opportunities which are now offered for access to the interior. Physically the African continent is in many respects unique. Five thousand miles in extreme length, and over 4,000 in breadth, its area is greater than that of any other continent except Asia, the latest estimates being 11,874,000 square miles. Its coast formation is peculiar in the absence of deep indentations, bays or harbors, and the small number of waterways which offer entrance to the interior. The fact that the greater part of the interior is an elevated table land extending on all sides to within a short distance of the coast renders access to the interior by the few large streams difficult. At the point where the rivers pass from the elevated plateau of the interior to the lowlands of the coast the falls or rapids which there exist prevent navigation, and as a result travel to the interior in Africa by water developed more slowly than in any other continent. Indeed, it was not until the explorations of Livingstone, Stanley, Speke, and others developed the true conditions and made known the fact that vast navigable water stretches were to be found in the interior that it occurred to man to transport steam vessels around these falls and put them afloat in the waterways of the interior. When these conditions were clearly established, however, modern ingenuity and energy soon found a means of transporting steamers in small pieces upon the backs of men through the forests, around the falls and rapids for scores and even hundreds of miles, and putting them together, set afloat the steamers, which penetrate thousands of miles into the interior and develop facts never before known and which could not have been developed by land exploration in tropical climates and jungles for many generations.

ROBERT WILHELM BUNSEN.

WITH the death of Bunsen there has passed away the last of those great German chemists of the middle of the present century, chemists who bore the greatest part of the work of laying the foundations of the modern science, and through whose efforts their fatherland has taken the first place in chemistry among the nations of the earth. The century began with Wöhler and Liebig; in the next decade came first Bunsen and then Hofmann and Kolbe and Fresenius; perhaps to these we should add Kekulé, who followed ten years later. Wöhler brought to Germany the chemical power and intellect of the Swede Berzelius; Liebig the brilliancy of the French school, where Gay-Lussac, Vauquelin, Thénard, Dulong, Chevreul, and other successors of the "Father of Chemistry" were full of activity. Wöhler, at Göttingen, and Liebig, at Giessen, became the progenitors of the German school. Bunsen and Kolbe were Göttingen boys, Hofmann and Fresenius (and we might add Kopp) were born at Giessen, while Kekulé was a youth in Bunsen's laboratory. This band of men were not merely discoverers of chemical fact and theory; they were the discoverers of men. Hardly a chemist of note to-day in Germany or England or America, who has passed young manhood, but has felt the direct impress of one or another of these men. They have been the world's teachers of chemistry, and to-day how many teachers are using their personal recollections of these their own instructors to inspire the next generation of pupils.

And now the last of these giants is gone. Liebig was the first to be taken, just rounding out his three score years and ten. A decade later and Wöhler and Kolbe passed. The last ten years have seen the death of Hofmann, Kekulé, Fresenius, and now, at the close of the century, a few months only before the hundredth anniversary of Wöhler's birth, Bunsen is dead.

The outward incident of Bunsen's life is quickly told. Robert Wilhelm Bunsen, the son of a distinguished theologian, was born at Göttingen, March 31, 1811. In 1831 he was graduated at the University of Göttingen as Ph.D., and after some study at Paris, Berlin, and Vienna he was appointed privatdocent and then assistant professor at Göttingen. In 1836 he succeeded Wöhler at the Polytechnic School at Cassel, and in 1838 was appointed professor of chemistry at Marburg. Here he remained for several years, went to Breslau for a short time, when he was called in 1851 to Heidelberg. Here he remained active till 1889, when he resigned from service; but he still retained all his old interest in the chemical laboratory. Some time before resigning, he received a very urgent call to the University of Berlin, but he was unwilling to change his home in his old age. He died at Heidelberg, August 16, 1899. Few honors which fall to the lot of chemists but were bestowed upon him. In 1858 he was elected foreign member of the Royal Society; in 1883, one of the eight foreign associates of the French Academy of Sciences. He received from the Royal Society in 1860 its Copley medal, and in 1877 he and his associate Kirchhoff were joint recipients of the newly founded Davy medal.

Bunsen was a broad chemist, confining his work to no one branch of the chemical field. He was equally at home in theory and in practice, and perhaps his most important work consisted in laying foundations on which others should erect the superstructure. He would hardly be called a prolific writer, and yet he is credited with more than a hundred articles, of most of which he was the sole author.

His first published work was in 1834 and consisted of a short note in the *Journal de Pharmacie* calling attention to the value of ferric oxide (hydrated peroxide of iron) as an antidote for arsenic poisoning. This was the beginning of his work on arsenic, from which he was to receive great reputation, but from which also he was to nearly lose his life. He could not have better shown his pluck and enthusiasm than by attacking the dangerous problem of the organic compounds of arsenic. It was a theme which has cost more than one chemist his life, but it was of great importance in Liebig's work on the "radical theory." More than twenty years earlier Berzelius had said: "The application of what is known regarding the combination of the elements in inorganic nature, to the critical examination of their compounds in organic, is the key by which we may hope to arrive at true ideas with respect to the composition of organic substances." Bunsen followed up this idea, showing that the so-called alkarsin, $As_2(CH_3)_2$, was a radical; but a compound radical, being made up of arsenic, an inorganic element combined with hydrocarbon radicals which are organic. This work of Bunsen's, though of course far less reaching in

importance than Wöhler's then recent synthesis of urea, was far more difficult and dangerous, not only than this, but also than Liebig and Wöhler's investigations of the benzoyl radical and Gay-Lussac's study of the cyanogen radical. This work of these four chemists established for the time being the "radical theory," which indeed was to be soon overthrown, but was later to reappear as a part of our theory of to-day.

At the time Bunsen was carrying on his researches on organic compounds of arsenic, he was beginning that series of investigations on the gases in the iron furnace which culminated in the report presented to the British Association in 1845 by himself and Lord Playfair, on the "Gases evolved from iron furnaces, with reference to the theory of smelting of iron." While the utilization of the waste gases of the iron furnace for fuel had been attempted at a much earlier date, it was not till the work of Bunsen, alone and with Playfair, that the enormous waste in these gases was impressed upon ironmasters; so that Bunsen can be said to have largely contributed to this great source of economy in the modern furnace. In other directions also these investigations bore practical fruit.

The study of furnace gases had demanded methods of gas analysis which at that time did not exist. Perfecting the old, originating new, Bunsen built up a system of methods of gas analysis which have remained the foundation of those subsequently used; indeed, he has been called the founder of this branch of analytical chemistry.

In this connection should be mentioned the Bunsen burner, now universally used in chemical laboratories, and almost as extensively outside, as in the Welsbach light. The principle of mixing a proper amount of air with a combustible gas and burning it from an open tube is very simple—after it is known, but it was unknown until discovered by Bunsen.

In 1841 and 1842, Bunsen published his experiments on the use of carbon in the place of the more expensive platinum in the Grove battery. The outcome of this work was the Bunsen battery, which has been one of the most useful as well as the cheapest of all batteries, and which may be said to have refused to yield supremacy until displaced with all other batteries by the dynamo.

Having a powerful source of electricity at his disposal,

THE LATE ROBERT WILHELM BUNSEN.

sal, he re-investigated the methods by which nearly fifty years before Davy had been the fortunate discoverer of so many new elements. Bunsen improved these methods, and made in connection with Matthiessen the first thorough study of lithium, which had been discovered by Arfvedson in 1817, and for the first time the metal was isolated by him.

All through this period and for many years later he took great interest in mineralogical chemistry, especially in the chemistry of rock formation. In 1847 he visited Iceland, and soon after published a number of papers on the chemical geology of that island and also on the theory of geysers.

A series of investigations carried out with Sir Henry Roscoe, on photo-chemistry, laid the foundations of actinometry. The work of Daguerre and his followers had just given birth to the art of photography, but the whole subject was up to this time empiric. By Bunsen and Roscoe it was placed on a scientific basis and the way blazed out for the many future investigators in this field.

One further study should be mentioned, that of Bunsen and Schischkoff on the theory of gunpowder. Gunpowder had been known for centuries; van Helmont had stated that its power was due to the production of gas, but beyond this little or nothing was known till these chemists took up the investigation of the gases formed and the powder residues, and formulated for the first time a theory of gunpowder. Here as in other cases the first incentive was given which resulted in the work of Karolyi and Abel and Nobel, and the many present-day workers in the field of explosives.

This résumé is but an outline of the more important work of this great chemist, during the first half century of his life. It was almost at the close of this half century that there was to come, as it were, a crown to his work, that great discovery with which the name of Bunsen will ever be most closely linked, spectrum analysis. For several years he had been interesting himself much in blowpipe analysis, and it seems probable that the key to this discovery came, not as a result of long and patient search, but rather grew from his daily work of laboratory instruction. It was the discovery of the teacher rather than of the investigator. Associating with him his colleague, Kirchhoff, together they worked out the practical application of

his discovery, and science stood armed with a new weapon, the spectroscope. Bunsen was the first to avail himself of the instrument and brought forth from the waters of Dürkheim two new elements, rubidium and cesium. Later other new elements have followed, as indium discovered by Boisbaudran and thallium by Crookes, and a host of "meta elements" differentiated only by the spectroscope, the latest of them, victorium, needing not only this instrument but also the camera, to render its "lines" apparent.

But far more important than the mere discovery of new elements was the widening of man's horizon in a new and unexpected way. Spectrum analysis was applicable not alone to those flames we could place before it within the confines of our laboratories; the light of the sun and the stars could be studied equally well and a means was at hand for learning the chemistry of the heavenly bodies. Yet this was not all, for by the displacement of lines the motion of stars and other bodies in line of sight becomes known. Astro-physics is rendered possible by Bunsen's work.

The last of the great investigations of Bunsen were on calorimetry. The Bunsen ice calorimeter was described by him in 1870 and rendered possible specific heat determinations, with quantities hitherto too small for investigation. While from this time his activity was much lessened, yet now and then papers continued to appear from his pen. The last few years of his life, however, were spent in the quiet retirement of the old university town which had so long been his home. As long as he was able, he took great delight in showing visitors over his old laboratory, and the writer will long remember a pleasant hour spent with the old man in his laboratory some years ago, how he showed the rooms and places where this or that historic work was done, and what a delightfully genial man he was to a young stranger.

As the old chemist's sun was sinking to the west there came to Heidelberg, like a brilliant meteor, one whose fame far outshone the older light. All things were changed, the old building passed, a new and magnificent laboratory took its place; again students flocked to the Neckarthal for chemical study, but the discoverer of the spectroscope was almost forgotten. A few brief years passed by, and as the light of the brilliant meteor is suddenly extinguished, so Victor Meyer was no more. But still Bunsen lingered, as if loath that a single year of the century ushered in by his master Wöhler should be left without the presence of one of the giant minds of chemistry. But now he too is gone, and the last link between the past and the present is severed as far as lives go; but upon the foundations laid by Bunsen many a superstructure will continue to rest, and yet many another building will be erected.—James Lewis Howe, in *Science*.

QUEBRACHO TANNAGE.

By W. EITNER.

QUEBRACHO has been mostly used in Austria in conjunction with pine bark in the tanning of sole leather. It has been found when this material is employed that the hides must be "raised" or "swollen" by the use of some souring agent, and that this "plumpness" must be maintained throughout the tanning process.

With the old method of tanning, the hides were passed through a succession of pits containing old sour tan liquors, which were never thrown away, but merely strengthened periodically by the addition of small quantities of fresh extract and bark each time a fresh pack of hides was placed in the liquor. The effect of such immersion in sour tan liquors (which lasted from four to five weeks) was to produce the desired swelling and coloring of the hides, or the partial tannage or "setting" of the grain. It was generally supposed that a sour liquor with a little tannin would not contract the grain of the hide; in other words, that the tannin was the main cause of this contraction. It is now known that it is to the acid present that contraction must be chiefly ascribed, aided in some degree no doubt by strong infusions of tannin.

The American tanners have indicated the rational method of coloring and swelling hides, viz., by plumping the goods in a short space of time in a perfectly pure and "sweet" liquor, moderately strong in tannin, and keeping them in a state of continual agitation by the "coloring" wheel until they are tanned.

In the case of the new process, in which the meager tanning extracts of pine bark have been strengthened by the addition of quebracho, the sour liquors used are much more effective. Quebracho generates only a small quantity of acid, so that the whole quantity of the latter present throughout the tanning process is relatively very much less than was the case when pine bark alone was used.

The problem, therefore, to be solved is to obtain with sour liquors containing less acids and more tannin an equal degree of plumpness in the hides. It is only quite recently that it has been possible to satisfy the desire of a tanner for a hide perfectly free from lime, but, nevertheless, thoroughly plumped, viz., by the use of certain substances which remove or neutralize lime. Hydrochloric acid may be used, but only in a capacious wooden vat, so that the hides may hang with space intervals of 5 centimeters between each of them. One-quarter of the required quantity of hydrochloric acid is now put into the vat with sufficient water and the hides are suspended for six hours; another quarter of the acid is added and the hides are again immersed, and the process is repeated at intervals of six hours until the whole quantity of acid has been added. The quantity of acid to be used is 10 grammes per kilogramme of green hide. Where a wheel is available, by means of which the liquor is continually agitated, the process of "de-liming" is much quicker. The lime stock treated in this manner begins to swell, and plumps without becoming flaccid, so that the hides, though soft, are, nevertheless, firm in texture, the grain smooth and even, and in this condition they may be introduced without washing direct into the liquors. The first liquor should be at from 10 to 12 degrees B. They are moved on through a series of gradually stronger pits for about 20 days and handled regularly. At the end of this time the grain is thoroughly set, the goods are firm and colored through, and they are in a suitable condition to go into layers. A suitable strength for the layer liquor is about 15½ degrees B., and should consist of about three-quarters of acid liquor and one-

quarter of fresh liquor, and the goods should be dusted down with 3 kilogrammes of coarsely ground pine bark per hide. The latter layers may have 10 to 15 per cent. of quebracho added, with pine bark as dusting material.—Der Gerber. Abstract from The Journal of the Society of Chemical Industry.

[Continued from SUPPLEMENT, No. 1240, page 19884.]
AN ADVANCE IN MEASURING AND
PHOTOGRAPHING SOUNDS.*

By Prof. BENJAMIN F. SHARPE, M.A.

ILLUMINATION.

THUS far it has been assumed that the light passing through the train of mirrors of the refractometer, and forming the interference bands viewed in the telescope, has its origin in a sodium flame. But, as a matter of fact, white light is used because of its greater intensity. Consequently the bands are not quite so simple as described, but instead of being alternately yellow and black, they are a series of rainbows with two black bands in the middle of the series. Elsewhere the very dark reds and blues serve the purpose of the black bands and afford a strong contrast to the brighter colors. In computation, of course, a mean wave length of light is employed. The source of the white light is

FIG. 12.—The Camera, with Shutter and Lens Turned Away.

a Welsbach gas lamp. It is very intense, constant, and quiet and serves the purpose excellently. No doubt an acetylene lamp would be convenient and satisfactory for out-of-door work.

A CAMERA TO PHOTOGRAPH SOUNDS.

For photographing sounds a good electric arc lamp is required, because the time of exposure is extremely short. Indeed, the arrangement is quite different from the one used thus far in direct observation. The photographic film does not precisely take the place of the retina of the eye—but the telescope with its vibrating object glass is removed, and a single fixed lens is substituted, which focuses the interference bands upon the film. This film is wound about a horizontal cylinder kept in constant and rapid rotation, as was attempted by Raps.† Here again we make use of the principle of the composition of motions. Only in this case we have added to the lateral vibration of the bands, due to sound, a steady motion in the vertical direction, instead of an oscillatory one up and down. Consequently the result is different. The screen with the narrow horizontal slit is now set as close as convenient to the film, so that, with the cylinder at rest, and with no sound, a strip like Fig. 11, only very much smaller, is focused on the film. If now the cylinder rotates, this strip will be continuously printed on the

camera. The lid has been removed and the back let down. The cylinder is shown belted to a small dynamo, which is almost completely covered with black cloth to prevent its sparking from fogging the film. But the pulley is shown, with black and white sectors upon its face. This is part of a stroboscopic device to observe and regulate the speed of the motor. Opposite this disk is a ruby glass window in the camera, for the purpose of viewing the disk. But this inspection is made between the tines of another tuning fork in vibration, as shown in Fig. 13. Two little screens, *S*, are fastened to the ends of the tines in such a way that they barely meet when the fork is still, but in vibration, slide over each other without touching. Thus the view is interrupted once during each complete vibration. Now, if the disk turns just fast enough for one of the black sectors to advance to the position of the next, during the interval that the screens are closed of course the disk will appear to be at rest. This rate of motion is secured by feeding the motor with a constant current of just the right strength. This again is no easy matter, but a Continental scientist, Lebedew,* only a short time ago, devised a method of accomplishing it satisfactorily. His method consists in the arrangement shown in Fig. 13. The current through the motor enters at *T*, and passes out at *T'*. In so doing it passes constantly through the resistance, *R*₁, which

film by blank spaces, or by overlapping pictures. It is therefore desirable that we make the shutter open for precisely a third of a second at each exposure. This is done by the device represented in Fig. 14. The shutter, *A*, is at the end of a long lever, operated by an electro-magnet, *H*. The armature, *I*, has a hinge motion by means of the thin, flat spring, *V*, which is firmly clamped at the end represented toward the right hand of the figure. The current from the bat-

FIG. 13.—Device for Regulating the Speed of the Motor.

tery, *O*, passes down the pendulum of the clock, which beats seconds, and around through the electro-magnet, provided that the platinum point of the pendulum happens to be passing through the mercury, *M*, and provided also that the key, *T*, is closed. We adjust the width of *M* so that the pendulum is in contact with it during about half of one swing; then, to make an

FIG. 14.—Device for Opening the Shutter.

exposure we close the key at the beginning of a swing in either direction, taking care to open the key when the swing is completed. This is best done by having the clock where we can see it. The ticking is no disturbance, for it dies away before the shutter is opened.

THE UTILITY OF A CAMERA FOR SOUNDS.

With such a camera we may photograph sounds of any sort. Fig. 15 gives a number of photographs of tones and combinations of tones. The straight, narrow, white line along the middle of each photograph is produced by the shadow of a fine wire, stretched vertically across the middle of the narrow slit of the camera.

FIG. 15.—Photographs of Pure Tones and Combinations of Tones.

film, the result being parallel bands with straight edges, like the photograph of quiet, Fig. 11. But any sound added now will cause a vibration of the points of the strip sideways, and the result will be a set of parallel, wavy bands, such as in Figs. 15 and 16.

The accompanying Fig. 12 shows the inside of the

width, and the cylinder is 50 centimeters in circumference, it is evident that the time of exposure is less than one three-thousandth of a second; consequently a very intense light is required.

But the time of exposure differs from the time that the shutter is open, for during this interval a series of pictures of the size of the shutter has to be made entirely around the cylinder, unless we wish to waste our

FIG. 16.—Photographs of Vowels.

This line is not shifted with the bands, so it affords a convenient position from which to measure the displacements of the bands. When picture No. 1, Fig. 15, was taken, the room was very quiet, so far as the ear could discern. But it appears that the instrument was more sensitive than the ear, for otherwise these lines would have been as straight as the reference line. Instead they show small oscillations of the little mirror, and therefore a sound is revealed. A strong tone causes a wide displacement, like No. 12, while a weak tone

* From the Monthly Weather Review, published by the United States Weather Bureau.

† Wied. Ann., 1893, Band 50, p. 194.

* Wied. Ann., 1896, Band 59, p. 118.