the behavior of hydrogen and palladium, the author described the apparatus he had used in his experiments, and showed it in operation. A vertical platinum tube provided with a palladium cap is inclosed within a glass vessel through which hydrogen and other gases may be passed, and outside the glass vessel is a vapor jacket by means of which a constant temperature can be maintained. The lower end of the platinum tube communicates through a graduated capillary tube with an adjustable manometer, which enables the volume of the inclosed gas to be kept constant.

Great precautions were taken for insuring purity and dryness of the gases used. After filling the palladium and platinum tube with dry nitrogen at atmospheric pressure and the desired temperature, hydrogen was passed through the glass vessel. Some of the hydrogen permeated the palladium walls, thus increasing the pressure inside. After some time (usually an hour or so) the pressure attained a steady value, and the total increase was then observed. Experiments were made with air, nitrogen, nitric oxide, nitrous oxide, carbon dioxide, carbon monoxide, and cyanogen in the palladium tube, and in some cases the hydrogen was diluted with nitrogen. In all cases the maximum pressure of the hydrogen within the tube was less than that of the hydrogen outside the tube.

After the palladium had been used once or twice, it became coated with mercury (vaporized from the manometer), and lost its permeable properties. It was found necessary to heat the tube to remove the mercury, and then dissolve off the oxide of palladium thus produced after each experiment. The permeable nature of palladium was found to depend greatly on the temperature, for at 232° Cent. the passage of hydrogen was so slow that the internal pressure was still rising after ten days; at 330° the passage was very rapid. An attempt to use the apparatus for giving a continuous indication of the amount of hydrogen in coal gas failed, because the palladium did not retain its activity sufficiently long. Other experiments showed that nickel is impervious to carbon monoxide.

In the latter portion of the paper the author discusses the various "so-called" explanations which have been given of the phenomena, but finds none satisfactory. Experiments in the absorption of gases by platinum and other metals are in progress, with a view to the further elucidation of the subject.

Mr. Mond thought the fact that rise of temperature accelerates diffusion tended to confirm Graham's view that the gases pass through openings in the solid, for increase of temperature would widen any pores which might exist in the metal.

The president inquired whether the author's argument against the possibility of palladium hydride condensing in the pores of the metal, because of its being unstable at the temperatures employed, would be affected by the fact of water being capable of existing in contact with glass at temperatures much above boiling point.

In reply, Professor Ramsay said the president's suggestion might be true, but if so another condition must be fulfilled, viz., that the hydrogen molecules must be split up into the atomic or nascent state.

THE LIQUEFACTION AND SOLIDIFICATION OF AIR AND GASES.

By HENRY WURTZ, Ph.D.

MATTER is generally classed under three distinct forms—solids, liquids and gases. This is popularly accepted and regarded as a sound division and definition.

But it is now well recognized by science that there are various intermediate forms between the perfectly solid and perfectly liquid states of matter. Absolute solidity involves rigidity, pressure leading only to fracture. From this some have held that all true solids are crystalline in structure. But there are true solids whose form can be changed only by fracture, yet totally devoid of crystallinity. Gelatine (solid) is one good example; shellac another. But among the solid bodies most handled by mankind, such instances as these are rather exceptional. An increase of pressure over that of the atmosphere will in most cases change the form of a substance seemingly solid, without fracture, proving more or less flow of its internal molecules. Some substances, like asphalt, pitch, paraffine waxes, etc., change their forms by their own weight, and, like liquids, return to their level (though slowly), unless kept very cold; and there are few substances which do not, on rise of temperature, develop these semi-liquid, plastic or malleable and viscous or ductile consistencies. Some require for this more, and some less, heat. There are also gelatinous substances, like India rubber and others, which resemble liquids in returning at once to their level (so to speak). Such possess plasticity and elasticity combined. These facts have been somewhat dwelt upon to show that our accepted classification into solids and liquids is not a natural one, and applies with strictness only to extreme cases. Mere changes of temperature subvert it and throw it into confusion.

Between the liquid and gaseous forms of matter, however, there are as yet no distinct indications of any intermediate conditions, unless we consider the vapor state as being such. In the case of saturated steam, for example, it is familiarly known that the vapor, when first formed, at 212°, contains some 966° per pound of "latent heat" of vaporization. But it is not so well known—indeed has apparently escaped attention altogether, so far as the writer knows—that, according to the accepted formula of Regnault, on rise of temperature this latent heat gradually diminishes and must become free or sensible heat of temperature. At about 1,600° Fah. it should altogether disappear, and steam should then become perfect gaseous water. Through ignorance of this, all calculations of flame temperatures (except those of Bunsen) have been vitiated. It is probable that this applies to all volatile liquids and to liquefied gases, being possibly connected in gases with the rapid departures from the law of Boyle above 10 atmospheres of pressure.

The first gas converted into a liquid was chlorine, in 1805—the history of this subject being, therefore, now about ninety years old. This liquid was discovered by an English chemist named Northmore, by applying a pressure of some 90 pounds per square inch to chlorine

gas cooled by ice. It remains liquid, under the ordinary pressure of the air, at 29° below zero Fah. It is very difficult, however, to solidify, not freezing at 130° below zero. It is yellow and one-third heavier than water. It is now manufactured and sold, inclosed in strong reservoirs, for bleaching and disinfecting uses. It has other uses also, some of recent discovery and of high importance, which cannot be explained here.

Eighteen years passed before the great chemist Faraday, in 1823, took up the subject of the liquefaction of gases. His inventive genius at once struck out a new path—followed in this fertile field, in certain ways explained below, up to the present day. This was to generate the gas to be liquefied, by heating a compound or mixture that evolves it in one limb of a glass siphon, both ends of which were sealed. The other limb of the siphon was immersed in a freezing mixture when found necessary. The gas was thus liquefied in the cold limb by the pressure proceeding from its own expansion. He thus obtained new liquid bodies from gaseous carbonic acid, sulphurous acid, nitrogen trioxide, laughing gas, cyanogen, ammonia, olefiant gas; and from hydrochloric, hydriodic and hydrosulphuric acid gases. So that, up to 1823, over seventy years ago, eleven gases (including chlorine) had been liquefied. Thenceforth all chemists believed that we would ultimately attain to the means of liquefying all gases. But a "weary time" passed before these anticipations were realized. It was more than half a century (55 years) before hydrogen, the last of them, yielded, in 1878. The heaviest pressures that could be contrived by mechanical devices were applied to all, in conjunction with the greatest degrees of cold then attainable, with few results further than those already obtained by Faraday. Modes were found, however, which are now employed for obtaining some of Faraday's products on a commercial scale.

There were especially certain individual gases, as oxygen, nitrogen, hydrogen, nitric oxide, carbonic oxide, marsh gas (natural gas, fire damp) and acetylene, which presented a peculiar behavior. After being compressed very heavily they underwent little or no further condensation by further compression, but nevertheless did not become liquid. These were for a time given up by most chemists, and designated as "incondensable gases." It was not until 1860 that the English chemist Andrews made a certain discovery which created much sensation in the scientific world. Carniand de la Tour had made similar experiments in 1822, but had not recognized their real significance. Andrews called his discovery that of a "continuity" between the liquid and gaseous states of matter. The application of this expression is not clear. It is a familiar fact that if a vapor of a volatile liquid, such as ordinary steam, be submitted to pressure, a certain amount of it will be compressed into the liquid form. Andrews found, however, that when any such vapor reached certain temperatures differing with the vapor, no pressure whatever would effect the smallest liquid condensation. Such temperature he called the "critical temperature" of the gas or vapor, which is a good term. That for steam is about 685° Fah.; that for carbonic acid gas, 87½° Fah. In other words, at and above their critical temperatures, liquids boil inevitably, under all pressures however high. They boil and spring into vapor, even when the whole space is filled with the liquid, and in that case we get vapors as dense and heavy as the liquids themselves. It appears therefore that liquids possess real boiling points independent of pressure. The significance of this principle, in many ways, is enormous. As an example, its application to volcanic theories.

This principle having been recognized, it followed, as a matter of course, that the "incondensable" gases had never yet been cooled down below their critical temperatures, and could not therefore have been liquefied by any pressure, however great. This gave a new impulse to the workers in this field of experiment, and they devised improvements in the modes of obtaining low temperatures, mostly founded on what may be called cumulative freezing methods, which had already been much used with solid freezing mixtures, and which were now applied to the production of more intense cold by the evaporation of one liquefied gas, which had been previously chilled intensely by the evaporation of another liquefied gas, and so on still further. Moreover, another device was introduced in combination, the use of air pump exhaustion for increasing the rapidity of these successive evaporations, and thus further intensifying the cold greatly. As an example, one liquid used in this way has been liquefied olefiant gas, or ethylene, which, though it can be liquefied under heavy pressure, even at the ice temperature, has the wonderfully low boiling point of 157° below zero Fah., and in a vacuum 213° below. When this liquid ethylene has been chilled by the evaporation around it in a vacuum of liquid sulphurous acid, and then this chilled ethylene itself boiled in a vacuum around a tube or vessel containing oxygen gas or air, the latter becomes liquefied.

By the above method, substantially, the Russian chemists Wroblevsky and Olszewski liquefied oxygen, nitrogen, marsh gas, etc. For liquid oxygen they found the boiling point 294° below the Fahrenheit zero, and for its specific gravity at this temperature a maximum of 1.137. A curious circumstance is that these chemists obtained their oxygen as a colorless liquid, whereas both Pictet and Dewar have uniformly reported liquefied oxygen as exhibiting a light blue color. The boiling point of liquefied nitrogen was as low as 318° below zero; and its specific gravity at the boiling point 0.83.

Dewar had also used liquefied ethylene largely in liquefying oxygen, nitrogen and air, in recent public lectures in London and elsewhere. He has even gone a step further and by surrounding a tube containing dry air with boiling liquefied oxygen, first obtained by means of the boiling ethylene, and applying the air pump, he has not only liquefied the air, but frozen it solid. Such frozen air has also been produced by Pictet.

By similar processes—and with apparatus which would require cuts to make clear—the French chemist Cailletet, and the Swiss chemist Pictet, of Geneva, succeeded first, almost simultaneously, in liquefying the lightest of the gases, hydrogen, and the last named went further still, obtaining hydrogen in a solid form, though not so that it could be handled and closely examined. Cailletet's results were obtained on Decem-

ber 30, 1877, and Pictet's on January 10, 1878, the interval between being but eleven days. Indeed Pictet's results were the first published to the world. Cailletet's methods had the great advantage over those of Pictet, that his liquid hydrogen was condensed in a glass tube, so that it could be seen, while that of Pictet was obtained only in an opaque metallic cylinder. Many chemists had expected that when hydrogen should be liquefied, it would turn out to be a metallic body, say like quicksilver, at least in aspect. But Cailletet's liquid did not justify this expectation, being transparent and colorless. Pictet, who obtained jets of his liquid hydrogen from his metal cylinders, says that when brightly illuminated by an electric light, these jets presented an opaque steel blue color; implying that he regarded his product as metallic. This may have been an illusion, though, considering the source of the statement, this is hard to credit. Pictet's pressure for hydrogen liquefaction was 360 atmospheres, or 5,300 pounds per square inch, and his temperature 236° below the Fahrenheit zero. He states that when the jets referred to, or the spray from them, fell on a solid surface, a rattling sound was heard, as from seed or small shot. This of course argues that the hydrogen was frozen solid by the cold from its own evaporation. With regard to Cailletet's work, it may be added that he liquefied also with his apparatus and methods, oxygen, nitrogen, marsh gas, carbonic oxide, and acetylene.

The *cui bono*? the question as to what utilities to mankind are to follow from these conquests over the "incondensable" gases, made within the last seventeen years, it remains for the future to answer. Scientific discoveries have often been compared to babies, which have to be reared up to maturity with expenditure of care, time, labor and money, and whose future utility to mankind may be small, or very great, as may have been decreed by the Creator of all. This parallel, however, is in one respect totally fallacious. The baby has but a transient race to run, while the scientific conquest over nature, once made, is for all time. The same cry of *cui bono*? was raised regarding the earlier discoveries of Faraday and others, in liquefying the more easily condensable gases. Let us see what has been the outcome already, within seventy years, of these earlier discoveries—by considering some of them individually, introducing such details as may interest both the practical man and the general reader.

Carbonic Acid Gas (Carbon Dioxide).—This requires for liquefaction at 60° F. 565 pounds pressure per square inch, or 38½ atmospheres. It forms a transparent, colorless, highly mobile liquid, that floats on water. Its specific gravity varies much, as obtained by different skillful chemists, the following figures having been found, all at 32°: 0.83, 0.909, 0.93 and 0.9471. This is analogous to the case of carbon itself, as is familiarly known, in its different polymeric forms of charcoal, gas carbon, graphite, diamond, etc., so that there must be similar polymeric forms of liquid carbon dioxide. It may be added that the figures obtained for the specific gravity of carbon dioxide, even in gaseous form, present two distinct sets, as found also in the case of gaseous oxygen and ozone. This, with similar facts relating to vapors of sulphur, and some other bodies, implies the prevalence of such polymeric forms in gases, as well as in liquids and so ids.

Liquid carbonic acid is the most expandable body known (with certainty); being more expandable than air. Thus, while 100 volumes of air (or other gas) at 32° become at 42° 102 volumes, 100 volumes of liquid carbon dioxide at 32° become at 42° 103½ volumes. Some other liquefied gases expand more than air. Its boiling point, in the open atmosphere, is 109° below zero. In Europe, where it has now for a number of years been manufactured and sold, and exported throughout the world, condensed in strong iron cylinders, it has been long since proposed, and probably used, for ice manufacture; being much the cheapest of the liquefied gases. For refrigeration of vessels, cars, warehouses, etc., it is the least objectionable among them, and has been preferred especially for steamers. In Krupp's works, at Essen, it has been employed for bringing enormous pressures to bear on melted steel in moulds, to prevent the formation of "blow holes." The most extensive use is of course for making mineral waters, and for aerating wines and other beverages. Experiments are said to be in progress now for perfecting and extending its use as a motor agent, for which it has hitherto been confined mainly to torpedo boats. A highly important use, which should be developed and extended as fast as possible, is for extinguishing fires in inclosed spaces, as on shipboard, in warehouses, etc. It has been used for raising sunken vessels with success; and a German ironclad is stated to have been thus raised.

When this liquid is allowed to spurt out into the air in a small jet, so much cold results that a portion is frozen into a mass resembling snow or magnesia. This, mixed with ether to a sort of slush, forms a freezing mixture of a temperature of 110° below zero. It is not an electrolyte, and is a poor electric conductor. Its solvent powers on other bodies are feeble.

Sulphurous Acid Gas (Sulphur Dioxide).—The gas formed when sulphur burns in the air. It is extensively employed in liquefied form, mainly for ice making and refrigeration generally, by Pictet's methods. It is also very cheap. It is an invaluable disinfectant, insecticidal and germicidal agent, and is used also largely for bleaching purposes. Its extensive introduction into commerce in liquid form, in portable reservoirs, is an assured thing of the near future. Liquid sulphurous acid boils at a temperature so (comparatively) high, 17½° F., that its liquefaction may be shown by sudden compression in a glass syringe. By its evaporation a current of air, a cold of 50° below zero is obtainable—low enough to freeze mercury. In a vacuum it freezes by its own evaporation to a snow-like mass. The specific gravity of the liquid at 32° is about 1.43. Its lower tension at ordinary temperatures makes it easily manageable. It dissolves iodine, sulphur, phosphorus, and resinous bodies. Pictet obtained with it, by rapid exhaustion of the vapor from the liquid, a cold of 85° below zero, with which he succeeded in liquefying carbon dioxide and laughing gas, at the comparatively low pressures of 59 to 103 pounds per square inch; using the latter in his operations for the liquefaction of hydrogen.

Ammonia Gas.—This, in liquefied form, is now a quite familiar agent. The large establishments for

artificial ice manufacture, and many of the "cold warehouses" and refrigerated cars employ it. The movements now being made to distribute refrigerated air throughout cities are also destined to develop immensely the preparation and use of liquefied gases. The methods of the French inventor Carré, with liquefied ammonia, are, so far, the most important of these developments. They depend on producing cold by the evaporation of liquefied ammonia, the gaseous ammonia thus formed being absorbed by cold water, which at 32° takes up 87½ per cent. of its weight of ammonia. Liquefied ammonia is then reproduced by warming this solution, and passing the cooled ammonia gas evolved into a confined space, where it liquefies again by its own pressure; after the original device of Faraday. Thus, not only have the new bodies, the liquefied gases discovered by Faraday, over which the *cui bono?* lament was made, come into extensive and increasing practical use, but even his novel modes of preparation and handling of them have been adopted and adapted by inventors and manufacturers. We therefore owe to the genius of this chemist the most essential elements of the valuable modern art of making artificial ice from purified and sterilized water. It is stated that by Carré's plans the burning of one ton of coal has made ten tons of ice. Doubtless the manifest superiority of this chemically made ice over nature's purest product will soon lead, as it should, to the entire displacement of natural ice in our cities at least.

Liquefied ammonia is a very remarkable body, and has properties and utilities yet undeveloped. One of the most surprising was discovered by an American chemist, Charles A. Seeley (now deceased). He found that this liquid ammonia has the power to dissolve certain solid metals, as the alkali metals, sodium, potassium and lithium, forming transparent blue solutions—not compounds, but true solutions. This latter he proved by showing that on mere evaporation of the ammonia, the metals were left with unchanged properties.

Liquefied ammonia has the specific gravity at 32° of 0.6864, and its tension at 60° is over 1,000 pounds per square inch. So that, as a commodity for transportation, the risk is certainly considerable. There are other valuable uses that will arise out of this high tension, together with its rapid absorption by cold water.

Chlorine Gas.—This was the first gas liquefied, as mentioned before. It is easily and very cheaply prepared by the Weldon-Pechiney process, though in admixture with other gases. But on compression of the chlorine to liquid form, it should be separated from these foreign gases.

Laughing Gas (called by chemists nitrous oxide, or, more strictly, dinitrogen monoxide).—This is another gas that has been introduced into commerce in cylinders, in liquefied form, notwithstanding its very low boiling point, which is away down to 126° below zero—implying an exceedingly high pressure at ordinary temperatures. It would appear safest to transport this agent in aluminum-bronze cylinders in refrigerated cars or vessels, and transfer it, for sale and distribution, to portable reservoirs in highly compressed gaseous form only. It is now just half a century since, in 1844, the first tooth was extracted from Dr. Horace Wells, of Hartford, while under the influence of laughing gas, by Dr. Colton. This was doubtless the first public practical demonstration of the grand discovery of *anæsthesia*, though it is believed by many that the Boston chemist, Dr. Charles T. Jackson, previously knew of ether *anæsthesia*, and had employed it privately.

Besides its universal dental uses, laughing gas is now held by numerous orthodox physicians to be a general remedial agent of high value, especially in nervous disorders, insomnia, and even in the terrible forms of mania called melancholia. This liquid is one of those which, like liquid carbonic acid, expand with rise of temperature more than gases. When poured into water the latter suddenly freezes solid, and there is an energetic explosion, from rapid gasification of the nitrous oxide. An interesting lecture experiment is to pour it over some mercury in a glass, and then throw in a piece of lighted charcoal. The mercury instantly freezes solid, and remains so, while the charcoal undergoes the most dazzling combustion in the nitrous oxide gas.

Pictet has not long since claimed that by the use of the intense cold of liquefied gases a number of chemical and medicinal agents can be obtained *absolutely pure*, impurities being either frozen out or remaining behind unfrozen on the solidification of the general mass. He mentions alcohol, ether, chloroform, etc. Coal tar benzole has long been purified by congelation. Pictet has been engaged during the last year in investigating the power of these excessively low temperatures in disinfection and the destruction of disease germs. Last September he reported almost incredible results, inasmuch as they included the fact that pathogenic bacteria actually retain their venom undiminished at a temperature more than 350° below the Fahrenheit zero! He produced this cold by means of atmospheric air frozen solid—air-ice we might call it—such as Dewar also has recently produced. Dewar has lately confirmed the above extraordinary fact at least down to 296° below zero, and has also found that the vitality or germinating power of some seeds was not destroyed by this latter temperature.

Dewar has been in later years one of the most industrious and successful experimenters in the field of gaseous liquefaction; especially with reference to the liquefaction (and solidification) of air and its component gases. He has improved the modes of preparation, so as to obtain these liquids, as reported, "by the pint." He takes highly compressed oxygen, and first chills it by the evaporation of liquid laughing gas, and then submits it to the cold produced by the boiling of liquefied ethylene in a vacuum. Nevertheless Dewar obtains in liquid form, as he states, but one-tenth of the oxygen he operates on. This illustrates well the present embryonic stage of the subject. Dewar has further discovered a most important mode of handling liquefied air and oxygen in open vessels, without the constant ebullition that has heretofore made it impossible to observe closely the properties of these bodies. This mode consists in jacketing the glass vessels containing the liquids, which are hung up in mid air, to avoid heat from contact with glass jackets, that is making them with double walls, and then exhausting

absolutely all the air, by improved mercurial pumps, from the interspace. He states that even a thousand millionth part of the air left in this interspace will manifest its presence by convection of heat to the liquefied gas.

Pure liquid oxygen he finds to have a pale blue color and to be taken up by a magnet, having one thousandth part of the magnetic attractability of soft iron. Faraday long ago discovered the magnetic quality of gaseous oxygen. Dewar finds, contrary to views hitherto held, that intense cold intensifies magnetism. A bar magnet increased in power in liquid air 50 per cent. His most remarkable results, among many, relate to the effects of these low temperatures on metals.

First: Their tensile strength is increased very greatly. A piece of iron which stood 34 tons stress increased to 64 tons in liquefied air; 88 per cent. increase.

Second: The electric resistance decreases so much that Dewar concludes that at what is called the "absolute zero," "all metals should become perfect conductors!"

MANUFACTURE OF OXIDE OF ZINC.

THE zinc ores from which oxide of zinc and spelter are manufactured come principally from the States of New Jersey, Pennsylvania, Virginia, Illinois, Missouri,

MANUFACTURE OF OXIDE OF ZINC.

and Wisconsin. Oxide of zinc is produced by burning in furnaces a mixture of fine or powdered coal and zinc ore, the burning of the mixture causing a vapor to rise from the mass, which, when coming in contact with the air, forms itself into a white powder.

Spelter is produced by burning the mixture in airtight retorts, the material in which vaporizes and forms itself into liquid zinc. The oxidizing furnaces are made of iron and brick, the inside of which is lined with fire brick. The burningspaces are about 6 feet in length, 4 feet in height, and about 4 feet in width. A charge—of which there are six daily—consists of about 400 lb. of fine coal and about 550 lb. of zinc ore crushed, which is moistened with water. When the furnace is ready to receive the charge, the mixture is put into the oven. After burning about one-half hour, an upper door of the furnace is thrown open to let the gas escape and prevent explosion. As the heat from the burning mass increases, a vapor from the heated ore arises, which is carried off through an 18 inch pipe or chimney, by means of a blast underneath the bottom of the furnace. This blast admits the oxygen, which, coming in contact with the vapor, causes it to form itself into a white powder. Running horizontally and attached to the pipe at the top of the furnace is a 4 foot pipe, which connects itself by an underground passage to a blower, which carries or forces the powder up into what is called the bag room. The pipes from the blowers run across the center of the room, connected to which every few feet apart, on each side, are a number of muslin bags ranging in diameter from 1 to 4 feet. The small bags are suspended to the rafters 50 feet above and are connected at the bottom to the large 4 foot bags, which run horizontally each way across the room, underneath the bottom of which are a number of 2 foot teats. The oxide of zinc is blown from the pipes into these

bags. After a quantity is collected, the blower is stopped and the bags collapse and are shaken by the attendant, causing the material to settle down into the teats, where they are emptied in common bags and then screened and bolted. After being bolted the material passes to the barrel packer. The material passes down through a hopper and into a metal cylinder about the length and the diameter of the top of the barrel. Running down through the center of this cylinder is an upright shaft, connected to the end of which is a wheel similar in shape to that of a propeller. When the machine is in motion the upright shaft and wheel revolve, the material passes out through the blades, at the same time pressing and packing it against the bottom of the barrel, which has been raised on the movable platform of the machine. As the quantity increases through the blades, the barrel gradually lowers until filled and another takes its place. The spelter furnaces are also made of iron and brick. They are square in shape and worked from both sides, the furnaces being divided off by a fire brick wall about one foot in thickness running across the center. The distillation is carried on in cylindrical fire clay retorts. These retorts are about 5 feet in length and about 1 foot in diameter and 1½ inches in thickness. There are 56 of these retorts on each side, placed in rows, so that they can be encircled by the fire and heat, the inner ends resting on projecting shelves in the center wall and placed so that the inner ends are a little higher than the other.

When the retorts are all in position they are filled with a mixture of fine coal and ore, the attendants putting the material in by means of semi-cylindrical shovels, the operation taking about three hours, each retort holding about 125 pounds. After the retorts have been filled conical shaped tubes or pipes of fire clay are plastered in the mouths of the retorts and the fires started. These conical tubes or condensers are

about 18 inches in length, about 5 inches in diameter at the base and taper down to about 3 inches at the mouth. As the temperature increases, small jets of flame of different colors issue from the mouth of the condensers; when it becomes a dazzling white it shows that the material is vaporizing and forming into liquid zinc, which begins running into the condensers. The condensers are drawn every 24 hours, the attendants emptying them by means of long iron rods ladle-shaped on the ends. These are drawn back and forth, drawing out the liquid zinc, which runs into iron receptacles held by the attendants. They are then taken away and moulded into 40 pound cakes of spelter. The retorts last from 2 to 6 weeks, the upper ones lasting the longest, on account of their not being close to the fire. The production of spelter in net tons amounts to about 40,000 tons yearly. The sketches were taken from the manufactory of the Passaic Zinc Company, Jersey City, N. J.

GASES IN KILAUEA.*

By WILLIAM LIBBEY, Jr.

In 1865 Mr. W. T. Brigham called attention to the existence of certain bluish-green flames which broke from the crust of Halemaunau during a disturbance of its slag-like surface.

In 1887 Mr. Emerson, of the Geological Survey of the

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