road construction are given in an instructive and interesting form. To quote the words of Mr. C. W. Dabney, Assistant Secretary of the Department: "It has been sought to make the volume a concise reference book of useful agricultural information based in great part upon the work of this and other Departments of the Government, without making it an encyclopædia of general information. In brief, the effort has been to make a book, and not a mere Government report—a book worthy to be published in an edition of half a million copies and at an expense to the people, if we count both publication and distribution, of over four hundred thousand dollars." The money thus spent in disseminating accurate knowledge of agricultural investigations may appear excessive, but it will be returned to the country a hundred-fold.

THE additions to the Zoological Society's Gardens during the past week include a Black-faced Kangaroo (*Macropus melanopus*, ♂) from Australia, presented by Mr. G. T. Wills; a Loder's Gazelle (*Gazella loderi*, ♀) from Oued Souf, Algeria, presented by Mr. A. B. Birdwood; a Gazelle (*Gazella* ——), two Hairy-footed Jerboas (*Dipus hirtipes*), a Spot-bellied Snake (*Zamenis ventrimaculatus*), an Ocellated Sand Skink (*Seps ocellatus*) from Arabia, presented by Dixon Bey; a Common Cormorant (*Phalacrocorax carbo*), British, presented by Miss G. Howell; two Passerine Parrots (*Psittacula passerina*) from South America, presented by Miss L. Scott Moncrieff; a Brown Capuchin (*Cebus fatuellus*) from Guiana, a Grey Ichneumon (*Herpestes griseus*) from India, deposited; two Patagonian Cavies (*Dolichotis patachonica*), two Ypecaha Rails (*Aramides ypecaha*), bred in the Gardens.

OUR ASTRONOMICAL COLUMN.

BROOKS'S COMET.—This comet, which M. Javelle, of Nice, has fortunately re-discovered, remains so faint an object, that other observations for the improvement of the elements, computed by Dr. Bauschinger, are still wanting. The one position secured has been utilised to correct the mean motion, and consequently the time of perihelion passage. This will take place November 4·18375, Berlin mean time, or only 0·2083 days later than the time determined from the last appearance. The excentricity needs probably a small correction, but the data for its determination are not yet existing. The following ephemeris, for Berlin midnight, is derived from the corrected mean motion and time of perihelion passage.

1896.		R.A. h. m. s.	Decl. ° ′ ″	Brightness.
Aug.	13	22 32 43·50	−18 54 24·1	1·8
	16	30 58·66	18 59 1·0	1·9
	20	28 26·73	19 4 4·9	1·9
	24	25 44·87	19 7 30·7	2·0
	28	22 58·22	19 8 52·5	2·0
Sept.	1	20 11·78	19 7 49·1	2·1
	5	17 31·14	19 4 1·2	2·1
	9	15 2·04	18 57 10·7	2·1
	13	12 49·63	18 47 8·8	2·0
	17	10 58·23	18 33 53·0	2·0
	21	9 31·79	18 17 22·7	2·0
	25	8 32·66	17 57 45·6	2·0
	29	8 2·93	17 35 8·0	1·9

For finding the comet, the bright star Fomalhaut will still be convenient, the region comprised in the ephemeris being about 11° north of the star, and on the meridian (London) about 1·45 a.m.

METEOR TRAILS.—We noted on July 30 (p. 301) that attention has been called by Prof. Johnstone Stoney and others to the desirability of observing the meteors in November next, which are likely to form part of the great November shower, particularly with the view of settling the question of the date at which the shower was introduced into the solar system. Improved methods of observation might have been expected to furnish more accurate information, and lead to a closer approximation to the orbit. It is therefore disappointing to read in the Report issued by Dr. Elkin, the Director of the Yale Observatory, that, notwithstanding repeated efforts, no photographic records of meteor trails have been secured. The apparatus was in use for the August meteors, but none were of sufficient brilliancy to impress themselves upon the film, which had become somewhat fagged by the strong moonlight. Other occasions were equally disappointing: but the Director is not discouraged, and in place of the two lenses now employed he hopes to substitute the complete battery of lenses for which the mounting was originally planned.

PERSONAL EQUATION IN OBSERVING TRANSITS.—The vexed question of the existence and necessary removal of personal equation in determining clock error has been attacked by Mr. R. H. Tucker, of the Lick Observatory. The particular form of the question to which Mr. Tucker has applied himself is that raised some years since by Prof. van der Bakhuyzen, of the effect of the brilliancy of the star on the time of transit determined by chronographic registration. Mr. Tucker placed over the object-glass four thicknesses of wire netting, which reduced the magnitude of the star 4·1 magnitudes, or, in other words, destroyed all but one forty-fifth part of the original light. The clock error was determined from the observations of stars, with and without the screen alternately, with the result that the faint stars were observed 0·037s. later than when seen at their full brilliancy. The correction to observed right ascension is −0·009s. for each magnitude, with a probable error of ±0·001s.

RECENT RESEARCHES ON RÖNTGEN RAYS.

THE subjoined summary brings together in a convenient form for reference a number of researches on Röntgen rays which have recently come under our notice. It will be seen that a large amount of detailed information with reference to the character and capabilities of the rays is being accumulated by investigators in various parts of the world.

Dr. A. Dupré, F.R.S., writes, under date July 29:

"The article by Mr. Benjamin Davies, in your issue of July 23, has recalled to my mind certain experiments of my own, made several months since, which may perhaps throw some light on Mr. Davies' results. I was then working with various vacuum tubes, and among others with an ordinary Geissler tube containing nitrogen, such as is used for obtaining spectra of gases. The capillary part of this tube gave a brilliant light, which had the power of inducing fluorescence of many substances, to a remarkable degree, the light falling direct on to the substance. The tube being in action, the screen covered with platino-cyanide of potassium fluoresced strongly ten feet from the tube, the active surface being towards the tube. This was, of course, to be expected, but, to my astonishment, the fluorescence was almost equally noticeable when the back of the screen was turned towards the tube, and remained so even when I interposed a book, a board, a sheet of tin-plate, or the human body between the tube and the screen. When, however, I placed my hand against the back of the screen, no trace of a shadow was noticeable; the same was the case when pieces of metal, or other objects opaque to the Röntgen rays were so placed. The screen all the while remaining strongly and uniformly fluorescent. This seemed to me to show that, whatever the nature of the rays producing the fluorescence of the screen, they could not be Röntgen rays; and I concluded that the fluorescence was really due to light striking the front, or active, surface of the screen after reflection, either from the walls of the room, or, perhaps, from the air. When accordingly all possibility of any light thus reaching the screen was excluded, all fluorescence was effectually stopped. Might it not be possible that in Mr. Davies' experiment the fluorescence of his screen was in part, at least, induced by rays reaching the active surface of the screen after reflection? Thus accounting for the fact that the hand cast no shadow whatever."

Mr. J. A. M'Clelland read a paper on the "Selective Absorption of Röntgen Rays" before the Royal Society on June 18. The experiments described in the paper were made to determine whether or not the Röntgen rays given off by a vacuum bulb were of a homogeneous nature, by examining the manner in which they are absorbed by different substances. The substance whose absorptive power was to be examined—say, a plate of glass—was placed so that the rays traversed it before falling on a charged disc, which was in connection with a pair of quadrants of an electrometer. The disc was discharged by the rays, and the transparency of the substance was measured by the rate at which the spot of light from the electrometer needle moved across the scale. Sheets of tinfoil were then substituted for the glass, and the number—n, say—taken, such that the rate of discharge of the disc was approximately the same as with the glass. The rate of discharge was accurately measured in the two cases. The ratio of the rate of discharge with the glass to that with the n sheets of tinfoil gave a measure of their relative transparency to Röntgen rays. The rays were then made to pass through a number of sheets of tinfoil, and then through the glass, and the rate of discharge measured. The glass was removed, and the same n sheets of tinfoil as were formerly used put in its place, and the discharge again measured. The ratio of the rate of discharge in the latter two cases was a measure of the relative transparency of the glass and the tinfoil sheets to Röntgen rays which had been already screened by passing through tinfoil. If the Röntgen rays were all of one kind, the two ratios thus obtained should be equal, but a difference in the ratios could only be explained by assuming that the rays were not homogeneous, and that some were more readily absorbed by the tinfoil, and others by the glass or other substance used. Various substances were tested against tinfoil in this manner. With some there was no selective absorption, with others it was very marked. Glass gave none, with mica and paraffin the effect was small, with fuchsine, eosine, and a number of other substances the effect was very marked. A table, given in the paper, showed the results obtained with these and other substances. The author concluded that the Röntgen rays are of different kinds, and that the substances given in the table differ very much from tinfoil in their selective absorption. It is important to observe that these results were obtained with a vacuum bulb which was working extremely well and discharging the disc very rapidly. With another bulb, which was not nearly so efficient, no evidence of selective absorption could be obtained. The radiation from this bulb was homogeneous as far as could be determined by this experiment. With a third bulb, better than the last, but not so good as the first, selective absorption was obtained, although less marked than with the first bulb. It seems, therefore, that as a tube becomes more efficient the character of its radiation becomes less homogeneous.

The effect of Röntgen rays in discharging electrified bodies continues to form the subject of investigation of several Italian physicists, whose conclusions may with interest be compared with the results obtained by Prof. J. J. Thomson in this country. Prof. Emilio Villari (*Atti della R. Accademia dei Lincei*) enunciates the following conclusions, in support of which an elaborate series of experiments are fully described. (1) The discharge of a conductor in air, when provoked by Röntgen rays, takes place by an electrical convection of the particles of air set in action by the radiations. (2) The discharge is retarded if the surface of the electrified conductor exposed to the air is diminished by covering part of it with paraffin. (3) When the conductor is covered all over with paraffin placed in contact with it, the discharge stops almost immediately after it has been started by the Röntgen rays. A little electricity conveyed by the surrounding film of air charges the paraffin, and further discharge was prevented. (4) If the conductor is surrounded by air enclosed within a tube of paraffin, and subjected to Röntgen rays, the discharge at first takes place fairly rapidly, but subsequently proceeds extremely slowly. The electricity carried off as usual by the air suddenly charges the walls of the tube, and afterwards is dispersed with difficulty. (5) The electricity dispersed by the body can be collected on a tube of paraffin, as in the preceding case, or on an insulated metal tube surrounding the discharged body. This collected electricity can be observed with an electroscope, and it is, of course, of the same kind as that of the body. (6) Metal tubes, whether insulated or not, surrounding the electroscope, serve to condense on it the charges imparted to them. They retard the discharge produced by Röntgen rays, either on account of the quantity of electricity accumulated by them, or owing to their imperfect transparency to the rays.

Prof. Augusto Righi (*Atti della R. Accad. dei Lincei*) also *still* considers it "non proven" that any but a gaseous dielectric becomes a conductor under the influence of Röntgen rays, thus agreeing substantially with Prof. Villari. Prof. Righi, however, has discovered a source of error in his previous experiments, which, however, does not affect this result. If in front of the aluminium window of a leaden box containing the Crookes' tube, a large disc of lead is placed, and the charged body is situated in the geometrical shadow cast by the disc, it might be supposed that no discharge would take place; but such is far from being the case, except when the leaden disc is closely pressed against the window.

In the succeeding number of the *Atti dei Lincei* this deflection of Röntgen rays behind opaque bodies is discussed at considerable length by Prof. E. Villari, who claims to have recorded the phenomenon as long ago as March last. Observations were made on the discharge of an electroscope placed in different portions of the shadow cast by a plate of lead, and, moreover, photographic impressions were obtained upon a sensitive plate placed just inside the geometrical umbra. Signor Villari concludes, that in order to discharge an electroscope it is not necessary that Röntgen rays should fall directly upon it. The presence of air previously traversed by these rays is sufficient to promote the discharge—a result in accordance with one o Prof. Röntgen's original observations.

In a subsequent paper in the same publication, Prof. Righ proves that the discharge of electricity produced in air by Röntgen rays takes place by convection *along the lines of electrostatic force*. The experiments were made by means of an insulated conducting sphere placed in the presence of a disc of ebonite having its lower side covered by a metal armature. Between the two a cross of ebonite was placed, and the conductor and armature were oppositely charged. After exposing the whole to the action of Röntgen rays for a few minutes, the ebonite was dusted over with a mixture of powdered red-lead and sulphur, when the shadow of the cross appeared red on a yellow background. In another experiment a cylindrical conductor was substituted, and the shadow was produced by a strip of ebonite placed parallel with its axis. The observed position of the shadow agreed exactly with that calculated from the form of the lines of electrostatic force, which in this case were, of course, coaxial circles.

It should be observed, however, that if the phenomenon were one of *conduction* instead of convection, the discharge would still follow the lines of force, just as in Prof. Righi's experiments.

The same indefatigable observer (Prof. Righi) also discusses in the *Comptes rendus* a paper by MM. Benoist and Hurmuzescu, who find that, "if Röntgen rays can develop an electric charge . . . this effect does not exceed the order of magnitude of the electromotive forces of contact." Prof. Righi finds that the positive potential to which an insulated conductor is raised when Röntgen rays fall on it, *is precisely* of that order of magnitude. In the experiments of MM. Benoist and Hurmuzescu, the electrometer and the conductor experimented on were enclosed in an uninsulated metal case; in Prof. Righi's experiments the case was made to enclose the Crookes' tube, which was placed at a considerable distance from the conductor, so as to remove the latter as much as possible from the influence of all conducting bodies. It appears probable that both dispositions are equally good.

Under the title "Raggi Catodici e Raggi-X" (*Nuovo Cimento*), Prof. Battelli and Dr. Garbasso give a continuation of their researches bearing chiefly on the question of whether there is really an essential difference between Röntgen rays and kathodic rays. These writers are of opinion that the two kinds of radiations do not differ from one another in any more essential characteristics than those which enable us, for example, to distinguish two flames of different colour.

In a further contribution to the *Nuovo Cimento*, Prof. Battelli and Dr. Garbasso examine the resemblance between Röntgen rays and ultra-violet light in their power of dispersing electric charges. The experiments, which were made by employing alternately a Crookes' tube and a voltaic arc with the same disposition of apparatus, lead to the conclusion that although ultra-violet light acts on electrified bodies in the same manner as Röntgen rays, the modification produced in the surrounding air (in the case of ultra-violet light) is less pronounced and less stable.

An important point in connection with the debated nature of Röntgen rays is the determination of their wave-length, which has been successfully effected by Dr. L. Fomm, of Munich (*Sitzb. der Bayerischen Akademie*, xxvi. ii.). As these rays show no measurable reflection or refraction, the only way available was by diffraction. The Röntgen rays emanating from a large Hittorf tube were made to pass through a brass slit 0·5 mm. in breadth, and, after being diffracted by a second slit, were received on the photographic plate. The width of the second slit could be varied from 0·1 mm. up to 2 mm., and with the former width an exposure of fifty minutes was required. As long ago as March last, Dr. Fomm obtained photographs showing interference bands, thus affording proof of the undulatory nature of Röntgen rays. By starting with a very narrow slit and gradually increasing its width, the interference lines approach closer together, until a dark line—the first minimum—appears in the centre. As the opening becomes still wider, this minimum gives place to a maximum with two minima, one at each side, and so on, and by means of Lommel's formula, the wave-length can be determined from this phenomenon. Dr. Fomm obtains $\lambda = 0{\cdot}000014$ mm., so that the wave-length is about fifteen times smaller than the smallest wave-length hitherto observed in the ultra-violet. Owing to the difficulty of determination, Dr. Fomm regards this number as giving the upper limit rather than the exact measure of the wave-length of the observed rays. Meanwhile MM. G. Sagnac, L. Calmette, and G. T. Lhuillier have published investigations in the same direction (*Comptes rendus*, cxxii. 13 and 16). M. Sagnac uses a wire grating, and from a scarcely measurable diffusion of the image of the slit he obtains 0·00004 as an upper limit to the wave-length. MM. Calmette and Lhuillier have made diffraction experiments with two slits, and have obtained bright and dark lines without expressing an opinion as to the wave-length of the rays.

Another closely allied question is whether Röntgen rays consist, like ordinary light, of radiations whose wave-lengths vary over a considerable range. Such differences of wave-length give rise in the case of light to the phenomenon of colour, and the corresponding phenomenon for Röntgen rays has been studied by Dr. F.-V. Dwelshauvers-Dery (*Bulletin de l'Académie Royale de Belgique*, No 6) under the name of *actinochroism*. Observing that differences in the degree of exhaustion of a Crookes' tube might be expected to give rise to differences of wave-length in the emitted rays, and that the higher the vacuum the shorter would the wave-lengths probably be, Dr. Dwelshauvers-Dery has examined whether certain substances are more transparent for certain Röntgen rays than for others. For this purpose, their transparencies were compared by placing the substances in front of a fluorescent screen and observing their shadows side by side with that of a test-object consisting of laminæ of tin-foil, whose total thickness could be varied at pleasure. To obtain the necessary variation in the nature of the Röntgen rays, it was found sufficient to compare the radiations from a new tube, which had not been previously used, with those emanating after the tube had been in action for some time. The observations were repeated on the new tube after a quarter of an hour, half an hour, an hour, an hour and a half, and two hours respectively, and transparency-curves obtained by plotting the results on paper. These curves show that (1) the transparency of every specimen, with the exception of obsidian, increases during the first few minutes; (2) agate and alum, after increasing in transparency for some time, become more and more opaque; (3) obsidian continually diminishes in transparency. It is, of course, here a question of relative transparency with respect to tin. Although we have no measure of the variations of the absolute transparency of the tin itself, the experiments suffice to prove that the absolute transparencies of different substances vary according to the state of the tube, and it is therefore, not considered hazardous to explain these variations by the actinochroism of Röntgen rays.

The same phenomenon has been observed by MM. Benoist and Hurmuzescu and, perhaps, by other physicists. In some of Mr. A. A. C. Swinton's experiments it will be remembered that the properties of Röntgen rays, and particularly their power of penetrating through organic tissues, varied with the degree of exhaustion of the vacuum.

Two papers on Röntgen rays appear in a recent *Bulletin de l'Académie Royale de Belgique* (No. 5). One, on the probable cause of the production of Röntgen rays and of atmospheric electricity, and on the nature of electricity, is by P. de Heen. Judging from the analogy of a pith ball oscillating between two electrified plates, and from the comparative sizes of the pith ball and the air molecule, it may be assumed that the molecules have a velocity of 330,000 metres per second. This agrees fairly well with J. J. Thomson's estimate of a velocity of 200,000 m. per second for the kathodic projections. Such a velocity corresponds to the excessively high temperature of 46 million degrees. Hence, wherever these molecules impinge upon a surface, they will produce ether waves of very high frequency. These waves are probably identical with Rontgen rays, which are therefore very short ultra-violet waves. The author also claims to have proved that an electrified surface impresses a sensitive plate quite apart from any radiating action. He proposes the theory that positive and negative electricity are propagated in different ways, the former by transverse, the latter by longitudinal, waves. Atmospheric electricity is generated by masses of gas emerging from the interior of the sun (protuberances), which send out ultra-violet waves, and charge the atmosphere positively and the earth negatively by induction.

The reflection of Röntgen rays is treated by F. V. Dwelshauvers-Dery, in the *Bulletin* referred to in the foregoing paragraph. No trace of a regular or geometric reflection of Röntgen rays can be discovered. The wave-length of the rays is evidently too small in comparison with the size of the molecules. In order to find whether there was any diffuse reflection, the author placed a sensitive plate with the film downwards. A piece of ruby paper half covered the film, and sheets of zinc, brass, copper, tin, and collodion were placed under this. Then followed a second plate with the film upwards. On exposing the whole to Röntgen rays, both transmission and reflection could be studied. As regards the former, it was found that collodion increased the activity of the rays. This fact may be utilised to diminish the exposure, a sheet of collodion being placed above the object and the film. Impressions were also obtained on the upper plate, apparently due to diffused reflection. The order of reflective power was: tin, zinc, copper, brass, iron, platinum, gold, lead, aluminium. Hence tin placed below the film may also be used to diminish exposure. The state of polish of the surface was without influence, which shows that there was no regular reflection. But the most important fact is that the ruby paper intercepted a large proportion of the reflected rays. Hence the latter are not Röntgen rays proper, but rays of greater wave-length, and it may be maintained that X-rays are not reflected as such.

Herr W. Arnold (*Centralblatt für Nahrungs- und Genussmittel-Chemie sowie Hygiene*) shows that Röntgen rays can be employed with considerable success in the detection of food adulteration. Carbohydrates, fats, and aniline dyes were found to be very transparent to these rays, though slight differences were noticeable. Among the vegetable oils the order of transparency was: (1) castor oil, (2) almond oil, (3) olive oil of Provence, (4) poppy oil, (5) oil of sesame, (6) linseed oil; the difference between the last five was very slight, but castor oil was considerably more transparent. Of fats, butter was the least transparent, lard came next, and margarine was the most transparent; while the opacity of a mixture of different fats was found to vary with the percentages of its constituents. Among the spices, Herr Arnold found that the transparency decreased as the proportion of ash increased, so that saffron was the least and pepper the most absorbent of Röntgen rays. Foreign matter mixed with spices, such as brick-dust, ochre, sand, &c., was conspicuous, while adulterations of flour with powdered fluor or other spar, or chalk, could readily be detected. Earthenware glazes containing lead differed strongly from ordinary glazes, since, of all substances, lead offers the greatest resistance to the passage of Röntgen rays. For colouring matters imbedded in gelatine the order was: (1) methylene blue, (2) cyanin, (3) methyl violet, (4) eosin, (5) fuchsin, (6) brown, (7) orange, (8) chrysanilin, (9) fluoresin; the order must thus be blue, red, yellow, so that the lightest colours are the least transparent. In wines the transparency decreased as the proportion of sugar increased, just as generally the absorbing power of fluids increased with their specific gravity, and that of the elements with their atomic weight. In salts, the radical had considerable influence, and arseniates, sulphates, and phosphates exhibited a far greater power of absorbing the rays than chlorides.

The same writer also discusses the luminosity of solids under the influence of Röntgen rays. Referring to the use of fluor spar in shortening the time of exposure of radiographs, as employed by Winkelmann and others, Herr Arnold states in the *Apotheker-Zeitung* that he and Herr Forster-Bern have obtained negative results, as no difference was noticed between the action of the rays on plates exposed with and without the spar; possibly this was due to the quality of the spar employed. In the *Zeitschrift für Electro-chemie* he states the results of a long series of observations on various forms of luminosity, namely, thermo-luminosity, kathodo-luminosity, and what he proposes to call "X-luminosity." Herr Arnold finds tungstate of lime to be the most luminous of all salts under the action of Röntgen rays, especially when in the form of the mineral known as tungsten. He thinks it exhibits the phenomena even in a more marked degree than platino-cyanide of barium. A solution of tungstate of copper in tungstate of calcium, moreover, glows with the same brightness as natural tungsten. A note on the best form of tungstate of calcium for showing fluorescence has also been published by Dr. Ferdinando Giazzi, of Perugia. By a certain process of heating in a coke furnace in the presence of oxygen, the tungstate is reduced to a white saccharoid mass which gives a much more brilliant glow than ordinary tungstate, but the effect can be further intensified by pulverising the mass and repeating the process, the final product which Dr. Giazzi calls the "bisaccharoid" form being, in his opinion, the best substance for shortening the exposure and intensifying the brilliancy of photographs taken with Röntgen rays.

Prof. Giuseppe Martinotti (*Rivista Scientifico-Industriale*) claims to have obtained shadow photographs of metal objects by the use of different kinds of light (including that of bisulphide of carbon), the light from a sulphur flame being found the best. Perhaps the radiations by which these results were obtained may be identical with Le Bon's *lumière noire*. This latter phenomenon deserves to be more fully investigated by physicists than has been done.

At a recent meeting of the *Société Française de Physique*, a discussion took place on a new arrangement of vacuum tube introduced by M. Colardeau, which gives, with short exposures, great clearness of images. The ordinary "focus" tubes are, according to M. Colardeau, open to several objections; amongst others, the thickness of the glass required to stand the external pressure arrests the passage of a large proportion of the rays; the energy of the discharge is not sufficiently concentrated round the kathode, and the distance between the kathode and anti-kathode is too great. The new form of tube is a cylinder of not more than 6 or 7 mm. diameter, containing a concave kathode of 4-5 mm. radius of curvature, which nearly fills the width of the tube. The lamina inclined at 45°, forming the anti-kathode, is only 7-8 mm. distant from the kathode, and just opposite the focus; and the glass of the tube is blown out into a hemispherical knob 1/10 mm. in thickness; the latter offers but little resistance to the passage of the rays generated at the focus. With this disposition stereoscopic radiographs were taken, which stand out in remarkable relief. The tube has stood the test of a discharge from a coil of very large dimensions without the least injury.

Finally, we would call attention to the excellent radiograph of an entire newly-born child taken by Prof. A. Imbert and M. H. Bertin-Sans, of the University of Montpellier, which is reproduced in the *Revue Générale des Sciences* for June 30. In sharpness of outline and general detail it far excels anything previously attempted in this direction.

METALLIC CARBIDES.

UNTIL about three years ago, the only definite compounds of carbon with metals whose existence had been proved with certainty were the acetylides of some of the metals of the alkalis and alkaline earths, and these were only known in an amorphous and impure state. The construction of the electric furnace by M. Moissan in 1893, in which the heating power of the electric arc was directly utilised, by extending the upper limit of working temperatures, added a powerful instrument of research to the laboratory. Among the many new fields of work thus opened up, the preparation of the difficultly reducible metals, such as tungsten, molybdenum, manganese and chromium, was attacked with much success by M. Moissan. These reductions being necessarily effected in the presence of carbon, the formation of definite metallic carbides of great stability soon became apparent, the properties of which proved to be of such interest that their preparation was systematically attempted. Certain metals, such as gold, bismuth, lead, and tin, do not form carbides at the temperature of the electric furnace, neither do they dissolve any carbon. The metals of the platinum group dissolve carbon with facility, but deposit the whole of it on cooling in the form of graphite, the metals being unchanged. Copper, silver and iron take up carbon in quantities that, although small, are sufficient to cause marked changes in the physical properties of the metals; it is noteworthy that no definite crystalline compound could be obtained with iron. On the other hand, fused aluminium takes up carbon readily with formation of the crystalline carbide Al_4C_3, and the oxides of many other metals furnish similar crystalline compounds when heated in the electric furnace with an excess of carbon. The behaviour of these substances with water furnishes the most convenient mode of classification. The carbides of molybdenum, Mo_2C, of tungsten, W_2C, of titanium, TiC, of zirconium, ZrC and ZrC_2, and of chromium, Cr_4C and Cr_3C_2, do not decompose water at the ordinary temperature. Of those reacting with water, the carbides of lithium, Li_2C_2, calcium, CaC_2, strontium, SrC_2, and barium, BaC_2, furnish pure acetylene; of aluminium, Al_4C_3, and of beryllium, Be_2C, pure methane; of manganese, Mn_3C, a mixture of equal volumes of hydrogen and methane; whilst the metals of the cerite group give crystalline carbides of the type RC_2 (CeC_2, LaC_2, YC_2, and ThC_2), all of which react with cold water, forming a complicated gas mixture containing hydrogen, acetylene, ethylene, and methane. But the most complex reaction is that furnished by uranium carbide, U_2C_3, with water. In this case, in addition to a gaseous mixture containing methane, ethylene, and hydrogen, liquid and solid hydrocarbons are produced in abundance, more than 100 grams of liquid hydrocarbons being obtained in one experiment from four kilograms of carbide. Cerium and lanthanum carbides have also furnished small quantities of solid and liquid hydrocarbons.

With the exception of chromium and zirconium, which form Cr_4C, and Cr_3C_2, ZrC_2, and ZrC respectively, only one carbide of each metal appears to exist, the formula of which is usually simple, and not always in accordance with what would be expected from the position of the metal in the periodic system. Thus, whilst the carbides of calcium, strontium, and barium have the formulæ CaC_2, SrC_2, and BaC_2, and yield pure acetylene upon treatment with water, beryllium forms Be_2C, from which pure methane is obtainable (Lebeau). As already mentioned, aluminium forms Al_4C_3 giving pure methane, whilst the higher members of the same group, yttrium and lanthanum, give YC_2 and LaC_2, yield, with water, complicated mixtures of acetylene, hydrogen, ethylene and methane, together with some liquid hydrocarbons. Cerium and zirconium, again, which are closely allied in the periodic system, form carbides having totally different properties, CeC_2 giving acetylene and methane with water, ZrC and ZrC_2 being unattacked under the same conditions.

These discoveries have already been applied technically in two directions—in the commercial production of acetylene from calcium carbide for enriching coal gas or for burning alone, and in the production of the carbides of silicon, CSi (discovered by Acheson), and of titanium CTi, both of which are extremely hard, the latter even cutting diamond. In organic chemistry, also, they afford a direct synthesis of many hydrocarbons, and offer a means of preparing pure methane and acetylene in large quantities. But perhaps their greatest interest lies in their bearing on certain geological problems. Starting with the fact that cast iron on solution in dilute acids gives a mixture of hydrocarbons, Bjasson and Mendelejeff twenty years ago suggested, independently, that the deposits of petroleum may be due to the infiltration of water into molten masses of metallic carbides, and this view was supported by an observation made about the same time by Silvestri, that some lavas of Etna contained petroleum.

In discussing this question in the light of his own observations, described before the Royal Society on June 18, M. Moissan protests against too hasty generalisation in this matter, as petroleums of different origins may exist, there being clear evidence in some cases that bituminous schists have been formed by the decomposition of organic matters. On the other hand, there is the continuous evolution of methane at Bulgonak and in Pennsylvania, which might well be formed by the action of water upon aluminium carbide; the presence of free hydrogen in the submerged volcanic vents at Santorin (Fouqué), and the occurrence of petroleum and carbonaceous products towards the end of a volcanic eruption, the violence of which would be fully accounted for by the supposition of the entry of water upon metallic carbides at a high temperature. There is also the possibility of explaining the occurrence of petroleums of different composition, for whereas a deposit of the carbides of the alkaline earths would yield acetylene, which at the extremely high temperature necessarily produced and in presence of free hydrogen might be expected to yield hydrocarbons of the Russian type, the carbides of aluminium and uranium, at perhaps a lower temperature, might account for petroleums of the American type. The whole work is extremely suggestive to vulcanologists, and will doubtless result in further investigation on the geological side.

G. N. H.