ASSAYING.

THE ASSAYING OF GOLD AND SILVER ORES.

A ton of rocks containing one thirty thousandth its weight of gold, or one fifteen hundredth its weight of silver, can in many instances be worked profitably; this is something like one fiftieth of a grain of gold or four grains of silver per pound of rock or ore. A quantity so small, even if in the metallic or free state when diffused through the rock, is difficult to detect with any degree of certainty by any physical examination or blowpipe test. Chemical analysis by the wet way is in this connection too slow and expensive, and without the greatest care and most expert manipulation the quantitative results in the case of poor ores are apt to be uncertain. The fire assay is by far the most expeditious, certain, and inexpensive method of testing such ores, as well as of quantitatively determining their value.

The apparatus and materials requisite in assaying are as follows:

A balance for weighing ore and fluxes, sensitive to a grain, with a weight of three ounces on each pan, with box of weights.

A finer balance, sensitive to one-tenth milligramme, with a weight of one gramme on each pan, with box of weights.

A small crucible or melting furnace, with hood to carry off the fumes produced in roasting ore.

A cupel or muffle furnace.

Crucible, scorifier, and cupel tongs, muffle cleaner, poker, and shovel, and stone hammer.

Brass moulds for making cupels.

Large iron mortar and pestle for breaking and grinding ores. Fine work with very hard ores also requires an agate mortar and pestle.

Brass wire gauze sieves—80, 100, and 120 mesh. Small spatulas, camel's-hair brush, and glazed paper.

Iron pans for roasting.

Tin samplers.

Moulds for pouring scorified charges.

Crucibles, scorifiers, annealing cups, parting flasks, and test tubes.

Silver foil, lead foil, granulated lead, litharge, floured charcoal, argol, niter, borax glass, boracic acid, bicarbonate of soda, salt, carbonate of ammonia, fine bone ash, and white silicious sand (silica), nitric acid (pure).

The first requisite in any assay is that the whole of the ore or rock to be tested be reduced to a uniformly fine powder or flour and separated from metallic scales or particles, if there be any. This is usually accomplished by breaking with the hammer, and then completing the reduction in the mortar or beneath a muller. The sample in process of reduction is from time to time thrown on the sieve to separate the finer portions and avoid the inconvenience and loss by dust. If any of the metallic particles or scales remain on the sieve these must be weighed and assayed separately, the results first proportioned to the weight of sample of ore taken being added to the results from the powdered ore assay.

The powdered ore should be well mixed together and weighed, then sampled. A handy sampler is made of three or four semi-cylindrical tin troughs cast six or eight inches long, about three-fourths of an inch in width, and one inch deep, placed parallel at a distance equal to their width, and soldered at the ends to a tin or wire frame or support. When powdered ore is sifted over this half falls through the openings, the other half being retained in the troughs, and the portion caught may in like manner be further divided, so that a large sample is reduced to one of suitable size for assay, the small sample correctly representing the large.*

The method of assaying depends much upon the character of the ore and gangue. If the ore contains any considerable quantity of sulphides, arsenic, or antimony it should be roasted. This is usually performed by spreading the weighed sample of ore on an iron pan, previously coated with oxide of iron or chalk, and gradually heated under a hood to low redness until all fumes cease. Carbonate of ammonia and powdered glass or sand is sometimes added to hasten or complete the action and prevent fusing or agglutination.

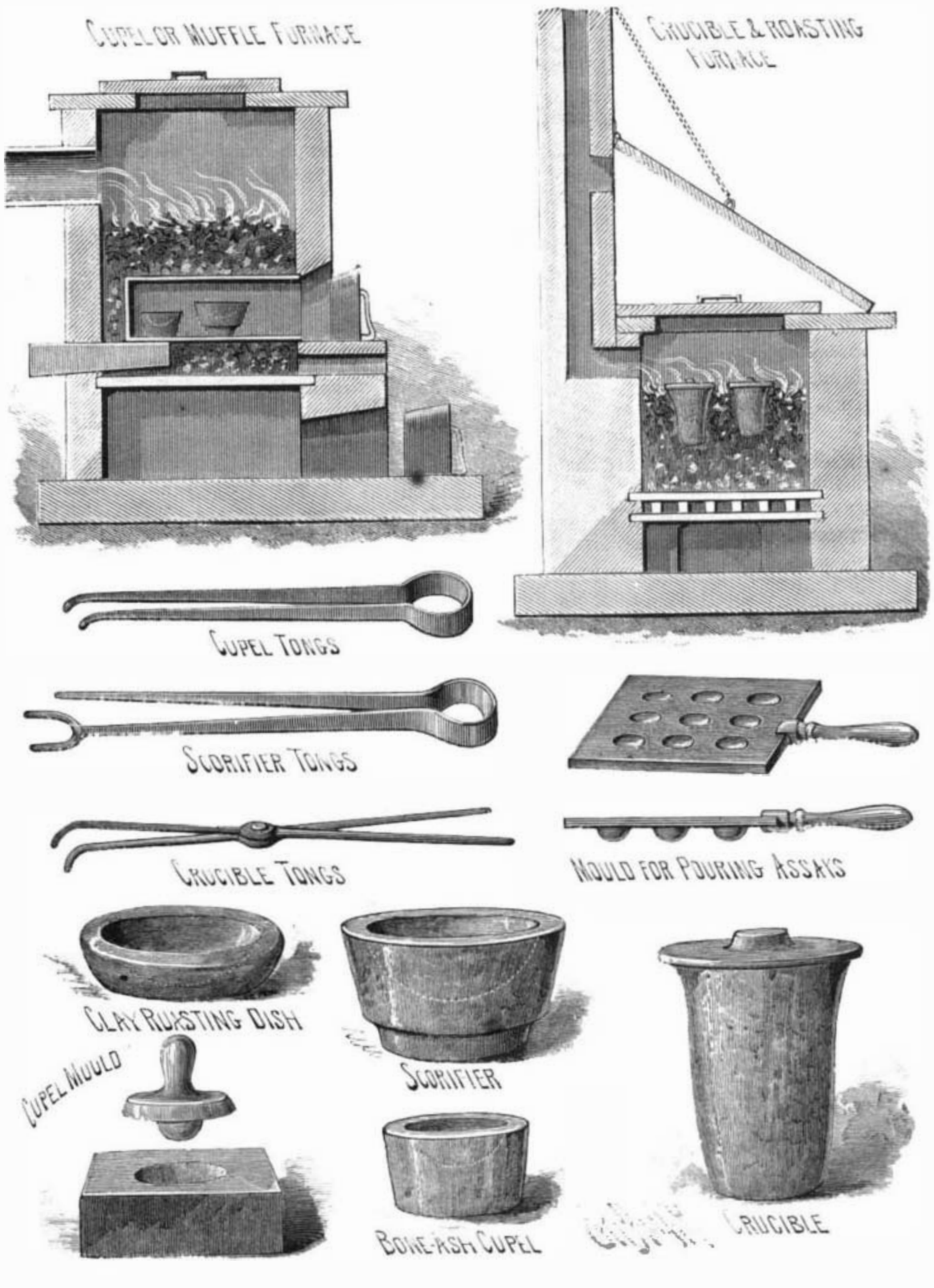
The scorification method is preferable in most cases where it can be applied, but owing to the limited quantity of ore that can be conveniently operated upon in this way its use is restricted to comparatively rich ores. Poor or presumably poor ores are best treated in the crucible which permits the working large samples.

With regard to fluxes, litharge (the yellow oxide of lead), carbonate of soda, and borax are the most important. Charcoal and argol as reducing agents, and niter as an oxidizing agent, are used in connection with them. Salt is used as a cover or wash in the crucible. Lead or its oxide, which is a powerful flux, plays a very important part in the gold and silver cupellation assay. In the crucible assay the oxide (litharge) is always used. The ore or the reducing agents mixed with the fluxes react upon it in such a manner that a portion of it is reduced to metallic lead, which, as the contents of the crucible becomes liquefied by heat, falls by reason of its greater gravity to the bottom of the vessel, washing down and alloying with the liberated particles of precious metal, so that when the crucible has been cooled and broken a button of lead is found at the bottom, and this button, if the assay has been properly conducted, contains all the precious metals.

In the scorification the metallic lead exposed to a current of highly heated air is partially converted into litharge, which, acting as a flux, liquefies the ore, the liberated gold or silver alloying themselves with the unchanged portion of lead at the bottom of the scorifier.

In the crucible assay the following proportions of flux will be found to work well with most quartzose ores:

Ore	1	A. T.
Litharge	2	"
Bicarbonate of soda	1	"
Argol	2½ grammes.	



APPARATUS FOR ASSAYING.

Too much argol will produce too large a button of lead, and too small a quantity the reverse, or none at all. The ore itself acts as an oxidizing or reducing agent in many cases. The use of oxidizers, such as niter, in the crucible are objectionable, and careful attention to the preparatory treatment or roasting will, in most cases, dispense with the necessity of their use Experience alone enables the assayer to judge of the oxidizing or reducing powers of the ores and the proper proportion of reducing material. Charcoal or flour or mixtures of these may be employed instead of the argol. These reducing agents should be in the finest state of division, and free from lumps and thoroughly dry. This applies equally to all the fluxes. Ores containing much limestone require a considerable addition of borax silica or borax acid (anhydrous); a similar addition to the charge is necessary if the ore be argillaceous—that is, slaty or earthy.

The ore and fluxes having been weighed out they are thoroughly mixed together and put into a dry and warm sand crucible, and covered with about one-quarter inch of dry salt loosely packed down. The crucible is then put into the melting furnace and covered with a good fire. Twenty minutes to half an hour is usually sufficient to accomplish the thorough decomposition and fusion of the ore, and the crucible is removed as soon as its contents are found to be in a state of complete fusion. It is allowed to cool thoroughly, then broken, and the button of lead at the bottom removed and cleaned by hammering it on an anvil. The appearance of the slag will indicate whether or not the decomposition and fusion were properly completed. The button of lead is put aside for cupellation (or scorification if necessary).

For the scorification assay the following charge will in most cases suffice:

Ore	$\frac{1}{10}$	A. T.
Granulated lead	3	"
Borax	q. s.	

Two or three pieces the size of peas are usually sufficient. The ore is mixed with part of the lead in the bottom of the scorifier, the rest of the lead being poured over the top and the fragments of borax placed on top. The scorifier must be large enough to admit the charge without filling it. When placed in the muffle, properly heated, the lead and borax melt, the surface of the former by contact with the air becoming converted into liquid litharge, which with the aid of the borax fluxes the ore, forming a ring of liquid slag, which finally covers the whole surface of the lead. As soon as this takes place the vessel is removed from the muffle and its contents dexterously poured into the iron mould, where it quickly chills, and the lead button is removed and cleaned by hammering. If the buttons are too large to be admitted to the cupel (which should weigh at least as much as the button) they must be scorified down; that is, placed in a scorifying dish and exposed in the open muffle. The hot air oxidizes and slags off the lead, and on pouring and cooling this may be separated from the reduced button by pounding as before; in many cases it separates itself.

When the button is of proper size it is dropped into the bone ash cupel, thoroughly dried and heated to bright redness, where it melts, and as the hot air converts the lead by degrees into liquid litharge, and this latter is absorbed into the porous cupel, the button decreases in size until the last of the lead is slagged off and there remains in the bottom of the cupel only the fused bright button of gold or silver or any alloy of these. By too high a heat or overlong exposure in the crucible there is apt to be a loss of silver through volatilization. If too low a heat the litharge is imperfectly absorbed by the dish and the button solidifies ("freezes").*

Gold is nearly always found associated in ores with silver, and the button or bead obtained from an assay usually requires "parting;" that is, the separation of these metals. The button having been carefully weighed is treated with pure nitric acid diluted with half its volume of water, and heated to boiling in a test tube or small parting flask. If the proportion of silver is not less than three to one of gold all the silver dissolves in the hot acid, the gold remaining as a dark spongy mass. If less than this proportion of silver is present the gold protects it from the proper action of the acid, and the silver dissolves out slowly, or not at all. In this case—and a little experience enables the assayer to judge from the color of the button whether enough silver is present or not—silver must be added. Enough silver is cut from the silver foil, wrapped about the button, and this in turn placed in a small cornet of lead foil and placed in a clean hot cupel, where it melts and alloys; the lead soon slags out and the button is ready for the parting in acid as described.

The gold sponge or particles of gold powder obtained in parting is washed by decantation with hot water in a test tube. While the tube is filled with water a small annealing cup or porcelain crucible is placed with its mouth over the tube or flask, which is then quickly inverted, so that the fine gold falls to the bottom of the cup or crucible. By immersing this and the mouth of the flask the latter may be removed without disturbing the gold, which after decanting as much of the water as possible is dried at a gentle heat, then heated to redness to give it coherence, cooled, and weighed.

The greatest care is necessary in weighing assay beads of gold and silver, as, owing to the value of the substances weighed, a very small error may make a great difference in the results.

The decimal or French system of weights are commonly employed in assaying. The *assay ton* is intended to simplify and facilitate the final calculations; the ratio which an A. T. bears to a milligramme is the same as that between a ton (2,000 lb. avoir.) and a troy ounce, so that if one A. T. sample of ore is assayed and found to contain one milligramme of

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*All assays should be made in duplicate to check any error.

*Large silver buttons must be removed with care from the muffle to avoid loss through spatting, occasioned by the escape of absorbed oxygen from the silver at the moment of solidification.

gold or silver it is known at once that a ton of the ore contains just a troy ounce of the metal.

The weight of gold found as above deducted from the weight of the bead before parting (or adding silver) corresponds to the weight of silver.

One ounce of pure gold has a value of twenty dollars and sixty-seven cents. The ounce of silver is worth about one dollar and fifteen cents; it varies with the market.

As nearly all commercial samples of lead and litharge contain traces of silver, those intended for use in assay should be carefully sampled and assayed, due allowance being made for silver found in calculating results.

The Zeromotor.

Mr. Isherwood has recently been employed to report to the United States Government on the merits of a very remarkable proposal made by Professor Gamgee. It will be remembered that this gentleman has given much attention to the construction of ice-making machines; and a few years ago his real ice skating rink in Chelsea attracted a great deal of attention. Of late Professor Gamgee has resided in the United States, and continued to occupy himself with ice and its artificial production. During the early portion of the present year he submitted to the United States Government the proposal to which we have referred, which is that he shall construct a new motor which will, to a large extent, take the place of the steam engine and work without fire. If such a scheme had been brought forward a few years since its inventor would have been regarded as a lunatic. But so much knowledge has been disseminated concerning the behavior of gases, and the conditions under which work is performed, that Professor Gamgee need have no fear now that his ideas will be neglected or passed over without due examination. Apparently the "zeromotor" is "perpetual motion" over again. But the inventor of perpetual motion engines is always trying to produce a machine which will work itself without external aid of any kind. Professor Gamgee's scheme has nothing in common with this. He proposes to utilize natural forces; and his engine would be, if constructed, a heat engine in just the same sense that the steam engine is a heat engine, only he proposes to work at much lower temperatures than the steam engine requires, and to use ammonia instead of water.

In order to make the principle involved perfectly intelligible, let us consider for a moment what takes place in a steam engine. We take water and heat it, thereby enormously increasing its volume, and converting it, in a word, into what we may call, for convenience, a gas. This gas is used to propel a piston against a resistance. It is then suffered to escape into a cool chamber, condensed, or in other words reduced in volume as much as it was before augmented, and pumped back in the boiler. We have thus a complete cycle, and the engine works between two temperatures, that of the boiler, say 320°, and that of the condenser, say 120°, and the efficiency of the engine is determined solely by the difference between these two temperatures. Now let it be supposed that the normal heat of the atmosphere was 320°, then water could not exist, but it would be still quite possible for beings who could live in such a temperature to work a steam engine, if only they could isolate steam from the air, which might be done easily enough; and if, besides, they possessed any means of reducing the temperature of a condenser to 120°. Given these two conditions, and their steam engine would work without fire. Considerable difficulties would, however, be met with in producing the low temperature required, while without the steam engine would be impossible.

Now we have several liquids which behave at normal temperatures, such as 60°, just as water would behave at 320°, and these liquids might be used to develop power if only we could obtain the low temperature needed to condense them. So long as sufficient difference of temperature exists power can be had; and it is of no consequence whatever, whether the range of temperature is at one end of the scale or the other. Power can just as well be obtained from a fluid working between zero and —200°, as from a fluid working between 320° and 120°. In the one we must provide heat to raise the temperature above the normal. In the other we must provide a source of cold, to speak popularly, and it is far more convenient to do the former than the latter. We have no stores of ice and salt, for example, to draw upon for the production of zero temperature, but we have stores of coal which will give us high temperatures. So much being understood, the rest will be easily comprehended. Without going into details it will be enough to say that Professor Gamgee proposes to work an engine between 60° and 40°, that is to say, through a range of 100°; and this he purposes to do by taking a quantity of liquid ammonia and putting it into a vessel, which we may call a boiler. In this the ammonia will be heated by the atmosphere to its own temperature. It will boil, and the gas will be used in an engine. So far all is quite clear. We have one-half the cycle, but we have yet to see how the low temperature, —40°, is to be obtained. It is, of course, out of the question to get this by the use of refrigerating agents; and it is here that the really beautiful portion of the invention comes in. When a gas is expanded and does work, it is cooled down. Professor Gamgee proposes to use his ammonia so expansively that it will be cooled down sufficiently to liquefy. Then it will be pumped back into the boiler and the cycle will be complete. An engine would thus be obtained capable of developing very great power without the use of fuel. It need hardly be said that the man who can achieve this object may hope for riches and honors such as the world has never before bestowed on inventors. Before we can say whether Professor Gamgee is or is not likely to obtain success, we must clearly understand the properties of the fluid with which he proposes to work.

Ammonia is a compound of one atom of nitrogen with three of hydrogen (NH_3). At ordinary temperatures and pressures it is a gas. Concerning certain of its physical properties a diversity of statement unfortunately exists. Thus, according to one authority, liquid ammonia—which must not be confounded with the water saturated with ammonia used by Lamm in a totally different way to propel tram-cars, as described in the *Engineer* for January 12, 1872, and popularly known when diluted as sal volatile and hartshorn—boils at —36° Fah.; while according to another it does not liquefy until a temperature of —40° is reached. The difference is apparently small, but it is very important at the lower end of the scale of temperatures. The higher the temperature at which liquefaction takes place the better in one way for Professor Gamgee. The specific gravity of the gas is 0·59, air being unity; and that of the liquid is 0·76, water being unity. The specific heat of the gas is 0·508. At a temperature of —22° the gas—to carry out the analogy we might term it ammonia steam—has a pressure of 17 pounds on the square inch absolute. At 32° its pressure is 60 pounds. At 68°, which is about the highest air temperature it is wise to reckon on, its pressure is 126 pounds on the square inch. The volume of the gas as compared with the fluid which produces it has not been tabulated. At atmospheric pressure and 62°, 1 pound of the gas would occupy about 23 cubic feet, and 1 pound of liquid ammonia would occupy about 36·5 cubic inches. The latent heat, or the heat absorbed by the liquid in becoming a gas, does not appear to have been ascertained. All the figures we have given must be considered as approximate only.

Hitherto comparatively little interest has attached to what we may term the mechanical properties of the gas, and this may account for the differences in the figures given by various authors, and the silence of all on such a question as the latent heat of gas. It will be seen that the maximum pressure which Mr. Gamgee can reckon on without the aid of artificial heat is 126 pounds absolute. But there is some doubt as to whether the gas will remain wholly unliquefied at this pressure and temperature. Kemshead states that it will liquefy at 60° and 105 pounds on the square inch; and it is more than probable that the pressures and temperatures we have given above are all critical; that is to say, those at which the gas is on the point of liquefaction. We do not think it would be safe under the circumstances to assume that a higher working pressure is attainable without the aid of heat than 100 pounds on the square inch.

So many points have to be considered that it is by no means easy to say precisely to what extent the gas must be expanded to produce the cold necessary for liquefaction. If we deal with it as a perfect gas we find that, if the initial temperature is 68° or 529° absolute, and the gas be expanded adiabatically three times, the final temperature would be —81°, or very much more than low enough. As, however, it will be impossible to prevent the gas from picking up some heat, it will not be safe to reckon on less than this amount of expansion; possibly much more will be required. A threefold expansion would give a terminal pressure of 33 pounds on the square inch absolute, but before this liquefaction would have begun, the average effective pressure in the cylinder would be 66 pounds less the atmosphere, 15 = 51 pounds, which is a good working pressure. So far it will be seen that much is in Professor Gamgee's favor, but it must not, therefore, be assumed hastily that its success is assured. Something remains to be learned concerning the behavior of the ammonia.

The zeromotor is in this dilemma, that if the expansion be not sufficiently extended no liquefaction will take place; while on the other hand, if it is sufficiently great, the engine may waste all its energy in overcoming the back pressure of the atmosphere. The intense cold of the cylinder will tend powerfully to reduce the pressure of the gas at the beginning of a stroke, while toward the end it will give out heat and prevent liquefaction. A very complex action has to be provided for, and nothing but direct experiment can settle the question at issue. Theoretically, the zeromotor is, so far as can be ascertained from the somewhat limited data available, sound in principle. It remains to be seen whether it can be reduced to practice. We agree with Mr. Isherwood, however, that the invention is one having sufficient promise to make its further investigation very desirable. "What is now mainly desired," writes Mr. Isherwood, "is that Professor Gamgee may be permitted to prosecute his experiment at the Washington Navy Yard to a conclusion, and there bring his engine to a practical test with as little delay as possible. Should the department be able to grant this, the favor will be well and properly bestowed in the interest of the navy and of the world."—*Engineer.*

Large Centrifugal Pump.

W. H. Allen & Co., Lambeth, have lately made a large centrifugal pump for the irrigation of extensive cotton fields in Egypt. The pump has a 60 inch disk and 36 inch pipes, and is capable of discharging 70 tons of water per minute. The lift against which it is to work is 15 feet. The pump will be driven by a horizontal engine of 125 indicated horse power, the power being transmitted by a belt 21 inches wide, and five-eighths inch thick.

Microscopic Structure of Metals.

Some observations on the minute structure of metals, recently communicated to *Nature* by Mr. J. V. Elsden, are both interesting and instructive. Notwithstanding the great opacity of metals, it is quite possible to procure, by chemical means, metallic leaves sufficiently thin to examine beneath the microscope by transmitted light. Silver leaf, for example, when mounted upon a glass slip and immersed for a short time in a solution of cyanide of potassium, perchloride of iron, or iron alum, becomes reduced in thickness to any required extent. The structure of silver leaf may also be conveniently examined by converting it into a transparent salt by the action upon it of chlorine, iodine, or bromine. Similar suitable means may also be found for rendering more or less transparent most of the other metals which can be obtained in leaf form. An examination of such metallic sections, says Mr. Elsden, will show two principal types of structure, one being essentially granular and the other fibrous. The granular metals (of which tin may be taken as an example) present the appearance of exceedingly minute grains, each one being perfectly isolated from its neighbor by still smaller interspaces. The cohesion of such leaves is very small. The fibrous metals, on the other hand, such as silver and gold, have a very marked structure. Silver, especially, has the appearance of a mass of fine elongated fibers, which are matted and interlaced in a manner which much resembles hair. In gold, this fibrous structure, though present, is far less marked. The influence of extreme pressure upon gold and silver seems to be, therefore, to develop a definite internal structure. Gold and silver, in fact, appear to behave in some respects like plastic bodies. When forced to spread out in the direction of least resistance their molecules do not move uniformly, but neighboring molecules, having different velocities, glide over one another, causing a pronounced arrangement of particles in straight lines. This development of a fibrous structure, by means of pressure, in a homogeneous substance like silver, is an interesting lesson in experimental geology, which may serve to illustrate the probable origin of the fibrous structure of comparatively homogeneous limestones like those of the Pyrenees, Scotland, and the Tyrol.

The Insulation of Electric Light Wires.

At a recent meeting of the New York Board of Fire Insurance Underwriters, the danger arising from the use of electric lights with uninsulated conductors came up for discussion. The matter had been investigated on account of an accident a short time ago in a jewelry store in Maiden Lane, when a man was on the roof running an electric light wire across. It came in contact with the telephone wire, and a flash passed down to the telephone box, destroying it. The shock loosened a considerable extent of plaster.

City Electrician Smith said that the shock must, he thought, have been very powerful, and had any one been at the telephone, he might have been killed; or if the flame had passed near light goods, there might have been a conflagration. The wires of the electric light ought to be thoroughly insulated.

Superintendent Harrison, of the New York Board of Fire Insurance Underwriters, said that the Board would ask the proper authorities to see that the electric wires were properly insulated. Owing to the rapid introduction of the electric light, and the many new wires that were being run over the city houses, the danger, he said, was constantly increasing. In the meantime buildings using the electric light would be rated as "specially hazardous," unless the insulation of the wires was approved.

A. A. Hayes, Jr., of the Brush Electric Lighting Company, has informed the board that the wires of that company were already insulated while the matter was under discussion; and since the action of the Board, the other companies have been experimenting in regard to the best method of insulation.

Actinic Zinc.

Dr. Phipson describes a zinc white of a dazzling purity obtained by precipitating a solution of zinc sulphate by means of barium sulphide, submitting the precipitate to strong pressure, and igniting it with limited access of air. If any barium sulphide escapes oxidation, the white compound, on exposure to the sun, begins to darken, and in about twenty minutes becomes of a deep slate color. If removed into a dark place it gradually loses color, and in about five or six hours it becomes again snow-white. This experiment may be repeated with the same specimen as often as desired. Further, this change of color does not take place under a slip of common glass, whether thick or thin; at most the compound takes a slight yellowish brown color on exposure to the sun for two hours. The sample on analysis was not found to contain silver or any other substance known as actinic.

The Fourth State of Matter.

The first public exhibition in this country of the experiments and apparatus employed by Professor William Crookes in his investigation of the ultra gaseous state of matter was made in this city, May 5, by Professor H. S. Carhart, of the Northwestern University, under the auspices of the New York Electrical Society. The experiments were admirably reproduced and explained by Professor Carhart, whose skillful manipulation of the delicate apparatus was only excelled by his terse and lucid presentation of the character and import of these novel explorations along the extreme verge of material existence.