compendium of chemical knowledge. Although Germany takes the lead in regard to chemical discovery, she is far behindhand in this respect. The new edition of the "Handwörterbuch," based on the well-known work of Liebig, Wöhler, and Kolber, now edited by Prof. Fehling, was commenced in 1871, but has progressed at a snail's pace, being only half way through the letter E, and the second of the six volumes which it will compose, not being yet completed. The Italian chemists have recently issued a dictionary of chemistry on a somewhat smaller scale than those alluded to above, but well edited and written.

THE additions to the Zoological Society's Gardens during the past week include two Pudua Deer (*Cervus humilis*) from Chili, a Black-faced Spider-Monkey (*Ateles ater*) from East Peru, deposited; an Arabian Gazelle (*Gazella arabica*) from Arabia, presented by Mr. W. W. Webb.

FOG SIGNALS[1]

DURING the long, laborious, and, I venture to think, memorable series of observations conducted under the auspices of the Elder Brethren of the Trinity House at the South Foreland in 1872 and 1873, it was proved that a short 5½ inch howitzer, firing 3 lbs. of powder, yielded a louder report than a long 18-pounder firing the same charge. Here was a hint to be acted on by the Elder Brethren. The effectiveness of the sound depended on the shape of the gun, and as it could not be assumed that in the howitzer we had hit accidentally upon the best possible shape, arrangements were made with the War Office for the construction of a gun specially calculated to produce the loudest sound attainable from the combustion of 3 lbs. of powder. To prevent the unnecessary landward waste of the sound, the gun was furnished with a parabolic muzzle, intended to project the sound over the sea, where it was most needed. The construction of this gun was based on a searching series of experiments executed at Woolwich with small models, provided with muzzles of various kinds. The gun was constructed on the principle of the revolver, its various chambers being loaded and brought in rapid succession into the firing position. The performance of the gun proved the correctness of the principles on which its construction was based.

Coincident with these trials of guns at Woolwich gun-cotton was thought of as a possibly effective sound-producer. From the first, indeed, theoretic considerations caused me to fix my attention persistently on this substance; for the remarkable experiments of Mr. Abel, whereby its rapidity of combustion and violently explosive energy are demonstrated, seemed to single it out as a substance eminently calculated to fulfil the conditions necessary to the production of an intense wave of sound. What those conditions are we shall now more particularly inquire, calling to our aid a brief but very remarkable paper, published by Prof. Stokes in the *Philosophical Magazine* for 1868.

A sound wave consists essentially of two parts—a condensation and a rarefaction. Now air is a very mobile fluid, and if the shock imparted to it lack due promptness, the wave is not produced. Consider the case of a common clock pendulum, which oscillates to and fro, and which therefore might be expected to generate corresponding pulses in the air. When, for example, the bob moves to the right, the air to the right of it might be supposed to be condensed, while a partial vacuum might be supposed to follow the bob. As a matter of fact, we have nothing of this kind. The air particles in front of the bob retreat so rapidly, and those behind it close so rapidly in, that no sound-pulse is formed.

The more rapid the shock imparted to the air, the greater is the fractional part of the energy of the shock converted into wave motion. And as different kinds of gunpowder vary considerably in their rapidity of combustion, it may be expected that they will also vary as producers of sound. This theoretic inference is completely verified by experiment. In a series of preliminary trials conducted at Woolwich on the 4th of June, 1875, the sound-producing powers of four different kinds of powder were determined. In the order of their sizes they bear the names respectively of Fine-grain (F.G.), Large-grain (L.G.), Rifle Large-grain (R.L.G.), and Pebble-powder (P.). The charge in each case amounted to 4½ lbs., four 24-pound howitzers being employed to fire the respective charges. There were eleven observers, all of whom, without a single dissentient, pronounced the sound of the fine-grain powder loudest of all. In the opinion of seven of the eleven the large-grain powder came next; seven also of the eleven placed the rifle large-grain third on the list; while they were again unanimous in pronouncing the pebble-powder the worst sound-producer. These differences are entirely due to differences in the rapidity of combustion.

These are some of the physical reasons why gun-cotton might be regarded as a promising fog-signal. Firing it as we have been taught to do by Mr. Abel, its explosion is more rapid than that of gunpowder. In its case the air-particles, alert as they are, will not, it may be presumed, be able to slip from places of condensation to places of rarefaction with a rapidity sufficient to forestall the formation of the wave.

As regards explosive material, and zealous and accomplished help in the use of it, the resources of Woolwich Arsenal have been freely placed at the disposal of the Elder Brethren. Gen. Campbell, Gen. Younghusband, Col. Fraser, Col. Maitland, and other officers, have taken an active personal part in the investigation, and in most cases have incurred the labour of reducing and reporting on the observations. Guns of various forms and sizes have been invoked for gunpowder, while gun-cotton has been fired in free air, and in the foci of parabolic reflectors.

On February 22, 1875, a number of small guns, cast specially for the purpose—some with plain, some with conical, and some with parabolic muzzles, firing 4 oz. of fine-grain powder, were pitted against 4 oz. of gun-cotton, detonated both in the open and in the focus of a parabolic reflector. The sound produced by the gun-cotton, reinforced by the reflector, was unanimously pronounced loudest of all. With equal unanimity, the gun-cotton detonated in free air was placed second in intensity. Though the same charge was used throughout, the guns differed considerably among themselves, but none of them came up to the gun-cotton either with or without the reflector. A second series, observed from a different distance on the same day, confirmed to the letter the foregoing result.

Meanwhile, the parabolic muzzle-gun, expressly intended for fog-signalling, was pushed rapidly forward, and on March 22 and 23, 1876, its power was tested at Shoeburyness. Pitted against it were a 16-pounder, a 5½-inch howitzer, 1½ lb. of gun-cotton detonated in the focus of a reflector, and 1½ lb. of gun-cotton detonated in free air. On this occasion, nineteen different series of experiments were made, when the new experimental gun, firing a 3-lb. charge, demonstrated its superiority over all guns previously employed to fire the same charge. As regards the comparative merits of the gun-cotton fired in the open, and the gunpowder fired from the best constructed gun, the mean values of their sounds were found to be the same. Fired in the focus of the reflector, the gun-cotton clearly dominated over all the other sound-producers.[1]

The whole of the observations here referred to were embraced by an angle of about 70°, of which 50° lay on the one side and 20° on the other side of the line of fire. The shots were heard by eleven observers on board the *Galatea*, which took up positions varying from 2 miles to 13½ miles from the firing-point. In all these observations, the reinforcing power of the reflector, and of the parabolic muzzle of the gun, came into play. But the reinforcement of the sound in one direction implies its withdrawal from some other direction, and accordingly we find that at a distance of 5¼ miles from the firing-point, and on a line, including nearly an angle of 90°, with the line of fire, the gun-cotton in the open beat the new gun; while behind the station, at distances of 8½ miles and 13½ miles respectively, the gun-cotton in the open beat both the gun and the gun-cotton in the reflector. This result is rendered more important by the fact that the sound reached the Mucking Light, a distance of 13½ miles, against a light wind which was blowing at the time.

Theoretic considerations render it probable that the shape of the exploding mass would affect the constitution of the wave of sound. I did not think large rectangular slabs the most favourable shape, and accordingly proposed cutting a large slab into fragments of different sizes, and pitting them against each other. The differences between the sounds were by no means so great as the differences in the quantities of explosive material might lead one to expect. The mean values of eighteen series of

[1] "Recent Experiments on Fog Signals." Abstract of paper read at the Royal Society, March 21. By Dr. Tyrdall, F.R.S., Professor of Natural Philosophy in the Royal Institution.

[1] In this case the reflector was fractured by the explosion.

observations made on board the *Galatea* at distances varying from 1¾ mile to 4·8 miles, were as follows :—

Weights	4-oz.	6-oz.	9-oz.	12-oz.
Value of sound ...	3·12	3·34	4·0	4·03

These charges were cut from a slab of dry gun-cotton about 1⅝ inch thick ; they were squares and rectangles of the following dimensions :—4 oz , 2 inches by 2 inches ; 6 oz., 2 inches by 3 inches ; 9 oz., 3 inches by 3 inches ; 12 oz., 2 inches by 6 inches.

It is an obvious corollary from the foregoing experiments that on our "nesses" and promontories, where the land is clasped on both sides for a considerable distance by the sea,—where, therefore, the sound has to propagate itself rearward as well as forward—the use of the parabolic gun, or of the parabolic reflector might be a disadvantage rather than an advantage. Here gun-cotton, exploded in the open, forms the most appropriate source of sound. This remark is especially applicable to such light-ships as are intended to spread the sound all round them as from central foci. As a signal in rock lighthouses, where neither syren, steam-whistle, nor gun could be mounted, and as a handy fleet-signal, which dispenses with the lumber of special signal-guns, the gun-cotton will prove invaluable. But in most of these cases we have the drawback that local damage may be done by the explosion. The lantern of the rock-lighthouse might suffer from concussion near at hand, and though mechanical arrangements might be devised, both in the case of the lighthouse and of the ship, to place the firing-point of the gun-cotton at a safe distance, no such arrangement could compete, as regards simplicity and effectiveness, with the expedient of a *gun-cotton rocket*. Had such a means of signalling existed at the Bishop's Rock Lighthouse, the ill-fated *Schiller* might have been warned of her approach to danger ten, or it may be twenty, miles before she reached the rock which wrecked her. Had the fleet possessed such a signal, instead of the ubiquitous but ineffectual steam-whistle, the *Iron Duke* and *Vanguard* need never have come into collision.

It was the necessity of providing a suitable signal for rock lighthouses, and of clearing obstacles which cast an acoustic shadow, that suggested the idea of the gun-cotton rocket to Sir Richard Collinson, Deputy Master of the Trinity House. That idea was to place a disk or short cylinder of the gun-cotton, which had proved so effectual at low levels, in the head of a rocket, the ascensional force of which should be employed to carry the disk to an elevation of 1,000 feet or thereabouts, where by the ignition of a fuse associated with a detonator, the gun-cotton should be fired, sending its sound in all directions vertically and obliquely down upon earth and sea. The first attempt to realise this idea was made on July 18, 1876, at the firework manufactory of the Messrs. Brock, at Nunhead. Eight rockets were then fired, four being charged with 5 oz. and four with 7½ oz. of gun-cotton. They ascended to a great height, and exploded with a very loud report in the air. On July 27, the rockets were tried at Shoeburyness. The most noteworthy result on this occasion was the hearing of the rockets at the Mouse Lighthouse, 8½ miles E. by S., and at the Chapman Lighthouse, 8½ miles W. by N. ; that is to say, at opposite sides of the firing-point.

On December 13, 1876, and again on March 8, 1877, comparative experiments of firing at high and low elevations were executed. The gun-cotton near the ground consisted of ½-lb. disks suspended from a horizontal iron bar about 4½ feet above the ground. The rockets carried the same quantity of gun-cotton in their heads, and the height to which they attained, as determined by a theodolite, was from 800 to 900 feet. The day last-mentioned was cold, with occasional squalls of snow and hail, the direction of the sound being at right angles to that of the wind. Five series of observation were made on board the *Vestal* at distances varying from three to six miles. The mean value of the explosions in the air exceeded that of the explosions near the ground by a small but sensible quantity. At Windmill Hill, Gravesend, however, which was nearly to leeward, and 5½ miles from the firing-point, in nineteen cases out of twenty-four the disk fired near the ground was loudest ; while in the remaining five the rocket had the advantage.

Towards the close of the day the atmosphere became very serene. A few distant cumuli sailed near the horizon, but the zenith and a vast angular space all round it were absolutely free from cloud. From the deck of the *Galatea* a rocket was discharged, which reached a great elevation, and exploded with a loud report. Following this solid nucleus of sound was a continuous train of echoes, which retreated to a continually greater distance, dying gradually off into silence after seven seconds' duration. These echoes were of the same character as those so frequently noticed at the South Foreland in 1872-73, and called by me "aerial echoes."

On March 23, the experiments were resumed, the most noteworthy results of this day's observations being that the sounds were heard at Tillingham, 10 miles to the N.E. ; at West Mersea, 15¾ miles to the N.E. by E. ; at Brightlingsea, 17½ miles to the N.E. ; and at Clacton Wash, 20½ miles to the N.E. by ½ E. The wind was blowing at the time from the S.E. Some of these sounds were produced by rockets, some by a 24-lb. howitzer, and some by an 8-inch Maroon.

In December, 1876, Mr. Gardiner, the managing director of the Cotton-powder Company, had proposed a trial of this material against the gun-cotton. The density of the cotton, he urged, was only 1·03, while that of the powder was 1·70. A greater quantity of explosive material being thus compressed into the same volume, Mr. Gardiner thought that a greater sonorous effect must be produced by the powder. At the instance of Mr. Mackie, who had previously gone very thoroughly into the subject, a Committee of the Elder Brethren visited the cotton powder manufactory, on the banks of the Swale, near Faversham, on June 16, 1877. The weights of cotton powder employed were 2 oz., 8 oz., 1 lb., and 2 lbs., in the form of rockets and of signals fired a few feet above the ground. The experiments throughout were arranged and conducted by Mr. Mackie. Our desire on this occasion was to get as near to windward as possible, but the Swale and other obstacles limited our distance to 1½ mile. We stood here E.S.E. from the firing-point while the wind blew fresh from the N.E. The cotton-powder yielded a very effective report. The rockets in general had a slight advantage over the same quantities of material fired near the ground. The loudness of the sound was by no means proportional to the quantity of the material exploded, 8 oz. yielding very nearly as loud a report as 1 lb. The "aerial echoes," which invariably followed the explosion of the rockets, were loud and long-continued.

On October 17, 1877, another series of experiments with howitzers and rockets was carried out at Shoeburyness. The charge of the howitzer was 3 lbs. of L.G. powder. The charges of the rockets were 12 oz., 8 oz., 4 oz., and 2 oz. of gun-cotton respectively. The gun and the four rockets constituted a series, and eight series were fired during the afternoon of the 17th. The observations were made from the *Vestal* and the *Galatea*, positions being assumed which permitted the sound to reach the observers with the wind, against the wind, and across the wind. The distance of the *Galatea* varied from three to seven miles, that of the *Vestal*, which was more restricted in her movements, being from two to three miles. Briefly summed up, the result is that the howitzer, firing a 3-lb. charge, which it will be remembered was our best gun at the South Foreland, was beaten by the 12-oz. rocket, by the 8-oz. rocket, and by the 4-oz. rocket. The 2-oz. rocket alone fell behind the howitzer.

On the following day, viz., October 18, we proceeded to Dungeness with the view of making a series of strict comparative experiments with gun-cotton and cotton-powder. Rockets containing 8 oz., 4 oz., and 2 oz. of gun-cotton had been prepared at the Royal Arsenal ; while others, containing a similar quantity of cotton-powder, had been supplied by the Cotton-powder Company at Faversham. With these were compared the ordinary 18-pounder gun, which happened to be mounted at Dungeness, firing the usual charge of 3 lbs. of powder, and a syren.

From these experiments it appeared that the gun-cotton and cotton-powder were practically equal as producers of sound.

The effectiveness of small charges was illustrated in a very striking manner, only a single unit separating the numerical value of the 8-oz. rocket from that of the 2-oz. rocket. The former was recorded as 6·9 and the latter as 5·9, the value of the 4-oz. charge being intermediate between them. These results were recorded by a number of very practised observers on board the *Galatea*. They were completely borne out by the observations of the Coastguard, who marked the value of the 8-oz. rocket 6·1, and that of the 2-oz rocket 5·2. The 18-pounder gun fell far behind all the rockets, a result probably to be in part ascribed to the imperfection of the powder. The performance of the syren was, on the whole, less satisfactory than that of the rocket. The instrument was worked, not by steam of 70 lbs. pressure, as at the South Foreland, but by compressed air, beginning with 40 lbs. and ending with 30 lbs. pressure. The trumpet was pointed to windward, and in the

axis of the instrument the sound was about as effective as that of the 8-oz. rocket. But in a direction at right angles to the axis, and still more in the rear of this direction, the syren fell very sensibly behind even the 2-oz. rocket.

These are the principal comparative trials made between the gun-cotton rocket and other fog-signals; but they are not the only ones. On August 2, 1877, for example, experiments were made at Lundy Island with the following results. At two miles distant from the firing point, with land intervening, the 18-pounder, firing a 3 lb. charge, was quite unheard. Both the 4-oz. rocket and the 8-oz. rocket, however, reached an elevation which commanded the acoustic shadow, and yielded loud reports. When both were in view, the rockets were still superior to the gun. On August 6, at St. Ann's, the 4-oz. and 8-oz. rockets proved superior to the syren. On the Shambles Light-vessel, when a pressure of 13 lbs. was employed to sound the syren, the rockets proved greatly superior to that instrument. Proceeding along the sea-margin at Flamboro' Head, Mr. Edwards states that at a distance of 1¼ mile, with the 18-pounder gun hidden behind the cliffs, its report was quite unheard, while the 4-oz. rocket, rising to an elevation which brought it clearly into view, yielded a powerful sound in the face of an opposing wind.

On the evening of February 9, 1877, a remarkable series of experiments was made by Mr. Prentice, at Stowmarket, with the gun-cotton rocket. From the report with which he has kindly furnished me I extract the following particulars. The first column in the annexed statement contains the name of the place of observation, the second its distance from the firing-point, and the third the result observed:—

Stoke Hill, Ipswich ...	10 miles	Rockets clearly seen and sounds distinctly heard 53 seconds after the flash.
Melton	15 ,,	Signals distinctly heard. Thought at first that sounds were reverberated from the sea.
Framlingham	18 ,,	Signals very distinctly heard, both in the open air and in a closed room. Wind in favour of sound.
Stratford, St. Andrews..	19 ,,	Reports loud; startled pheasants in a cover close by.
Tuddenham, St. Martin	10 ,,	Reports very loud; rolled away like thunder.
Christ Church Park ...	11 ,,	Report arrived a little more than a minute after flash.
Nettlestead Hall	6 ,,	Distinct in every part of observer's house. Very loud in the open air.
Bildestone...	6 ,,	Explosion very loud, wind against sound.
Nacton	14 ,,	Reports quite distinct—mistaken by inhabitants for claps of thunder.
Aldboro	25 ,,	Rockets seen through a very hazy atmosphere; a rumbling detonation heard.
Capel Mills	11 ,,	Reports heard within and without the observer's house. Wind opposed to sound.
Lawford	15½ ,,	Reports distinct: attributed to distant thunder.

It is needless to dwell for a moment on the advantage of possessing a signal commanding ranges such as these.

The explosion of substances in the air, after having been carried to a considerable elevation by rockets, is a familiar performance. In 1873, moreover, the Board of Trade proposed a light-and-sound rocket as a signal of distress, which proposal was subsequently realised, but in a form too elaborate and expensive for practical use. The idea of the gun-cotton rocket with a view to signalling in fogs is, I believe, wholly due to the Deputy Master of the Trinity House.[1] Thanks to the skilful aid given by the authorities of Woolwich, by Mr. Prentice, and Mr. Brock, that idea is now an accomplished fact, a signal of great power, handiness, and economy, being thus placed at the service of our mariners. Not only may the rocket be applied in association with lighthouses and lightships, but in the Navy also it may be turned to important account. Soon after the loss of the *Vanguard* I ventured to urge upon an eminent naval officer the desirability of having an organised code of fog-signals for the fleet. He shook his head doubtingly, and referred to the difficult of finding room for signal-guns. The gun-cotton rocket completely surmounts this difficulty. It is manipulated with ease and rapidity, while its discharges may be so grouped and combined as to give a most important extension to the voice of the admiral in command.

I have referred more than once to the train of echoes which accompanied the explosion of gun cotton in free air, speaking of them as similar in all respects to those which were described for the first time in my report on fog-signals, addressed to the Corporation of Trinity House in 1874.[1] To these echoes I attached a fundamental significance. There was no visible reflecting surface from which they could come. On some days, with hardly a cloud in the air, and hardly a ripple on the sea, they reached us with magical intensity. As far as the sense of hearing could judge, they came from the body of air in front of the great trumpet which produced them. The trumpet-blasts were five seconds in duration, but long before the blast had ceased the echoes struck in, adding their strength to the primitive note of the trumpet. After the blast had ended the echoes continued, retreating further and further from the point of observation, and finally dying away at great distances. The echoes were perfectly continuous as long as the sea was clear of ships, "tapering" by imperceptible gradations to absolute silence. But when a ship happened to throw itself athwart the course of the sound, the echo from the broadside of the vessel was returned as a shock which rudely interrupted the continuity of the dying atmospheric music.

The day on which our latest observations were made was particularly fine. Before reaching Dungeness the smoothness of the sea and the serenity of the air caused me to test the echoing power of the atmosphere. A single ship lay about half a mile distant between us and the land. The result of the proposed experiment was clearly foreseen. It was this. The rocket being sent up, it exploded at a great height; the echoes retreated in their usual fashion, becoming less and less intense as the distance of the surfaces of reflection from the observers increased. About five seconds after the explosion, a single loud shock was sent back to us from the side of the vessel lying between us and the land. Obliterated for a moment by this more intense echo, the aërial reverberation continued its retreat, dying away into silence in two or three seconds afterwards.

I have referred to the firing of an 8-oz. rocket from the deck of the *Galatea*, on March 8, 1877, stating the duration of its echoes to be seven seconds. Mr. Prentice, who was present at the time, assured me that, in his experiments with rockets, similar echoes had been frequently heard of more than twice this duration. The ranges of his sounds alone would render this result in the highest degree probable.

There is not a feature connected with the aërial echoes which cannot be brought out by experiments in the laboratory. I have recently made the following experiment:—A rectangle 22 inches by 12, is crossed by twenty-three brass tubes, each having a slit along it from which gas can issue. In this way, twenty-three low, flat flames are obtained. A sounding reed, fixed in a short tube, is placed at one end of the rectangle, and a "sensitive flame" at some distance beyond the other end. When the reed sounds, the flame in front of it is violently agitated, and roars boisterously. Turning on the gas, and lighting it as it issues from the slits, the air above the flames becomes so heterogeneous that the sensitive flame is instantly stilled by the aërial reflection, rising from a height of 6 inches to a height of 18 inches. Here we have the acoustic opacity of the air in front of the South Foreland strikingly imitated. Turning off the gas, and removing the sensitive flame to some distance behind the reed, it burns there tranquilly, though the reed may be sounding. Again lighting the gas as it issues from the brass tubes, the sound reflected from the heterogeneous air throws the sensitive flame into violent agitation. Here we have imitated the aërial echoes heard when standing behind the syren-trumpets at South Foreland. The experiment is extremely simple and in the highest degree impresssive.

[1] I have proposed that it should be called the "Collinson Rocket."

[1] See also *Philosophical Transactions* for 1874, p. 183.

THE IRON AND STEEL INSTITUTE

THE ninth annual meeting of the members of the Iron and Steel Institute was commenced on Thursday in the rooms of the Institution of Civil Engineers in Westminster. The chair was occupied by Dr. C. W. Siemens, F.R.S., the President of the Institute, and the proceedings were commenced by the reading of the Annual Report of the Council, which stated that the total number of members now exceeds 900, while a steady accession of new members continues, there being 47 proposed for election at the present meeting. The Council referred to the increase of foreign members, which shows the interest taken in the institute by Continental and American metallurgists. An invitation received from M. Tresca on behalf of the Société des Ingénieurs Civils, to visit Paris in the ensuing summer and the concurrent holding of the International Exhibition in that city,