunswick and it will run across the cretaceous bed at right angles, and cut three distinct beds or layers of greensand. The marl or greensand was probably deposited at three Epochs, and the different layers represent three periods of change, by which these beds became submerged and covered with sand. Of course the depth of water, the number and size of the organic creatures, and the amount of vegetable debris was different at various points along this margin. Where a harbor was deep, concave and land-locked, the deposit of mud would be deep and even. The little polythalmia would multiply and work undisturbed. When such a bed became overwhelmed with a mass of ocean sand, we should expect to find a layer many feet thick, alike in all its parts, and equally rich in animal remains. This is the description of the best marl beds as yet uncovered in New Jersey. In waters that were shoaler or nearer the margin and overhung with forests, or where rivers brought down a mixed debris and sometimes flung it rudely and sometimes laid it quietly upon the bottom of a bay or lagoon, we should expect a chaotic and irregular deposit. This is just the condition disclosed by the spade, the borer and the excavator in the marl beds of New Jersey. Marl as a deposit in the earth, having more or less value as a fertilizer, occurs in many parts of the world, and has been in use by the farmers of England and France for several generations. But the New Jersey deposit is quite different from common marl, and much more valuable. By the word marl the English geologist understands a bed of clay or alumina mixed with sand, with considerable carbonate of lime. On soils requiring alumina, as most sandy lands and where lime is not abundant, such marl is a useful application and pays for transporting short distances. But it is the greensand, the result of the life and death of myriads of small sea animals, that gives New Jersey marl its peculiar value, and makes it not only a local but a commercial fertilizer.

Greensand is found in many other parts of the world, and especially along the Atlantic coast. Professor Bailey examined a specimen taken from the depth of 140 feet in an artesian well at Charleston; and the soundings of the Coast Survey brought up from the depths of the ocean, in and near the Gulf Stream, a substance which was found identical in appearance with the contents of the Squankum beds.

Ehrenberg, found the rounded particles to be the casts of minute shells. The shells themselves have disappeared, but their material form has been retained in the more durable silicate of iron. This silicate of iron is mixed with phosphate of lime or phosphoric acid. The latter is no doubt of animal origin. Sea water and acids from the soil have eaten away some of the carbonate of lime, but the phosphoric acid remains and gives the deposit its greatest agricultural value.

The cretaceous belt of New Jersey, in most parts of which greensand is found, extends from a line connecting Trenton and New Brunswick, on the north-west, to a line nearly parallel with this, but about ten miles south-east, connecting the mouth of Shark River (a little south of Long Branch) with Salem on the Delaware. The region thus bounded on the north and south extends from Raritan Bay to Delaware River, being nearly fifteen miles wide on the Atlantic side of the State and not over five miles wide on the Delaware side. There are three beds or layers of greensand in the cretaceous belt, but the upper or newest deposit runs over into the tertiary or sandy formation that takes in all Jersey south of the marl beds. The general bearing or strike of these beds is north fifty-four degrees east, and they all dip or run away under the sandy deposit above them, getting twenty-five or thirty feet lower each mile as one passes to the southeast. The region over which these beds may be reached by digging from three to fifty feet, is ninety miles in length and on an average about seven or eight in width, and its area is nine hundred square miles. The strata themselves are fifteen to thirty feet thick. Near streams the sand and clay that covers these beds have been washed away; hence the marl is discovered by looking along the banks of the brooks that run from the cretaceous lands, either northwest into the Delaware, or southeast into the Atlantic. In places, the marl is within three or four feet of the surface, so by removing a slight top layer of sandy loam the bed may be reached; but generally a stratum several feet thick, of spurious or useless marl covers the greensand.

As already stated, sand and quartz are pure silica; still there is no mineral that assumes so many forms and colors as quartz, though none is more easily distinguished. Its characteristic features are:

1. Its hardness, which is from 6.5 to 7, enabling it to scratch glass with facility.

2. Its infusibility; when heated alone before the blow-pipe it does not melt.

3. Its insolubility, as it is not, like limestone, attacked by the strong mineral acids.

4. Its want of cleavage, which has been mentioned above. This is one of the first characteristics of quartz.

5. Its crystalline character, occurring mostly in in six-sided prisms, more or less modified and terminated.

6. Its low specific gravity of 2.5 to 2.7, is an unfailing distinctive character of quartz.

Rock crystal is a pure pellucid quartz, and was known by the ancients under the name of *crystallos*, meaning ice. It is used for optical instruments, spectacle glasses, and cut with facets, for jewelry. The crystals are often called real California diamonds. In ancient times it was cut into cups and vases, and it is said that on hearing of his final overthrow, Nero dashed into pieces a cup which was worth $3,000. To this class of quartz belongs the finest ornaments which adorn the palaces of ancient and modern times; and some forms, such as amethyst, rose quarts, *false topaz*, *smoky quartz*, known as Scotch pebbles, or cairngorm, the favorite ornaments of the sportsmen of the Highlands, are used as jewels.

Milky quartz, or greasy quartz.

Prase is of leek green color.

Avanturine, more commonly known as gold-stone, is a quartz spangled throughout with scales of golden yellow mica, although the artificial imitation looks more beautiful than natural stone.

Chalcedony is a translucent variety of quartz, which often lines the cavities of other rocks, and in the form of stalactites, which are then called icicles of chalcedony, and forming grottoes several feet in diameter. We find such in the Faroe Islands, in Florida, and in many volcanic rocks, probably owing to siliceous waters filtering at some period through the rock, and deposited by their concentration. Chrysoprase is but an apple-green chalcedony.

The *carnelian* is a bright red chalcedony, of a clear, rich, flesh-colored tint; it is a great favorite with the Japanese.

The *sard* is a deep brownish red chalcedony.

Agate is a variegated chalcedony, and its colors are distributed in clouds, spots, or consecutive lines, which may be straight, circular or zigzag forms. When the outlines are angular, resembling a fortification, it is called a fortification agate; if dendritic or moss-like delineations, arising from disseminated oxide of iron or manganese, it is called mocha stone or moss agate. The color of agate is much darkened by boiling the stone in oil, and then dropping it into sulphuric acid; a little oil is absorbed by some of the layers and the acid blackens or chars it.

The *onyx* is an agate, where the colors are arranged in flat horizontal layers, formed usually of light clear brown and an opaque white. When this stone is a sard and white chalcedony in alternate layers, it is called sardonyx.

The antique cameos and sculptured small ornaments from onyx are well known, such as the Mantuan vase, at Brunswick, seven inches high and two and one-half inches broad, representing a cream pot, and cut from a single stone; having white and yellow groups of raised figures, representing Ceres and Triptolemus in search of Proserpine.

The cat's eye is a greenish gray translucent chalcadony, having an opalescence or reflection, like the eye of a cat, when cut with a spheroidal surface, probably owing to filaments of asbestos.

The jasper is a dull red siliceous rock, containing some clay and yellow or red oxyd of iron, and has all the varieties of riband, Egyptian resin and porcelain, all assuming a high lustre and polish.

Bloodstone or heliotrope, is of a deep green color, slightly translucent, and containing red spots, resembling red drops of blood; many superstitious people have attached much importance to these red spots, and a bust of Christ in the Paris museum represents quite natural blood drops.

The lydian, or touchstone, is a velvet black, siliceous stone, or flinty jasper, which is used on account of its hardness and black color for trying the purity of the precious metals. This is done by comparing the color of the tracing left on it with that of an alloy of known character.

Petrified wood, called also silicified wood, containing the texture of the original wood, which when sawn across and polished is remarkably beautiful.

Quartz crystals are often found inclosed with other minerals, such as rutile, asbestos, actinolite and topaz, oxyd of iron, tourmaline, chlorite and anthracite coal; those containing the rutile look as if needles or fine hairs passed through them in every direction, and when cut for jewelry, pass by the name of love's arrows, or *flèches d'amour*.

The *opal*, one of the most fashionable jewels, is silica, with some water; it exhibits internal reflections of rainbow colors, and forms a gem of rare beauty; it is usually cut with a convex surface. Among the varieties of opal are fire-opal or girasol; it has a yellow, bright hyacinth, or fire-red reflections. The common or semi-opal, has a milky opalescence, but does not reflect a play of colors.

Hydrophane, cacholong, hyalite, menilite, wood opal, jasper, siliceous sinter, pearl sinter and fabasheer, all belong to the same class of silicious minerals, and are of more interest to the mineralogist than to the general reader.

Among all the discoveries relating to the arts, none exceed in importance and usefulness to mankind, the art of glass making. Glass is a chemical combination of sand and alkali or alkaline earth, heated to fusion, and presenting after fusion a transparent and hard body. The benefits conferred by it upon all classes of human society have been immense; the spectacle, the microscope, the telescope, and spectroscope, have showered incalculable blessings upon the world, and there are probably still greater discoveries in store for us. The history of the manufacture of glass may be traced from the present time through that of the Romans and Phœnicians, to the Egyptians, some of whose productions remain to this age. The art flourished in Tyre, in Alexandria, and lastly in Rome; and after being depressed for some ages, again revived under the Venetians, who transmitted the improved art to the rest of the nations of Europe. Pliny relates that glass was first discovered by accident in Syria, at the mouth of the river Belus, by certain merchants driven thither by the fortune of the sea and obliged to remain there and dress their victuals by making a fire in the ground. There being great abundance of the herb kali in that vicinity, the ashes of the plant, mixed and incorporated with the sand, formed glass.

Boerhave says, that the art of glass making is of ancient origin, being first cultivated in Egypt, while glass was rendered malleable in the age of Tiberius, and is now manufactured in the greatest perfection. It is one of the most useful arts to mankind; for by it in conjunction with the grinder's help, we obviate the natural infirmities of the eye. Without it, old people, and those whose optic nerves are affected, would be debarred the knowledge of reading letters or books, and would be unable to sit within doors, or in a coach or ship, and see all things clearly around them, yet without being exposed to the scourging heat or freezing cold, or being annoyed with the east wind, or the ingress or extraneous filth. Pure glass will scarcely receive any stain, and is easily cleansed again. Although the essential constituents of glass are silex and alkali, it generally contains other substances, such as metallic oxides, which are designed to modify its external character of hardness, fusibility, brilliancy, color and transparency. Many kinds of glass contain either potash or soda; the first is not much employed by the manufacturers of common glass. Some kinds contain lime and oxide of lead and alumina and oxide of iron; the two latter are however mere accidental impurities. The following constitute the principal materials of glass:

1. Silex, or sand, which is, as already stated, very abundant on the globe; the sand mostly employed is the white sand, either obtained from the disintegrated sandstone rocks, which are numerous in the United States, as in Missouri, near St. Genevieve, and Berk-

shire county, Mass.; or from the river sand which is found in large beds of white sand at Maurice river, in New Jersey and Florida. Drift sand is brought by the winds from the sea coasts or deserts, but mostly from the lower sands of sea shores, as we find them for 100 miles on the Long Island shore; this sand when washed forms a good sand for glass.

The infusorial deposits of the siliceous shells, called the *diatoms*, which form immense deposits both inland and on the coasts, yield a good material for the manufacture of glass.

2. Alkali. If potash is used, the purified pearlash is employed, particularly for plate glass and the fewer kinds of crown glass, as also *soda ash*, which is the carbonate of soda, is also used for the better qualities of glass; while sulphate of potash, glauber salt, salt-cake or common salt are employed for common glass.

3. Lime, either as air-slaked, quick-lime, or as carbonate of lime, such as marble or chalk, is used for the manufacture of green glass.

4. Oxide of lead, or litharge, or red lead, are usefully employed in the manufacture.

5. Certain materials are used for improving or purifying the glass, such as the binoxide of manganese, nitre, arseneous acid and white arsenic. Oxide of lead, in the form of minium, is principally used in flint glass, as it increases its brilliancy, the purity of its color and the power of its refraction. The binoxide

of manganese, was formerly known as glass-maker's soap; its effect is ascribed to the facility with which it gives up its oxygen, which combines with the coloring principles and destroys them. In other words, it converts the protoxide of iron, which would give the glass a dark green color, into a sesquioxide, which is of higher oxydation and which leaves the glass clearer.

Borax and boracic acid, as also the borate of lime, called Hayesine, from Peru, are like the Chili saltpetre, very useful and powerful agents for accelerating the fluxing of the silex.

The silex mostly used in England is sea sand, and not river sand, as is extensively used in the United States; it consists chiefly of quartz, and the finest qualities are obtained from Alum Bay, in the Isle of Wight, and from near Lyon, on the coast of Norfolk; the black flint, when raised to a red heat, and plunged in cold water, is frequently used, and probably gave the name to a species of glass, flint glass or crystal glass.

The manufacture of glass is divided into several classes:

A. Window glass, which includes,
  1. Crown glass.
  2. Sheet glass.
  3. Brown plate, silvered or unsilvered.
  4. Colored sheet, pot metal or flashed.

B. Painted and other kinds of ornamental window glass.

C. Cast plate glass.
  a. Rough plate.
  b. Pressed plate.
  c. Rolled plate.

D. Bottle glass.
  1. Ordinary bottle glass.
  2. Moulded bottle glass.
  3. Medicinal bottles.
  4. Tubing.

E. Glass for chemical and philosophical purposes, retorts, reservoirs, large water pipes, etc., etc.

F. Flint or crystal glass, with or without lead; white, colored, ornamented, for table ware, etc.
  1. Blown.
  2. Moulded and pressed.
  3. Cut and engraved.
  4. Reticulated and spun with a variety of colors, incrusted, flashed, enameled of all colors, opalescent, imitation of alabaster, gilt, gelatinized, silvered.
  5. Glass mosaic, miliflori, aventurine and Venetian glass weights.
  6. Beads, and imitation of pearls, etc.
  7. Chandeliers, candlesticks, and lamp aparatus.

G. Optical glass, flint and crown.
  1. Rough disks of flint and crown, to make

lenses for telescopes, microscopes, stereoscopes, spectroscopes, daguerreotype and calotype apparatus.

2. Flint and crown, blown, or cast in plates for the optician.

3. Fine glass for microscopes.

4. Refractive apparatus, prismatic lenses for lighthouses.

The above classification was made at the London universal exhibition of 1851. Another classification is made in the following kinds, according to their constituent materials:

1. The soluble glass, silicate of soda or potash, or both alkalies combined with silica.
2. Bohemian glass, a silicate of potash and lime.
3. Crown, or spread, a silicate of soda and lime.
4. Plate, a silicate of soda and lime cast into plates.
5. Bottle, a silicate of potassa, lime, alumina and oxide of iron.
6. Crystal, silicate of potash and oxide of lead.
7. Flint contains more lead than the last.
8. Strass, or paste, contains still more lead than flint.
9. Enameled and colored glass, from all the above except No. 1 and No. 5.

An excess of alkali is often used in order to obtain a more fusible glass, but such glass is more readily acted upon by acids; even when water is boiled in it, it will readily convert red litmus to blue, on account of its alkali; caustic alkali attacks glass by dissolving the silica, and fluohydric acid decompose glass readily.

As regards the physical characters of glass, it may be remarked that all glass is fusible, but the temperature for different kinds is different; oxide of lead, or a larger amount of alkaline silicate imparts more ready fusibility, and a similar effect is produced by borax. Bottle glass, containing oxide of iron and aluminum and less alkali, is more difficult of fusion than other kinds. When melted glass is cooled it is perfectly flexible and plastic before it is cooled down to rigidity; the softer kinds, such as flint or borax glass, when heated, begin to be plastic below a red heat; when in the plastic state pieces will unite together as firmly as if they were melted together. When glass is much softened by heat, it may be readily drawn out into rods or tubes, or, if passed around a revolving wheel, into minute flexible threads, called thin glass hairs, and these properties causes the glass to be formed into numberless shapes demanded by the wants of civilized life.

Glass conducts heat so imperfectly, that the end of a rod heated to whiteness may be held with safety by the hand, within an inch or two of the heated end; the bad conducting power of glass, combined with the cohesive force of its particles, gave rise to the manufacture of Prince Rupert's drops, which are pear-shaped pieces of glass, with a long thin stem, made by dropping melted glass into water; the bulb may be struck without injury, but if the smallest particle of the stem be broken off, the whole drop flies into powder with explosive noise and violence, owing to the bad conducting power of glass, combined with the cohesive force of its particles. Glass expands when heated and contracts on cooling, which must be done very slowly, in order to allow the particles to come uniformly close together. If suddenly cooled by dropping melted glass into water, the outside suddenly assumes the rigid and more contracted form, while the interior is still soft and expanded from the bad conducting power of the glass. When thoroughly, cooled, the interior must still retain the expanded state, so contrary to its cohesive force at common temperature, and when the cohesion of the outer layer is in the least disturbed, as by a scratch or slight fracture, the whole of the cohesive force exerts its power to fracture the entire mass. From this fact, it is necessary to cool more slowly than can be done in the air and the process of annealing is indispensable. This consists in placing a glass vessel, as soon as made, and while still hot in one end of a long annealing oven, with a fire at this end and gradually pushing to the further or cold end of the oven; the particles of the interior and exterior have then time to arrange themselves uniformly according to their cohesive force at each point of temperature, until they become perfectly rigid.

Glass is very elastic, as is easily shown by any strip of window glass, but more strikingly by hollow balls suspended by strings. On playing with your fingers on the windows, the harmonious sounds indicate their elasticity. A glass harmonicon consists of small strips of window glass of different sizes, suspended on parallel strings. They may be graduated to any scale; goblets of various sizes are also sometimes employed in a similar manner, and are made to vibrate by passing the moistened finger around their upper edges.

As has been stated, one of the various kinds of glass is the *soluble glass*, or silicate of soda or pottassa, or both combined, and on account of an excess of alkali, has become a soluble salt. It is termed also water glass, and has the formala, 2 KO. or Na O3, $Si O^3$, according to the old notation. The uses of silicate of soda are for the application to wood and textile fabrics, as a paint and substitute of dunging salt in calico printing, have been fully discribed in the proceeding treatise.

The *Bohemian glass* is manufactured largely in Bohemia, from 100 parts of silica, purified pearlash, sixty parts, and carbonate of lime, sixteen parts. These three substances are fritted in a reverberatory oven called calcar, and while still red hot, thrown into the glass pots, already in a glowing heat, and there melted, and when perfectly liquid, scooped out or taken out with an iron rod. The objects of fritting are to expel moisture and carbonic acid, and produce a caking of the materials, which facilitates the fusion. This glass is employed for making panes, tumblers and other articles, which are characterized by their beauty when compared with flint and crystal glass. They also possess greater infusibility and resistance to chemical agents; for this reason it has become celebrated and indispensable in the laboratories.

The *vial and spread glass* has a similar composition to the last described, and contains silica, soda, lime and sometimes potash in similar proportions, as before; but a smaller amount of soda is requisite than of potash, because soda has a lower equivalent. For spread or common window glass, a considerable quantity of soda is used in order to flux the materials rapidly, and the addition of salt is believed to clear the glass.

For making window panes, a lump of melted glass is taken out of the pot, blown and elongated in to a pear, then blown and rolled into a cylinder, which is slit longtudinally on one side for its whole length; it is then placed on the smooth hearth of the flattening kiln, with the slit side uppermost, and when softened by heat, is opened, until it spreads out upon the hearth, a flattened sheet.

Crown glass is composed of materials similar to those of the preceding kind, but they are generally poorer; to 100 parts silica, sixty parts soda ash, eight parts potash, ten parts lime, four parts saltpeter or nitrate of soda, one-eight part of white arsenic is thrown in the melting pot. The mixed materials are placed in a furnace, which is of rectangular construction, containing from four to six clay pots, of the capacity of half a ton of glass, and is now quickly heated up to the melting point. When the first charge is melted down, the next is thrown in, and so on until the pot is sufficiently filled. The temperature is then lowered for a few hours, during which some of the foreign matters subside, and the glass all rises to the top, when, after raising the fire a little, it is skimmed. It is called crown glass on account of the shape it assumes when broken off from the coal formed at the end of the iron rod called the punto.

Plate glass is composed of 100 parts silex, thirty-three parts carbonate of soda, twenty parts carbonate of lime, and a very small proportion of paroxide of manganese; say one-half part. This glass is usually cast into large plates, for mirrors and large panes; all materials must be very pure. The arrangement for casting the ton of glass into the forms are very interesting, and must be seen personally, at St. Gobin, in France, or at Ravenhead, in England, to be appreciated.

Bottle glass is composed of the coarsest materials of silex, soda, lime, oxide of iron, and clay. It is generally of less specific gravity than any other variety; it is tougher and resists chemical action. In New Jersey, green sand is added to spread glass for beer bottles, etc., etc.

Lead glass comprises three varieties, crystal, flint glass, and strass, differing in the proportions of litharge and red lead they contain; it may be shown that crystal glass contains but little oxide of lead, in comparison to the famous paste called strass, which contains more oxide of lead than silica. The crystal glass is composed of 100 parts of silica, ten parts oxyd of lead, thirty-five parts purified potash, and thirteen parts carbonate of lime. The common flint glass contains 100 parts silica, sixty-six parts oxide of lead, twenty-six parts purified potash, and seven part saltpeter. Optical glass contains 100 parts silica, 100 parts oxyd of lead, twenty-three parts purified potash, and a very small proportion of saltpetre and borax. Strass contains 100 parts silica, 133 parts oxyd of lead, and thirteen parts purified potash. The dried and mingled materials are then thrown into the white-hot melting pots, and when full of melted glass, the mouths of the oven are closed. Some heavy combinations of lead sink to the bottom, while the salts, which will not incorporate with the glass, rise to the top as a scum, called *glass gall* and *sandiver*. The greater part of this is skimmed off.

Strass is the basis of a beautiful glass, and was invented in the seventeenth century by a man named Strass, of Strasburgh, who first conceived the importance of imitating the real gems as respects their hardness, specific gravity, and refraction of light, and the white mass obtained by his receipt has produced a beautiful base for imitating the diamond, the rock crystal, and the white topaz. It is now manufactured in large quantities in France, as a base also for the production of all other colored gems, such as ruby, emerald, sapphire, amethyst, aquamarine, garnet, chrysoprose, opal, hyacinth, rubellite, indigolite, or blue turmaline, chrysolite, turquoise, lazulite, and agate. Although the properties which are usually considered as constituting excellence in glass for ordinary purposes may be easily obtained, yet in glasses for optical instruments, and to be employed in the examination of objects so remote and so minute as to require the most undeviating accuracy, the difficulty of obtaining the metal (or the mass) sufficiently free from the defects to which glass is incident, has until a late period baffled every attempt to produce a lens, except of comparatively small dimensionns; although purity, unchangeableness of color, transparency, and a certain degree of refractive power may be obtained, but perfect uniformity in the structure of the glass, so as to render its composition absolutely homogeneous in all its parts, is not so easy to be accomplished, and it is precisely this quality which is the most indispensible in the manufacture of optical glass. The achromatic telescope has been of the utmost importance in the science of astronomy. Galileo, Dolland, D'Artigus, Guinaud, Utzschneider, Bontemps and Ross have all contributed to accomplish the object; Frauenhofer and Fresnel have carried off the palm in the solution of these great problems. The telescope and microscope of 1869 are proofs of what has been done in this department of applied science.

The artificial gems as prepared by the Royal Porcelain Works in Berlin, are composed of a frit of 6 drachems of carbonate of soda, 2 drachems burnt borax, 1 drachem saltpetre and 3 drachems red lead and 1½ ounces fine white sand. The colors to be given for the various imitation gems are as follows:

Sapphire: 10 grains carbonate of Cobalt;
Opal: 10 grains oxide of Cobalt, and
15 " " manganese,
30 " " iron.
Amethyst: 5 grains carbonate manganese.
Gold Topaz: 30 grains oxide of uranicum.
Emerald: 20 grains proloxide iron, and
10 " carbonate of copper.

The various uses of glass.—When we consider the many uses which glass is applied, its cheapness, its purity, its beauty, we find that it possesses the valuable qualities of nearly all the metals;—incorruptible as gold, clear as silver, useful as iron, what would our houses be without it? It keeps the cold out, it lets the light in. We drink out of it, and we see ourselves in it. Besides fulfilling a thousand common and domestic uses, it is made into gems that rival the brilliancy of the diamond, and into lenses which give new realms to human vision. It restores eyesight to the aged, and remedies the defective eyesight of the young. It magnifies objects invisible to the naked eye, so that they can be distinctly seen and studied; and it brings the heavens near. To it we owe our intimate acquaintance with the stars. The telescope is the father of modern astronomy, and the soul of the telescope is glass.

Colored Glass.—With few exceptions, the oxides of the heavy metals possess the property of producing with silica colored compounds, which may be combined with ordinary glass, the latter being, when pure, a colorless compound of silica with oxides of the light metals. The light metals are, potassium, iodine, calcium, magnesium, aluminium, etc. The heavy metals used to form colored compounds are, iron, copper, cobalt, antimony, gold, uranium, manganese, chromium, etc. Lead is an exception, as its oxide forms no colored compound with silica, but a perfectly transparent and colorless one; in fact, it transforms common glass into flint-glass. There are two methods of coloring glass; one is to mix the metallic oxide intimately with the material of common glass, or of the flint-glass, and put both together into the pot; this kind of glass is therefore called *pot-glass*, and is only used for the colors produced by the cheaper metallic oxides. The second method produces the so-called *flashed* glass, and consists in covering only the surface of colorless glass with a very thin layer of the colored glass. This may be accomplished in two ways. By having two pots, one with colorless and one with colored glass, and dipping a globe of hot colorless glass into the pot with colored glass, a layer of the latter will adhere, and by the dexterity of the workman may be extended over the whole surface of the object he is making, be it a goblet or a window-pane. The other way is by means of a brush to cover the glass object after it is made with a cream-like mixture containing the coloring metallic oxide. After it is dry, it is placed in a suitable furnace, and heated as highly as the glass can stand without melting. It is then slowly cooled, and the operation repeated if the layer applied has not been fused sufficiently to combine with the surface. It is evident that this coloring layer must be slightly more fusible than the original glass object, and this is a very delicate point. If the colored mixture be too fusible, it will melt and run down; if not fusible enough, the original glass itself may become soft before this combination has taken place.

The art of painting on glass consists chiefly in the preparation of the diverse metalic oxides, which, by previous tests, are known to produce certain colors. The operation is rendered peculiarly difficult from the fact that, at the time the colors are used by the artist, they all look nearly alike, being a dirty brown. The desired colors appear only after the pane of glass on which the painting has been made is exposed in a furnace to such a heat as to melt the compound and cause it to combine, to a greater or lesser depth, with the surface of the colorless glass beneath. In olden times this art was highly esteemed, as is evidenced by the painted windows in many churches on the European continent, some of which are justly celebrated as containing master-pieces of the highest artistic merit. Among them stand foremost those in the Protestant cathedral in the city of Gonda, Holland, a Christian Mecca for lovers of peculiar art productions. Among the common people of Europe an idea prevails that some secret in regard to this art has been lost; this, however, is by no means the case. The manner and means of their production have always been perfectly known; but we no longer have the artists who devoted their lives to the practice of this very difficult and hazardous department of art.

In this kind of work, as in the preparation of colored glasses in general the effects are calculated for transmitted light, the colors being transparent. On the other hand, enameled and opaline glasses are intended for reflected light, and in such cases, opaque or semi-translucent glass and colors are used.

In general, it has been found that it is easier to color glass when it contains lead, that is to say, flint-glass; in fact, all the imitations of precious stones, gems, etc., are made from a very soft lead-glass, its fusibility and aptitude to take the color being greater, and its brilliancy being more marked. Soda and lead oxides make glass more brilliant and fusible, but at the same time very soft, whence the name of paste, which is applied to this compound, such imitation stones being in reality as soft as a paste when compared with the genuine gems, whose hardness is so extreme that they never lose their polish and original lustre, as is the case with imitations. For this reason, the so-called doublets have been introduced, in which a thin genuine gem is pasted on the exterior or exposed surface of an imitation of the same color made of soft glass. This is extensively practiced in the East Indies, and such stones will of course retain their polish, but can never be fully as brilliant as the genuine article.

The coloring materials for glass are the same as for the imitation gems, only in glass any variety of color may be used, while in the imitation of gems we can adopt only such peculiar colors as resemble special gems.

Yellow glass.—This is produced as follows: 1st. A dirty yellow by charcoal, passing into a dark brown if the coloring agent be used in excess. 2d. A beautiful bright yellow by antimony, in the state of the so-called glass of antimony, or antimonite of potash. 3d. Silver in combination with alumina, in the state of chloride of silver and clay. 4th. Uranium, in the state of oxide, produces a beautiful but expensive canary yellow; this glass is very interesting to the scientist, as, by being exposed to electricity in the dark, it becomes illuminated by a peculiar greenish fluorescence.

Red glass.—1st. Iron, used in the state of bloodstone or ochre as derived from the nitrate, gives a cheap brownish-red color, whose quality depends on the purity of the sesquioxide of iron used; the protoxide gives another color, to which we shall refer hereafter. 2d. Copper, in the state of suboxide, gives a very brilliant red, which has long been known. A peculiarily is that this glass looks nearly colorless, with a slight tinge of green, when leaving the furnace, and only becomes red when, after cooling, it is heated a second time. As this red is so intense as to make the glass opaque if not used in very small quantity, it is always flashed. 3d. Gold, in the form of purple of

Cassius, gives a scarlet, carmine, rose, or ruby tint; as it is very expensive and intense, it is always flashed.

Orange glass is made in Bohemia, from a glass of antimony, red lead, and a little oxide of iron.

Violet glass.—Manganese, in the state of peroxide; care is to be taken that no coal or soot shall come in contact with it during the melting, as the carbon would reduce the peroxide to a protoxide, which gives no color at all.

Blue glass.—Oxide of cobalt, in its different forms as smalt, zaffre, etc., is the only true blue color produced in glass; the shade and tone is modified by different quantities and admixtures.

Green glass.—1st. Protoxide of iron, in small quantity; the resulting glass has little brilliancy. 2d. Peroxide of copper gives a beautiful emerald green; if the glass contains lead, it is more brilliant still; if the glass is not transparent, but dull or only translucent, it becomes deep blue. 3d. Chromium, in the state of the sesquioxide, or genuine pure chrome green, gives a brilliant grass-green color. It bears a high price. 4th. A mixture of the oxides of nickel and uranium; this is used in Bohemia, where the color produced is called modern emerald-green, to distinguish it from the peroxide of copper green, which they call ancient emerald-green.

Black glass.—A mixture of forge-scales, (protoxide of iron,) bone-ashes, (phosphate of lime,) and charcoal, (carbon,) in excess, added to ordinary materials, makes a black glass, which in Bohemia is called jasper; it is perfectly opaque, very hard, and possesses a remarkable lustre. Its properties are such that it may be used for boiling liquids without risk of breakage. It is reported that in Bohemia basalt or lava is used, with or without the forge-scales.

Bronze colored glass.—If, in the last recipe, lead slags are substituted for the forge-scales, an opaque yellowish bronze-colored jasper is produced. Bottles of the opaque blackish kinds of glass are now extensively used by chemists and photographers, to protect many chemicals that are sensitive to light against its decomposing influence. These bottles are mostly imported from Bohemia.

INDEX.

ERRORS,

WHICH HAVE BEEN OVERLOOKED, AND WILL BE CORRECTED IN THE NEXT EDITION BY THE AUTHOR.

For	refractory,	read	reverboratory,	page	13,	4th	line.	
"	silica,	"	silicic,	"	18,	1st	"	
"	when,	"	then,	"	22,	10th	"	f. b.
"	shist,	"	schist,	"	34,	10th	"	"
"	fine,	"	fire,	"	35,	14th	"	"
"	acidity,	"	alkali,	"	42,	1st	"	"
"	silification,	"	silicification,	"	58,	13th	"	"
"	linicular,	"	lenticular,	"	75,	2d	"	"
"	sillification,	"	silicification,	"	113,	6th	"	"
"	do.	"	do.	"	113,	16th	"	"
"	do.	"	do.	"	114,	11th	"	"
"	do.	"	do.	"	131,	10th	"	"
"	appled,	"	applied,	"	133,	2d	"	"
"	sillification,	"	silicification,	"	140, at the head, and the whole chapter.			
"	eolite,	"	oolite,	"	283,	2d	line.	
"	siluvian,	"	silurian,	"	300.			
"	is,	"	are,	"	297.			
"	ooletic,	"	oolitic,	"	295.			
"	group,	"	gravity,	"	289.			
"	150,000,000,	read	150,000,	"	309			