periodic intervals of 33 years meet and surround the earth, producing bright showers of falling stars. We have finally learned the cause of such a phenomenon, which, from the year 902 of the common era even until to-day, has occurred so many times and always been seen with new wonder; and to this progress not a little has been contributed by Tempel's discovery of that burning comet in a very favorable time, just in time to explain the last return of meteors, which was in the night between the 14th and 15th of November, 1866.

The stay in Marseilles marked a very calm and very fruitful period in the life of Tempel, to which, unfortunately, the political whirlwind of 1870 put too early an end.

Expelled from France for no other offense than that of being a German, in the beginning of 1871 he went to Milan, where he was established as assistant in the Royal Observatory of Brera. Then giving up the art of lithography, he gave himself wholly to science, and in his new field of work engaged in useful labors. In the four years that he stayed in Milan (1871 to 1874) he discovered four more comets, 1871 II, 1871 V, 1871 VI, 1873 II. Besides these, he observed and drew several other comets, particularly the splendid one of Coggia, that appeared in 1874, whose appearance he represented in a way that has not yet been excelled.

Though so tireless a hunter of comets, Tempel in the number of his discoveries did not rival Pons, to whose life his own presents many analogies. Yet it may be said that no astronomer has made discoveries in this line more important and more useful.

I have already shown how timely and how fruitful in its results was his discovery of the comet 1866 I; to this I should add that, of the ten comets of short periods yet known, three are due to Tempel. The story of these comets belongs to the most interesting part of astronomy. The changes through which, by the powerful attraction of the larger planets (for the most part of Jupiter), they were drawn in periods sometimes not very distant to become lasting members of the planetary system; the exact forces whose application has caused these disturbances through the planetary bodies; the notions that some of them have given and can still give in the future about a supposed resisting ether filling all the heavenly space; and, finally, the destruction that one of them, Biela's, and perhaps also Vico's, has suddenly undergone, as if before our eyes separating into small fragments; all these questions give to these bodies of feeble light and modest appearance a degree of importance not inferior to the largest and brightest comets.

His age and the state of his health made his labors very severe, continuing nightly observations in the trying climate of Milan; and in the beginning of 1875 he was led to accept the position of astronomer in the new observatory founded by Donati a few years before in Arcetri, where he lived and worked alone, expecting a definite arrangement at that fine observatory. There at first he continued his assiduous investigations of comets; his last discovery in this field was the comet 1877 V. Finding himself entirely his own master and having two large telescopes by Amici that were distinguished for the clearness of their images, he gave himself, with the zeal that he put in every act, to the study of the nebulae, whose forms and details he represented in a large number of drawings, which are the finest and the most accurate yet made in this line.

For this labor he was thought, in 1880, worthy of the royal prize which the Royal Academy gives every six years to astronomical work. So perfect are these drawings that Tempel in vain sought an artist capable of reproducing them satisfactorily to him; and they are among his unpublished works; but their existence and their value are not unrecognized in the astronomical world, and already a movement has been made in Germany to acquire and publish them.

The reason for so great an interest in them is not hard to find, for besides an eye skilled in astronomy, Tempel had a practiced artist's hand—two qualities that are rarely both found to so high a degree in the same person. The drawings of the nebulae that he left are, in the opinion of all who have seen them and compared them with the heavens, a faithful representation of the appearance presented by the nebulae to a telescope of the present time. Therefore they can give to astronomers in the future a means of judging upon the question of the possibility of change in these bodies; which perhaps we could now do, had there been a Tempel provided with a telescope upon the Nile with the builders of the pyramids, or in an observatory upon the roofs of the temples of Babylon. It is then of great importance not to allow to perish or become forgotten a work whose value will always increase with the ages.

One might think that photography applied to representing the heavenly bodies would now render useless drawings made by the aid of the telescope. But let me say that is an error; for those rays or vibrations of light by which the heavenly bodies are made visible to the human eye are generally different from those other rays by means of which these bodies are figured upon photographic plates. So it can happen that a star in which at first sight prevail rays of great intensity appears very bright to our eyes and yet acts with feeble impression on the plate of the camera. On the other hand, another heavenly body, whose light abounds in chemical rays, can act with strong effect upon the photographic plate and yet be hardly visible to the human eye, or entirely invisible. There are such essential differences existing in the character of the light emitted by different stars, and also by different nebulae; and they can exist in different parts of the same nebula, which will appear of different aspect whether seen by the eye or photographed. A remarkable instance is seen in the case of the nebula of the Pleiades, which in a photograph shows an appearance quite different from that seen through the telescope. Not only therefore will the drawings of the nebulae made by the eye in the usual way never be useless, but when they are compared with the photographic impressions there will rise very instructive ideas about the different characters of the nebulae.

In the last years of his life Tempel was obliged to give up entirely night observation as too fatiguing to his declining health. The impossibility of completing these tasks, which would bring him the greatest fame and happiness, contributed not a little to increase his illness. After a year's sickness a sudden crisis ended his sufferings on the 16th of March, 1889.

Although Tempel had not received a regular education, he was not wholly without culture; he had a strong love of nature and art, and poetry made a strong impression upon him. In mathematics he had, without the aid of teachers, and by himself, mastered the first steps, and was never troubled in making the needed calculations.

His honesty of character made him worthy of high esteem; but his mind was very sensitive and ill-fitted to bear the inevitable disagreements caused by daily contact with his fellows; nor had he learned the necessary art of bearing them philosophically. He often kept himself brooding over injuries, and sometimes without any real cause; and this produced the impression in those who did not know him that he was a distrustful and unaffable man. Only a long acquaintance with his character could correct this judgment and give a just estimate of his faults, which injured no one but himself and were fully compensated by the strength of his noble qualities.

His friends cannot forget his pure and disinterested love which made of a humble workman a wise astronomer, gaining for his memory a name that will last as long as the study of the heavenly bodies is held in honor by men.

ELECTRICAL SMELTING AND PRODUCTION OF ALUMINUM.*

By Mr. WILLIAM BOBY, London.

YOUR worthy chairman has asked me to give you a description of the Cowles process of electrical smelting and the production of aluminum. I feel great pleasure in doing my best to bring the subject fully under your notice, it being one which, I think, is destined to play an important part in metallurgy as applied in practical matters, and more particularly to the calling which this institution represents. Although the process is at present employed almost solely for the production of aluminum alloys, it appears probable that its uses may be extended over a much wider field, as, by its agency, materials may be obtained which, at present, owing to the difficulty in their reduction, are curiosities to be found only in the chemist's laboratory, and possibly it may be employed where at present, in many instances, costly chemical processes are in use. Silicon and chromium have already been obtained in the form of alloys with other metals in practical quantities and at small cost. Other rare metals have also been obtained experimentally; but attention, so far, has been turned to the production of aluminum, as offering the widest

amount of work done. The application of the furnace is as follows: The two electrode rods are connected to the two leads of the dynamo, the cable, connected to the positive pole, sending the current into the left hand electrode, whence it travels through the charge, where it meets with the resistance which causes the heat, and passes by way of the right hand electrode into the cable connected to the negative pole of the dynamo. The resistance is caused by the particles of carbon which are mixed in the charge. Thus, it will be seen, the current acts independently of the structure of the furnace itself, acting simply on the charge which is in immediate contact with the carbon by means of which the heat is produced. The heat developed is enormous, and, of course, fire bricks have no capability of withstanding it. Charcoal is found the most convenient form of non-conductor of which to form a protective lining, but the intensity of the heat converts it in a short time into graphite, so that it loses its non-conductive properties. To renew the charcoal lining frequently entailed considerable expense, and formed a difficulty which was overcome by dipping the partially graphitized charcoal into limed water, the lime being found to render the charcoal again sufficiently refractory. The process of liming is as simple and cheap to carry out as it is satisfactory. The charcoal is put into a cistern of limed water, and afterward dried in a revolving steam-jacketed cylinder. When charging a cold furnace, some charcoal is put into the bottom and lightly beaten down till it forms a fairly firm bottom of sufficient thickness. The electrodes are run inward till their ends nearly meet in the furnace, and the charge is then put into the center of the furnace, and surrounding the electrode ends. The charge for copper alloy consists of close upon 300 lb. of materials, about one-fourth being ore broken up small, about four per cent. of carbon, a good deal of which is supplied by means of broken-up slag taken from a former heat, slag to the amount of about ten per cent. being introduced, and the balance copper. If iron alloy is required, the charge consists of a larger proportion of slag, and the iron is broken into small pieces. The copper is granulated by being poured when in its molten state into water.

The ore employed is sometimes corundum, a sample of which is on the table, and which for some time was the only ore employed by the Messrs. Cowles in their process; but at present the ore employed at Milton is bauxite, which after repeated experiments was found to answer equally well and at a fraction of the cost. The charge, while being inserted, is prevented from spreading out laterally, in which case some portions of

field, at present, for the products of the furnace. I propose, this evening, to describe the Cowles furnace and its action, then to give you some account of the machinery for producing the current, and afterward to say a few words respecting the products obtained by the use of the process.

The works of the Cowles Syndicate Company, Limited, are at Milton, near Stoke-on-Trent. The cut shows a section through the longitudinal center of one of the furnaces built in the beginning of 1888. I may mention that the inventors, Messrs. Eugene and Alfred Cowles, being engaged at their American works, the selection and arrangement of plant, and the erection of buildings, furnaces, etc., was placed in the hands of myself and my partner, Mr. S. G. Browne, and carried out by us between October, 1887, and April, 1888. You will observe that the furnace consists of an oblong receptacle, the internal dimensions being 5 feet long, 3 feet 3 inches deep, and 20 inches wide. It is built below the floor line, and lined with fire bricks. Into the ends are built cast iron tubes, inclined, as shown, for convenience in working the electrodes. On the ends of the tubes are covers having bosses upon them, through which pass the electrodes. On to the covers are screwed blocks of wood surrounding the bosses. Near the outer ends of the electrode rods are easily removable clamps, each of which holds a nut, through which passes a screw having a T handle at its outer end, while its inner end rests against the wooden block. The rotation of this screw moves the electrode inward or outward. The top of the brickwork is covered by iron plates, and an iron cover, as shown, is placed over the mouth of the furnace. In the cover is a hole through which the gases issue as they are driven off by the heat in the furnace. The electrodes consist of carbon rods $2\frac{1}{4}$ inches in diameter, and nine of them are attached to each electrode rod. The attachment, as shown on the drawing, consists of metal which is cast around the ends of the carbons and of the electrode rod, so as to form a conductor, which is in perfect contact with the whole of the parts connected. The metal from which this attachment is cast is selected to be suitable for the alloy which is to be dealt with in the furnace, as; although in comparison with the actual charge it is not subjected to a very intense heat, yet the metal of which it is formed is found to exercise a slight influence upon the furnace product.

Here, then, we have a covered furnace, provided at its ends with two electrodes, which are capable of being easily moved apart. As you will see, it is extremely simple, without complication of parts, and built entirely of very cheap materials, excepting the electrode rods and carbons, the former being of copper and permanent, while the cost of the renewal of the latter is a very small item in comparison with the

it might be too distant from the electrodes, by two pieces of sheet iron, connected by a distance piece, which are placed one on either side of the electrodes; the charge is put in between them, and charcoal is then filled in between the sheet iron and the sides of the furnace, after which the sheet iron is withdrawn, the top of the charge covered, and the ends of the furnace filled up with charcoal to the depth of a few inches above charge and electrodes. Then the iron cover is adjusted over the furnace and luted round its edges with fire clay to render it as gas tight as possible, and the furnace is ready to receive the electric current. The full amount of current is not applied at first; the engine is started at a moderate speed, so as to provide about 2,000 to 3,000 amperes. This finds its way through the charge and gradually heats it and the lining immediately surrounding the ends of the electrodes. As the ore and metal of the charge become fused, the resistance decreases, when the speed of the engines is gradually increased, and the electrodes drawn apart until the whole of the ore and metal in the charge is fused, before which time, having a larger body of materials to act upon, we have the full 5,000 amperes of current flowing through the charge. Immediately after the electrodes are withdrawn the necessary distance, and the entire charge is fused, which takes an average of one hour and thirty minutes to one hour and forty minutes, the engine is slowed to a few revolutions per minute, the shunt-exciting current is switched off the magnets, so as to break the field, and the brushes are raised; the electrode rods are then disconnected from the leads and another furnace is connected to the current. The slowing down of the engine, disconnection and reconnection of leads, and starting again occupies a few minutes only.

As soon as the current flowing through the furnace begins to produce a considerable heat, a light smoke commences to rise from the hole in the top cover. When it has reached a fair volume, a light is applied and it burns brightly, the gas given off being carbonic oxide, which, although of an explosive character, simply burns quietly, though vigorously, as it comes off. If the lid be raised immediately after the engine is stopped, the heat is seen to be of a very intense nature. On the first occasion of this kind at Milton, Mr. Eugene Cowles, who was present, remarked to me that we probably had before us the highest temperature that had ever been produced in England. No method has at present been devised for obtaining any idea of the temperature; it seems probable, however, and indeed there can, I think, be little doubt, that the metals in the charge are volatilized, after the more volatile oxygen has been driven off, and, rising in that condition from the neighborhood of the electrodes, meet the cooler portions of the lining and become precipitated, the metallic alloy being found in the form of a slab on the charcoal lining below the electrodes. It is assumed

* Paper read before the Cleveland Institution of Engineers, December 17, 1888.—Iron.

that the aluminum combines with the metallic base of its alloy while both are in the gaseous condition; it is certain that the alloys formed by this process possess a completeness of union between their component parts, a homogeneity and strength, which, as far as we can ascertain, is superior to those qualities as found in aluminum alloys otherwise compounded. The furnace, as illustrated, had to be allowed to cool before the contents could be removed and the charge renewed. This was a source of loss and delay, and an improved set of furnaces is now in use, of similar form to that in the drawing, but raised above the ground, and having a tap hole from the side into the interior, by means of which the metal is run out in a molten condition. The furnace also is recharged without being allowed to cool, a most important economy being thus effected over the original method.

The production of aluminum at the Milton works is at present about 200 lb. of actual aluminum per day of twenty-four hours, when the aluminum is produced as an alloy with copper, or, if the alloy has iron for its base, a less amount is obtained, being about 150 lb. The average number of runs per day of twenty-four hours is about twelve to fourteen, so that we obtain about 15 lb. to 18 lb. of pure aluminum (embodied in the alloy) per run, when producing bronze. The attendance required upon the furnace is small; two lads attend to the adjustment of the electrodes for the regulation of the current, and to the connecting to and disconnecting from the dynamo leads; while two men weigh out the ore, etc., charge the furnaces, and run the molten metal off. The ferro-alloy frequently comes from the furnace complete and ready for the market, but in some cases it contains a proportion of the charcoal lining mechanically mixed with it, in which case it is remelted in an ordinary furnace, when the charcoal floats on the surface and is easily removed. The cupro-alloy comes from the furnace in the form of a nearly pure white metal, which is highly charged with aluminum, but which, by a very simple process, is fused and mixed with the necessary amount of copper to form a bronze of the grade required.

Before going more particularly into the subject of the finished products, I will give a description of the machinery employed for generating the current. The boilers are two in number, of the well known Babcock & Wilcox type, made at their Glasgow works. They answer the purpose well, working day and night, there being no spare boiler. They are fired by means of Juckes' mechanical stokers, and burn rough slack coal, obtained in the neighborhood. The coal is quite unscreened and contains a large amount of dust. The performance of the boilers is very creditable. They are 145 horse power nominal each, and as the engine often indicates 500 to 540 horse power for a considerable time together, it speaks well for their steaming qualities that they supply it with sufficient steam. They supply, besides, steam to three small engines on the works, and a small quantity for other purposes. The engine is compound and condensing, of the tandem form, having cylinders 23 inches and 43 inches diameter, with a stroke of five feet. It draws its condensing water direct from the canal. The engine was built by Messrs. T. Bates & Co., and is a finely designed and well finished machine. It is built with a special view to high speeds, and runs ordinarily at from 66 revolutions per minute at the commencement of the run to 80 revolutions per minute toward the end of the run. Its valve gear is not of the trip kind, but all three slides are moved by eccentrics, the high pressure slide being of the piston form, with another piston valve inside it for regulating the cut-off. The current is subject to considerable irregularities of flow, which are sometimes very sudden, and the efficient regulation of the engine is of great importance. The governor acts by turning the piston expansion valve, and is quite successful in controlling the engine within very narrow limits. An arrangement is fitted to the governor, by means of which the speed of the engine can be varied at will. We selected this gear as being more suitable for such quick running than the trip gears now usually found on engines of this size. The engine runs with such absence of noise that, standing with one's back to it, it is hard to believe that it is working. The fly-wheel is twenty feet in diameter, its periphery being grooved by ropes, by means of which the power is transmitted to the dynamo. The engine is evidently working under conditions unfavorable to economy, owing to the variations in the amount of current required by the furnace; but I found on a careful test, extending over a number of runs, that the consumption of the common slack coal named above, and including the intervals between the runs, only amounted to 3 1 lb. per I. H. P. per hour. An electrical apparatus worked by a small battery is fitted to the stop valve, so that the steam can be turned off the engine instantaneously by pressing a push button, several of which are fixed to the wall and the columns in the neighborhood of the dynamo and the furnaces. The apparatus opens a cock in the condenser, and breaks the vacuum at the same time that the steam is shut down. Thus the dynamo and furnace tenders can at once stop the engine, should it be found desirable to do so, without having to signal to the engineman.

The dynamo furnishes probably the largest amount of current of any machine in existence, its normal output being 5,000 amperes at a tension of 60 volts. It was built by Messrs. Crompton & Co., and is of the constant current type, with drum armature. The shaft is of steel, 7 inches in diameter, and carried in three bearings, two of which are placed on either side of the driving pulley and one outside the commutator. The driving pulley is 4 feet diameter, grooved to correspond with the fly-wheel; its weight is about 2 tons. The central part of the shaft is larger, having been made 14 inches diameter, but is planed down to 10 inches, leaving, however, four ribs projecting, and these ribs act as keys to carry round the core. The core consists of disks of Swedish iron about 18 1/4 inches diameter, 900 in number, making a total length of core of about 36 inches. The winding upon the core consists of 128 radial copper bars seven-eighths of an inch deep and three-eighths thick at the top. They are coupled at the ends of the core by means of crescent-shaped bars on a system patented by Crompton and Swinburne so as to form 32 conductors. The whole arrangement was thought by its designers to be one which would avoid any considerable amount of heating of the armature, but in practice this result has not been obtained, and a fan is now employed to send a strong current of

air of considerable volume through the armature. The winding bars were originally held by thirty-two projecting steel pins, fixed to the core, but these gave way and were replaced by double the number of larger size, and made from the Cowles Company's 10 per cent. aluminum bronze, with a strength greatly exceeding that of steel. Bands of steel wire are wound over the bars to hold them tightly to the core. The commutator has 64 parts, is 20 inches long, with a center tightening ring on account of its length. It is fitted with eight brushes, mounted on a separate ring, and the current is carried off by a large number of strips of stencil copper. The field magnets are of soft wrought iron of the double type, placed horizontally. There are four turns of 1 1/2 inch by 1 inch copper bars round the magnets. The machine is wound in series with shunt coils, which excite the field magnets, and a current is produced with a potential proportionate to the speed of the engine. A separate dynamo was used at first to excite the field, but it is now unnecessary. The ordinary full working speed of the armature is 380 revolutions per minute, though it is frequently run up to 400, the normal output of 5,000 amperes and 60 volts being then somewhat exceeded. Occasionally also the current jumps for a moment to a very high point, owing probably to metal in the charge fusing in such a way as to suddenly give the current a considerably freer passage. The lubrication of the bearings is effected by castor oil and water. A safety cut-out is provided between the dynamo and furnace rooms. It is calculated to fuse at 8,000 amperes.

In the furnace room is a current indicator having a dial fronting to the furnaces and another one on the other side of the partition wall in the engine room. It consists of a solenoid of nine turns, which was made by casting a cylinder of copper and then cutting it spirally by means of a parting tool. The whole of the current passes through this coil, which is interposed in the main positive lead. The core of the solenoid is geared to the dial spindle. The markings of the dials were made by actual experiment after the dials were in place; they extend to 5,000 amperes, which amount of current sends the hands about two-thirds round the dial. Tapped from the main lead is a pilot light suspended over the dial in the furnace room, and which gives light for reading the latter. The main leads from the dynamo consist of bars of copper 3 inches by 1 inch; there are three of these alongside each other in the furnace rooms from each pole of the dynamo, and they are slightly over 50 feet long in one piece. From these depend flexible cables connected at one end with the electrode rods, and at the other to flat bars, which are clamped between the bars of the leads, and provided with wheels which roll along the top edges of the leads for convenience in shifting the connections from one furnace to another.

Very few hands are required to work the process proper. Besides the two boys, and two men named as attending to the furnace, we have one man each to engine, boilers, and dynamo; one man and one boy employed in preparing and moving charcoal; two men in the foundry, who standardize bronze and castings, and an occasional electrode holder, and who also attends to the remelting when required of the ferro-alloy. There are, besides, other men employed, as there would be in any other works, such as a carter, fitter, carpenter, night watchman, and store keeper; altogether when working double shift as at present, about twenty-five men and boys. The plant at Milton is small at present, but there is ample space on the site and in the main building for extension. I found, by tests taken over a series of runs, that one pound of actual aluminum in the bronze alloy is produced by 20 electrical horse power and in the ferro-alloy by about 28 electrical horse power. Improvements in the details of the process have gradually lowered the amount of horse power since the commencement, and no doubt more is to be done yet in this direction, more particularly by the employment of a still larger volume of current, which is in contemplation, when more machinery shall be put down.

Turning now to the products of the furnace, we have two principal alloys. I will first call your attention to the ferro alloy. This, as already mentioned, is ready for the market as it runs from the furnace, or is rendered so with very little expenditure of labor. The amount of concentration of the alloy is not an important point, so long as it is definitely known, the use of the ferro alloy being entirely for mixing with other iron, either cast or wrought, or (which indeed appears to be its greatest field of usefulness) with cast steel. The selling price of the ferro alloy is regulated by the amount of its concentration, which is at present decided by analysis. It is, however, possible that it may be ascertainable by other means; for instance, we already know that when the concentration exceeds a certain amount the alloy becomes non-magnetic, not being attracted by a loadstone. This is a property which may possibly be found to be of practical value. A valuable property of aluminum, as produced by this process, here comes into play, viz., we can melt up any desired quantity of the ferro alloy and be quite certain that an analysis of a few grains of it will represent the concentration of the entire bulk. This quality of equal diffusion is of high value when it is considered that by its means a ladleful of, say, molten steel will be impregnated with a minute proportion of aluminum if a small quantity of the broken-up alloy has been placed in the bottom of the ladle before the steel was poured in. The combination of aluminum with the iron having taken place in the electric furnace, it has never been in contact with oxygen, and the very thin film of oxide which at once forms upon the pure metal when exposed to the atmosphere, and which causes considerable trouble in dealing with pure aluminum, does not come into existence in the alloy.

The use of ferro-aluminum has not up to the present obtained any large dimensions in this country; in the States it is already largely in use. The effect of the alloy upon steel is to raise its elastic limit and ultimate strength, while it lowers its melting point and facilitates the making of sound castings—this latter point will be recognized as of great importance. This alloy is employed by the makers of the "Mitis" castings in America, who obtain it from the Cowles Company's works at Lockport, and by the makers here, who obtain it from the Cowles Syndicate Company. The sale of this alloy in America has reached considerable dimensions. My partner, when spending a few days at the Lockport works a few months back, saw an or-

der come in for 10 tons, and when it is borne in mind that 0.1 per cent. of aluminum is an ordinary proportion to add to steel castings, it will be seen that this represented operations of some magnitude (1,000 lb. steel receives 1 lb. of aluminum, or 10 lb. of 10 per cent. ferro-aluminum). The effect of ferro-aluminum upon puddled bar iron was investigated by Mr. G. W. Thompson, of Messrs. P. & W. McLellan's firm, with most satisfactory results. The tensile strength being raised to 31 tons with 22 per cent. elongation, he states that the quality is equal to that of the finest mild steel. The paper by Mr. Keep, of the Michigan Stove Company, which appeared in *Iron* of September 21, 1888, bore testimony to remarkably beneficial effects of the Cowles Company's ferro-aluminum as applied to cast iron; his tests also show that after the iron had been cast the aluminum remained in it, and continued to influence it beneficially even after several remelts. It has been held by previous investigators that under such circumstances the aluminum passed off; if so, Mr. Keep's experiments show the superiority in this respect of the electrically formed alloy over that made by mixing pure aluminum in the ordinary manner. Mr. Keep is the head of one of the largest stove-making concerns in the States, which now advertises that aluminum is employed in all its castings, reaching about 60 tons of stove plates per day. English firms are commencing to use the alloy, and no doubt its use will rapidly extend. Some of the best-known steel founders are now employing it in England.

(To be continued.)

ON ALLOTROPIC FORMS OF SILVER.

By M. CAREY LEA, Philadelphia.

SILVER is capable of existing in allotropic forms possessing qualities differing greatly from those of normal silver. There are three such forms, or rather three modifications of one form, differing from each other in many respects, but all more nearly related to each other than any one of them to normal silver. One of these forms is soluble in water, passing readily to an insoluble form, and this last may, by the simple presence of a neutral substance exercising no chemical action upon it, recover its solubility. Another form closely resembles gold in color and luster.

Whether metallic silver shall be reduced from its compounds in its normal or in an allotropic form depends upon the reducing agent applied, so that it cannot be said with any certainty whether it exists in its compounds in its ordinary normal form or in an allotropic condition; the latter alternative seems at least equally probable.

These allotropic forms of silver are broadly distinguished from normal silver by color, by properties, and by chemical reactions. They not improbably represent a more active condition of silver, of which common or normal silver may be a polymerized form. Something analogous has already been observed with other metals, lead and copper.

Much having been written, especially within the last few years, on the products of the reduction of silver compounds, a brief summary of what has appeared may be desirable before proceeding further. The study of this subject has led to remarkable divergencies of opinion on the part of the chemists engaged in it. Almost all the views advanced have been successively disproved by each subsequent publication. It follows that what has obtained a place in the text books is almost wholly incorrect.

The earliest experimental work was Faraday's, but his product has been proved to be a mixture.* The next was the well known paper of Wohler, published in 1839. It is not my purpose here to enter upon a criticism of this memoir. If this illustrious chemist succeeded in obtaining by the means employed a true citrate of silver hemioxide—as would appear from his analyses—no chemist since his time seems to have done so. The next publication to Wohler's was that of Von Bibra, who used Wohler's method and, while affirming that he obtained a similar citrate, found an entirely different constitution for the corresponding chloride. For instead of obtaining a hemichloride Ag_2Cl , he gives as the result of 15 concordant analyses the constitution of his product as Ag_2Cl_3 .† A citrate, to yield such a chloride (if such a chloride exists), by the simple action of hydrochloric acid, could scarcely have the constitution assigned to it by both Wohler and V. Bibra.

In 1882, Pillitz published two papers.‡ He commences by disputing the probability of the existence of Ag_2O on grounds of valency; namely, as implying that oxygen may be quadrivalent. Although it is very doubtful that any one has up to the present time obtained Ag_2O , the argument seems futile, as are many arguments deduced from supposed laws of valency. Similar reasoning would make Ag_2Cl impossible, which substance undoubtedly exists, and it would also deny the existence of K_2Cl , which stands upon such authority as that of Rose, Kirchhoff, and Bunsen.§ Pillitz carefully examined the so-called hemioxide precipitated by alkaline solutions of antimony and tin, and could find no trace of Ag_2O in any of them. He did not examine Wohler's products.

The first person to deny categorically the existence of Wohler's series of hemi-compounds of silver appears to have been Dr. Spencer Newbury. In two interesting papers,|| he describes a repetition of Wohler's methods and declares it to be impossible to obtain products of constant composition. The red solution taken by Wohler to be argentous citrate, Dr. Newbury concludes to be a suspension of finely divided silver. Muthmann¶ after a careful examination of Rautenberg's products, concludes that that chemist was wholly in error in asserting the formation of compounds of chromic, molybdic, and tungstic acids with silver hemioxide. He next studies the red liquid obtained by Wohler's process, and comes to the same conclusion as

* G. H. Bailey and G. J. Foster, Chem. Soc., 1887, 416. Bericht d. ch. G., xx, Ref. 360.

† Erdmann, J. prakt. Chim., 1875, 120, 39. Von Bibra precedes his paper with a brief summary of the conclusions reached by previous chemists on the subject of the action of light and chemical reducing agents on silver compounds. The collection is interesting as showing to what inconsistent and even contrary opinions careful observers have come on these reactions.

‡ Zeitschrift für an. Chemie, xxi, p. 27, p. 493.

§ Gmelin Kraut, ii, 1, 72.

|| Am. Chem. Jour., vi, 407; viii, 196.

¶ Bericht der d. ch. Ges., xx, 983.