From the Imperial Indian Government's Agricultural Research Station at Pusa has been issued Bulletin No. 28 on "The Cultivation of Lac in the Plains of India," by C. S. Misra, a well-illustrated account of the insect (*Tachardia lacca*), the trees on which it thrives, their culture, the collection of the product, the manufacture of shellac, and its economic uses. The most dangerous enemies of the lac insect appear to be the predaceous caterpillars of four species of moth.

FORESTS AND CLIMATE.

THE very general belief in the influence of forests upon climate, and especially upon rainfall, is discussed by Prof. R. de Courcy Ward in an interesting article in the April number of *The Popular Science Monthly*. The subject is very complicated, and the author points out that we must be careful not to put the cart before the horse; in other words, the forests are the result of the rainfall, and not *vice versâ*.

The various questions involved are discussed in detail, the following being among the points dealt with:—(1) The historical method; (2) why forests should influence climate; (3) influence upon (*a*) temperature, (*b*) humidity and evaporation; (4) the cases frequently cited as showing an influence upon rainfall; (5) recent European studies. Among the authorities quoted, Hellmann has shown that the increase in the rainfall over a forest is accompanied by a lessened fall to leeward—simply a slight difference in distribution. Both Voeikof (Russia) and Hann (the leading authority on climate) believe that the vast tropical forests may increase the amount of rainfall. But as regards our own latitudes the author considers that there is at present no conclusive evidence that forests have a significant effect upon the amount of rain*fall*, as distinguished from the amount of the rain*catch* in the gauge.

There is comparatively little popular interest in the possible influence of forests upon temperature; the forest is a little cooler than the open in summer, and possibly very slightly warmer in winter. Supan sums up the case as follows:—"No one will care to maintain that the system of isotherms would be radically altered if Europe and Asia were one great forest from ocean to ocean." With regard to moisture, the author thinks that the local supply from forests cannot play any considerable part in the great rain-producing processes.

SYSTEMS OF LONG-DISTANCE WIRELESS TELEGRAPHY.

THE Advisory Committee appointed by the Postmaster-General to consider and report on the merits of existing systems of long-distance wireless telegraphy has made its report. The Committee heard evidence in private from representatives of the Marconi, the Telefunken, the Poulsen, the Goldschmidt, and the Galetti interests, and of the Admiralty, and the members visited a number of stations.

The report is strictly limited to practical considerations, and deals with matters of engineering rather than of scientific interest. From the point of view of the building of stations for immediate operation in the Imperial wireless chain, the report is overwhelmingly in favour of the Marconi Company, not only on account of its plant, but also on account of its experience; though the Committee points out that it would be possible for the Government to get together a highly trained staff and erect the stations, using any desirable patents under the provisions of section 29 of the Patents and Designs Act, 1907. The Marconi spark plant was tested by the Committee as to duplex working, and as to automatic transmission at the rate of sixty words per minute, across the Atlantic, a distance of 2300 miles. The Committee found Transatlantic communication practically continuous, though there are periods when the signals become very weak; and there are occasional periods when no signals at all can get through. These weak periods are due to natural causes, and can probably only be overcome by the use of high powers.

The Committee received no evidence supporting the reported transmission from San Francisco to Honolulu (2100 miles) by the Poulsen arc, but witnessed transmission over a relatively short distance at seventy words per minute. The members also saw the Goldschmidt alternator transmit at the rate of sixty words per minute. It is interesting to note that the Marconi Company and the Telefunken Company are both experimenting with generators of continuous waves. The Marconi machine consists essentially of a rapidly rotating contact-maker in a direct-current circuit with special dispositions of other circuits to give continuous oscillations in the antenna. The Telefunken machine is an alternator constructed to give as high a fundamental frequency as may be convenient in the first instance, the frequency being doubled or quadrupled by a polarised transformer method. The Marconi machine was witnessed working across the Atlantic.

SOME FURTHER APPLICATIONS OF THE METHOD OF POSITIVE RAYS.[1]

THE method to which I shall refer this evening is the one I described in a lecture I gave here two years ago. The nature of the method may be understood from the diagram given in Fig. 1. A is a vessel containing the gases at a very low pressure; an electric discharge is sent through these gases, passing from the anode to the kathode C. The positively electrified particles move with great velocity towards the kathode; some of them pass through a small hole in the centre, and emerge on the other side as a fine pencil of positively electrified particles.

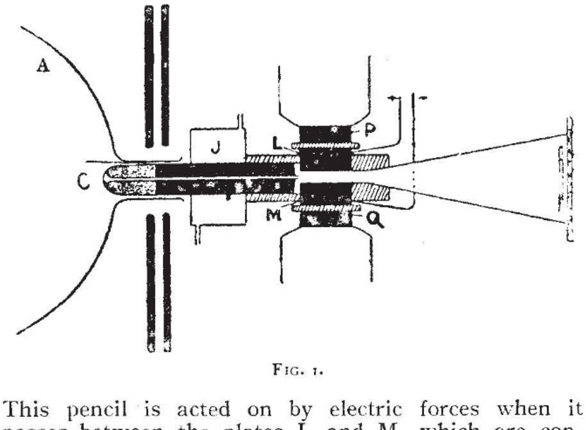

FIG. 1.

This pencil is acted on by electric forces when it passes between the plates L and M, which are connected with the terminals of a battery of storage cells, and by a magnetic force when it passes between P and Q, which are the poles of an electromagnet. In the pencil before it passed under the influence of these forces there might be many kinds of atoms or molecules, some heavy, others light, some moving quickly, others comparatively slowly, but these would all be mixed up together. When they are acted on by the electric and magnetic forces, however, they get sorted out, and instead of travelling along the

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[1] Discourse delivered at the Royal Institution on Friday, January 17, by Sir J. J. Thomson, O.M., F.R.S.

same path they branch off into different directions. No two particles will travel along the same path unless they have the same mass as well as the same velocity; so that if we know the path of the particle we can determine both its mass and its velocity. In chemical analyses we are concerned more with the mass than with the velocity, and we naturally ask what is the connection between the paths of particles which have the same mass but move with different velocities. The answer is that all such paths lie on the surface of a cone, and that each kind of particle has its own cone; there is one cone for hydrogen, another for oxygen, and so on. Thus one cone is sacred to hydrogen, and if it exists there must be hydrogen in the vessel; so that if we can detect the different cones produced from the original pencil, we know at once the gases that are in the tube. Now, there are several ways of identifying these cones, but I shall only refer to the one I have used in the experiments I wish to bring before you this evening. These moving electrified particles, when they strike against a photographic plate, make an impression on the plate, and a record of the place where they struck the plate can be obtained. Thus, when a plate is placed in the way of the particles streaming along these cones, the sections of these cones by the plate (parabolas) are recorded on the photograph, hence we can identify these cones by the parabolic curves recorded on the photograph, and these parabolas will tell us what gases are in the vessel.

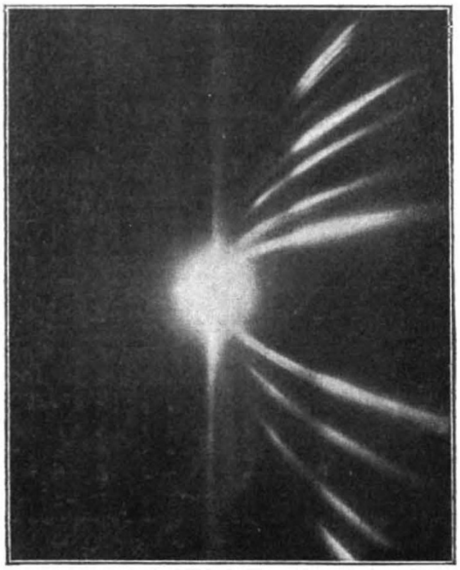


FIG. 2.

The first application of the method which I shall bring before you this evening is to detect the rare gases in the atmosphere. Sir James Dewar kindly supplied me with two samples of gases obtained from the residues of liquid air; the samples had been treated so that one might be expected to contain the heavier gases, the other the lighter ones. I will take the heavier gases first. The photograph of these is shown in Fig. 2. When the plate is measured up it shows a faint line corresponding to the atomic weight 128 (xenon), a very strong line corresponding to the atomic weight 82 (krypton), a strong argon line 40 (argon), and the neon line 20. There are no lines unaccounted for, and hence we may conclude that in the atmosphere there are no unknown gases of large atomic weight occurring in quantities comparable with those of xenon or krypton. This result gives an example of the convenience of the method, for a single photograph of the positive rays reveals at a glance the gases in the tube. I now turn to the photograph of the lighter constituents shown in Fig. 3; here we find the lines of helium, of neon (very strong), of argon, and, in addition, there is a line corresponding to an atomic weight 22, which cannot be identified with the line due to any known gas. I thought at first that this line, since its atomic weight is one-half that of CO_2, must be due to a carbonic acid molecule with a double charge of electricity, and on some of the plates a faint line at 44 could be detected. On passing the gas slowly through tubes immersed in liquid air the line at 44 completely disappeared, while the brightness of the one at 22 was not affected.

The origin of this line presents many points of interest; there are no known gaseous compounds of any of the recognised elements which have this molecular weight. Again, if we accept Mendeléef's periodic law, there is no room for a new element

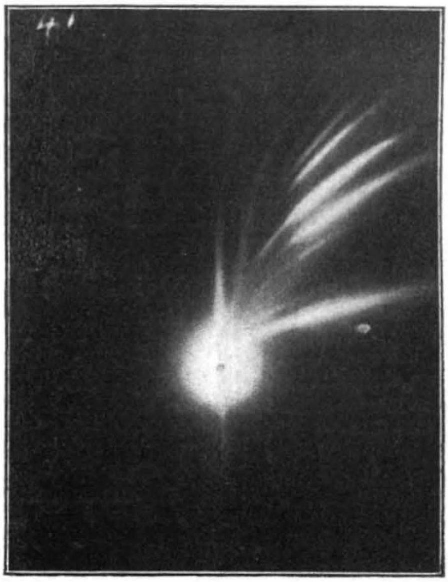


FIG. 3.

with this atomic weight. The fact that this line is bright in the sample when the neon line is extraordinarily bright, and invisible in the other when the neon is comparatively feeble, suggests that it may possibly be a compound of neon and hydrogen, NeH_2, though no direct evidence of the combination of these inert gases has hitherto been found. I have two photographs of the discharge through helium in which there is a strong line, 6, which could be explained by the compound HeH_2, but, as I have never again been able to get these lines, I do not wish to lay much stress on this point. There is, however, the possibility that we may be interpreting Mendeléef's law too rigidly, and that in the neighbourhood of the atomic weight of neon there may be a group of two or more elements with similar properties, just as in another part of the table we have the group iron, nickel, and cobalt. From the relative intensities of the 22 line and the neon line we may conclude that the quantity of the gas giving the 22 line is only a small fraction of the quantity of neon.

Let me direct your attention again to the photograph of the heavier gases in the atmosphere. You will notice that the parabolas corresponding to many of the elements start from points which are all in the same vertical line; this indicates that the atoms or molecules which form these parabolas all carry the same charge. Several of these lines, however, do not follow this rule; you will notice, for example, that the neon line has a prolongation which comes nearer than the normal line to the vertical line drawn through the undeflected spot. Measurement of the photograph shows that the neon line begins at a distance from this vertical line which is only half the normal distance; this shows that some of the neon atoms in the positive rings possess two charges of electricity; the majority of them, however, only possess one. If you examine the argon line you will find that it comes even nearer to the vertical than the neon line; in fact, it begins at a distance from the vertical only one-third of the normal distance; this proves that the argon atom can have as many as three charges of electricity. If now you examine the krypton line you will find that it comes nearer to the vertical line than even the argon; its least distance is one-fourth of the normal distance, showing that the krypton atom may have as many as four charges. The mercury line comes so close to the vertical line that it is only on large photographs that it can be seen that there is in reality an interval; this interval is only one-eighth of the normal interval, showing that mercury may acquire eight positive charges, *i.e.* that it may lose eight corpuscles. The mercury atom when it is on this line must have only the normal charge, *i.e.* it must have regained all but one of the corpuscles it previously lost; if it had retained two positive charges it would have been on the line corresponding to the atomic weight 200/2 or 100; if it had retained 3, or 4, 5, 6, 7, 8 on the lines corresponding to the atomic weights, 200/3, 200/4, 200/5, 200/6, 200/7, 200/8 respectively. All these except the last have been detected on the plate. The lines corresponding to the multiple charges on krypton, argon, and neon have also been detected. It appears, then, that in a vacuum tube a mercury atom, for example, may be ionised in two ways; in the one way the atom loses one corpuscle, in the other it loses eight.

I would suggest that these two types of ionisation may result from the two different types of collision which the atom must experience. The first type is collision with a corpuscle; since the corpuscle is an exceedingly small body moving with a very great velocity, it can pass freely through the atom, and the collision it makes with the atom is really a collision with a corpuscle inside the atom; this may result in the corpuscle it strikes acquiring such a great velocity that it is able to escape from the atom; this type of collision will result in the detachment of a single corpuscle. The second type of collision is when the atom collides with another atom and not with another corpuscle; the result of this collision may be that the atom suffers a sudden change in its velocity. This change is not at first shared by the corpuscles, so that these just after the collision may have a very considerable velocity relative to the atom. If there are several corpuscles which are comparatively loosely attached to the atom, these may all be detached from it and leave it with a positive charge corresponding to the number shaken out. It is this type of collision which we regard as giving the multiply-charged ions, and we see that the magnitude of the charge is a measure of the number of corpuscles in an atom which are readily detachable from it. We have seen that the greater the atomic weight the greater the charge it can acquire, the maximum charge being roughly proportioned to the square root of the atomic weight, hence the heavy elements have a larger number of detachable corpuscles than the lighter ones.

Another application of the method I should like to bring before you is the use of it for the discovery and investigation of a new substance. I have in previous lectures said that sometimes there appeared on the plates a line corresponding to a particle with an atomic weight 3; this must either be a new element or a polymeric modification of hydrogen, represented by H_3. The other possibility that it is a carbon atom with four charges is put out of court by the fact that it frequently occurs when the carbon line is exceedingly faint, and when there is not a trace of a carbon atom with even two charges, though the doubly-charged carbon atom occurs readily under certain conditions. In addition to this, the carbon atom parabola never approaches the vertical near enough to allow of its having four charges. I thought the study of the substance producing this line would be of interest, and I have for some time been working at it, and although the research is by no means completed, I have obtained some results which I should like to bring before you.

At first I was greatly hindered by not knowing the conditions under which the line occurred; although it appeared from time to time on the plates, its appearance was always fortuitous and sometimes for weeks together the plates would not show a trace of the line. The line sometimes appeared, but why it did so was a mystery, and I could not get it when I wanted it. I began an investigation, which proved long and tedious, to find the conditions under which the line appeared. I tried filling the discharge-vessel with all the gases and vapours described in the books on chemistry without success. At last I tried bombarding various substances with kathode rays. Under this treatment the substances give off considerable quantities of gas the greater part of which is hydrogen, carbonic acid, or carbon monoxide. When I came to analyse by the positive rays the gases given off in this way, I found that with a large number of substances these gases contained the substances giving the three lines, so that I was now in a position to get this line whenever I wanted it, and investigate the properties of the gas to which it owes its origin. The question of the gases absorbed and given off by solids is an extremely interesting one, and a considerable number of investigations have been made on it. In all these, so far as I know, the method has been to heat the solid to a high temperature, and then measure and analyse the very considerable amount of gas which is driven off by the heating. So far as I know, no experiments have been made in which the gases were driven off by bombardment with kathode rays. This treatment, however, will cause the emission of gas even when ordinary heating fails to do so.

Belloc, who has recently published[2] some interesting experiments on this subject, after spending about six months in a fruitless attempt to get a piece of iron in a state in which it would no longer give off gas when heated, came to the conclusion that, for practical purposes, a piece of iron must be regarded as an inexhaustible reservoir of gas. There are some interesting features about the emission of gas from a heated solid. If the body is kept for a long time in a vacuum at a high temperature, the emission of gas becomes too small to be detected; if after this treatment the temperature is raised considerably, there will be a further copious emission of gas, which again diminishes as the heating continues. After it has fallen to zero, all that is necessary is to raise the temperature again and you will get a fresh supply of gas; and so far as my experience goes, after you

[2] *Ann. de Chimie et de Physique* [8], xviii., p. 569.

have got all the gas you can out of the solid by heating it, you have only to expose it to kathode rays to get a fresh outburst. This effect of increased temperature in renewing the stream of gas from the solid seems to me to be too large to be accounted for merely by an increase in the rate of diffusion of the absorbed gas from the interior to the surface; it seems to be more analogous to the case of the emission of the water of crystallisation from some salts. There are some salts, for example, copper sulphate, which when heated lose their water of crystallisation in stages; thus, if the temperature is raised to a certain value, some of the water of crystallisation comes off, but the rest remains fixed, and you may keep the salt at this temperature for ever without getting rid of all the water of crystallisation; on raising the temperature, however, fresh water of crystallisation is given off. Something of this kind seems to take place in the case of gases absorbed in metals, and there seem to be indications that there is some kind of chemical combination between the gas and the metal. This absorbed gas may influence the behaviour of the substance. For example, an ordinary carbon filament gives off, when raised to a white heat, large quantities of negatively electrified corpuscles; but Pring and Parker[3] have shown that when great precautions are taken to get rid of the absorbed gas, the emission of these corpuscles falls to less than one-millionth of their previous value. It is in the gases given off by certain metals when they are bombarded by kathode rays that I have found an unfailing source of the substance, which I shall denote by X_3, giving the line corresponding to the atomic weight 3. The arrangement I have used for investigating the presence of this gas is shown in Fig. 4. A is a vessel communicating with the bulb B in which the positive rays are produced by two tubes, one of which is a very fine capillary tube, while the other one is five or six millimetres in diameter; taps are inserted so that one or both of these vessels can be closed, and the vessels A and B isolated from each other. A is provided with a curved kathode such as are used for Röntgen ray focus tubes, and the kathode rays focus on the platform on which the substance to be bombarded is placed. (It is not absolutely necessary to focus the kathode rays in this way, but it makes the supply of the gas X_3 more copious.) After the metal or other solid to be examined has been placed on the platform, the taps between A and B being turned so as to cut off the connection between them, A is exhausted until the vacuum is low enough to give the kathode rays; the discharge is then sent through A, and the kathode rays bombard the solid. The result of this is that in a few seconds so much gas, mainly CO_2 and hydrogen, is driven out of it that the pressure gets too high for the kathode rays to be formed, and unless some precautions to lower the pressure were taken the bombardment would stop. To avoid this, a tube containing charcoal cooled by liquid air is connected with A, and this absorbs the CO_2 and enough of the hydrogen to keep the vacuum in the kathode ray state. To see what new gases are given off in consequence of the bombardment, a photograph is taken while the connection between A and B is cut off. After this is finished, and when the bombardment has gone on for about four hours, the tap is turned and a little of the gas from A is allowed to go into B; another photograph is taken, and those lines in the second photograph which are not in the first represent those gases which are liberated by the bombardment, and have escaped being absorbed by the charcoal. I have here a slide (Fig. 5) representing the result of bombarding nickel. There are two photographs, one (α) before turning the tap, and the other (β) after; in the second you see the 3 line very distinctly, while it is absent from the first, showing that the gas giving the 3 line has been liberated by the bombardment. I have got similar results to these when, instead of nickel, iron, copper, lead, and zinc have been bombarded. I have tried two specimens of meteorites kindly lent to me from the Mineralogical Museum, Cambridge, and found there the 3 line. Nearly every substance I have tried gives, the first time it is bombarded, the helium line as well as this line due to X_3; if, however, the same substance is bombarded a second time, the helium line is in general absent (occasionally it is still to be detected, though exceedingly faint); and on the third bombardment is invisible in all the substances I have tried except monazite sand, where it is given off in exceedingly large quantities so long as the bombardment continues. It is remarkable that monazite sand, which contains so many elements, gives no trace of the 3 line when bombarded.

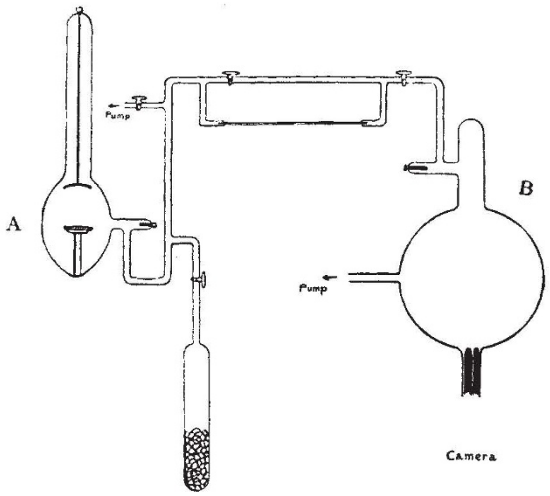
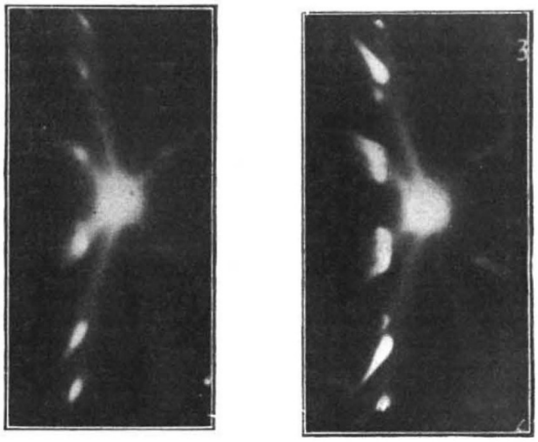


FIG. 4.



α FIG. 5. β

I have also obtained the X_3 line and also the helium line when the tube A was replaced by one containing a Wehnelt kathode; with this the current of kathode rays through the tube was much larger than with the other kathode, though the velocity of the rays was

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[3] *Phil. Mag.*, xxiii., p. 192.

smaller. The Wehnelt kathode gives the line without placing pieces of metal in the tube, so that in this case nothing is bombarded by the kathode rays but the glass walls of the tube; the strip of metal forming the kathode is, however, bombarded by the positive rays.

The 3 line when present at all continues even though the bombardment is very prolonged. In some cases the bombardment has been prolonged for twenty hours, and at the end of that time the line seemed almost as bright as at the beginning; indeed, I could not feel certain that there was any difference. This might lead one to suspect that X_3 was manufactured from the lead or other metal by the bombardment rather than stored up in it, and this view might be regarded as receiving some support from the fact that very little of the X_3 is liberated by heating. The following experiment is an illustration of this. I took a piece of lead, and instead of bombarding it with kathode rays I placed it in a quartz tube connected with vessel A, and heated the tube to a bright red-heat for several hours. Large quantities of CO_2 and hydrogen were driven off by this process; this was absorbed by charcoal, and the residual gases, which had accumulated in A, were admitted into the vessel B; the X_3 line and helium line could just be detected, and that was all. I then gave the lead a second heating, raising this time the temperature until the quartz was on the point of softening. The lead was boiling vigorously; the heating was kept up for about three hours. In this time about three-quarters of the lead had boiled away. I then let the gases which had been given off at the second heating into the vessel B, and took another photograph; no trace of the line due to X_3 or helium could be detected. The fraction of the lead which had not been boiled away was now placed in A and bombarded by kathode rays. It now gave the 3 line quite distinctly; the helium line was visible, but faint. By the bombardment with the kathode rays the lead was only just melted, so that the average temperature was much less than when it was heated in the quartz tube. This rather suggests that the X_3 might be due to a kind of dissociation of the metal by the kathode rays, and not to a liberation of a store of that substance. Another experiment shows, however, that for lead, at any rate, this view is not tenable. I took some lead which had just been deposited from a solution of lead acetate by putting a piece of zinc into the solution, and forming the well-known lead-tree. When I bombarded this freshly precipitated lead, I could get no trace of the X_3 line; the helium line, too, was absent. I then tried another experiment. I took a piece of lead and divided it into two parts. The first of these I bombarded by the kathode rays: it gave the X_3 line quite distinctly. The other part I dissolved in boiling nitric acid, getting lead nitrate. The nitrate was heated and converted into oxide, and this was bombarded by the kathode rays: it did not give the X_3 line, showing that the X_3 is not produced by the bombardment, but is something stored up in the lead, which can be detached from it when the lead is dissolved. I have tried several samples of lead; the one which gave the X_3 line most distinctly was a piece of lead from the roof of Trinity College Chapel, several hundred years old. A sample of Kahlbaum's chemically pure lead, which must, I suppose, at no distant date have been subjected to severe ordeals by fire and water, showed the line quite distinctly, though not so well as the older lead. I have tried similar experiments with iron, and found that iron which gave the 3 line very distinctly ceased to do so after it had been dissolved in acid.

As the most obvious explanation of X_3 is that it is H_3, bearing the same relation to hydrogen that ozone does to oxygen, and produced in some way from the hydrogen dissolved in the metal, I tried if I could produce it by charging metals with large quantities of hydrogen, and then seeing if the hydrogen coming from the metal gave any traces of H_3. Thus, for example, I tested the hydrogen given off from hot palladium, but found no trace of X_3. I then charged nickel at a temperature of about 355° C. with hydrogen in the way recommended by Sabatier, but found no increase in the brightness of the X_3 over nickel that had not been deliberately exposed to hydrogen. I tried if the brightness of the line would be increased by adding hydrogen to the bulb A, in which the bombardment took place, but found no effect. I also tried adding oxygen to this bulb, thinking that if it was H_3 it would combine with the oxygen, and thus be eliminated, but no great diminution in the intensity was produced by this treatment. The gas seems quite stable, at least it can be kept for several days without suffering any diminution that can be detected; indeed, when once it has got into a bulb, there is considerable difficulty in getting the bulb free from it. It must be remembered, too, that by the method by which it is produced the gas is subjected all the time to electric discharges which would break it up unless it possesses very great stability. Thus if X_3 is a polymeric modification of hydrogen, it must possess the following properties:—

(1) It must be very stable.
(2) it must resist the action of oxygen.
(3) It must not be decomposed by long-continued exposure to the electric discharge.

These are properties which *a priori* we should scarcely have expected an allotropic modification of hydrogen to possess.

Mendeléef predicted the existence of an element with an atomic weight 3. According to him this element should be intensely electro-negative and possess the properties of fluorine to an exaggerated extent. The gas X_3 can, however, be kept in glass vessels, which we should not expect to be possible if it possessed more than fluorine's power of combining with glass. I prefer to defer expressing any opinion as to the actual nature of the gas until I have had the opportunity of making further experiments upon it. It is only about two months ago that I found how to get the gas with any certainty, and, as the method involves long bombardments, each experiment takes a considerable time. This has prevented me from making several experiments which suggest themselves, and which ought to be made before coming to a final decision. I thought, however, that the investigation, though incomplete, might not be unsuitable for a Friday evening discourse, as the gas, whatever its nature, is certainly one of considerable interest, and its detection illustrates the delicacy of this new method.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The Sudbury-Hardyman prize offered for an original dissertation by a graduate member of Emmanuel College under the standing of M.A. has been increased to 40*l*., and divided between G. E. K. Braunholtz, formerly scholar and research student, and R. D. Vernon, research student. Mr. Braunholtz's dissertation was "The Nomina of Italy, peculiar to Gallia Transpadana," and Mr. Vernon's "The Geology and Palæontology of the Warwickshire Coal-field."

THE electors to the Michael Foster research studentship in physiology give notice that there will be an