fier is more efficient, that is, there would be less loss of energy than with a continuous current, as the charging is carried on at a lower rate, more time is allowed for the chemical action to take place, and the gassing of the battery is less.

In Fig. 6 is shown a small rectifier outfit designed to meet the demands of dentists who are often confronted with the problem of operating dental motors where only an alternating current is available. This consists of a small 5 ampere tube arranged to operate on 110 volts, 40 to 140 cycles, and to deliver approximately 5 to 15 amperes at any direct current voltage up to 45 volts. The panel is not equipped with either meters or regulating devices, since it is the customary practice to provide dental motors with these.

THE TUNNEL UNDER THE SEINE RIVER.

BY L. RAMAKERS.

Work has been commenced on the construction of line No. 4 of the Metropolitan Underground Railway of Paris, the north-and-south cross town line, extending from the Clignancourt gate to the Orléans gate, and crossing both branches of the Seine.

The construction of a railway tunnel under the Seine at any point constitutes so difficult a problem that the Prefecture of the Seine deemed it expedient to invite competitive solutions. The commission in charge of the competition, which included both plans and methods of construction, selected the solution offered by L. Chagnand, one of the ablest of Parisian contractors, according to which the cost of construction will amount to 15,614,000 francs ($3,203,000) for a tunnel 1,093 meters (0.68 mile) long, with a station at each end.

In the plan annexed to the announcement of the competition the tunnel descended 40 millimeters to the meter (4 to 100) to a point vertically under the bank of the Seine. The next section of the tunnel was to be horizontal, with the rails 14 meters (46 feet) below the surface. This section was to extend from the Place du Chatelet to a point two-thirds of the distance across the small arm of the river, beyond which point there were to be two rising grades of 40 millimeters to the meter (4 to 100) separated by a level, corresponding to the Place St. Michel, the Boulevard St. André and the Place St. André des Arts.

The tunnels and stations were to be of the following types:

The tunnels were to be two in number, circular in section, excavated by the compressed-air method, and lined with metal. Each tunnel was to have an internal diameter of 5 meters (16.4 feet) and an external diameter of 5.30 meters (17.38 feet), the axis of the tunnel being situated 1.40 meters (4.6 feet) above the rails. The stations, also constructed with the aid of compressed air, were to be short, metal-lined tunnels of circular cross-section, with an internal diameter of 6.50 meters (21.32 feet) and an external diameter of 6.90 meters (22.63 feet). The center of the section was to be placed 1.534 meters (5.03 feet) above the level of the rails and 1.190 meters (3.8 feet) distant, horizontally, from the middle line of the track. This eccentricity would leave room for a landing platform made of armored concrete.

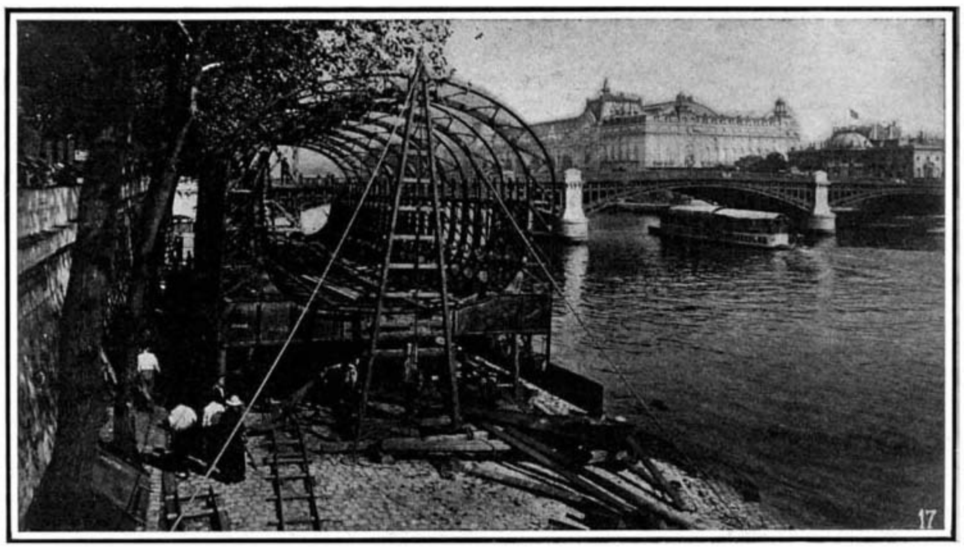
The advantages presented by the Chagnand project and which led to its adoption are of two kinds.

1. Instead of employing twin tunnels of small bore, it keeps the two tracks together in a single tunnel of the same dimensions as the other sections of the Metropolitan.

2. The construction of the tunnel under the Seine by means of caissons sunk vertically makes it possible to raise considerably the level of the rails under the river and, consequently, to diminish the grades of the approaches and the depth of the stations. In the plan adopted the lowest level of the rails is level 16.05, or 11.15 meters (36.57 feet) below the surface of the Seine, while in the original plan it was level 13.10, or 2.95 meters (9.67 feet) lower.

In the Chagnand project the grade of 4 per cent., which is the maximum grade allowed in the Metropolitan system, is employed only in order to pass under the Metropolitan line, the Orléans railway, and the Bièvre collecting sewer.

The internal section of the tunnel differs very little from that of a masonry tunnel of the ordinary type. Except under the bed of the Seine the tunnel will be excavated with the aid of a shield of special design. The walls will be composed of cast-iron rings 60 centimeters (2 feet) broad, the rings themselves being built up of voussoirs of varying curvature, according to



Erection of the First Caisson on the Quai des Tuileries.

their positions and the pressures to which they are subjected. The pieces are to be bolted together, the joints being made water-tight by the interposition of strips of creosoted wood. Cement will be injected behind this iron tube to fill any cavities that may exist between its exterior and the surrounding earth.

The metal lining will itself be lined, successively, with a layer of armored concrete of thickness equal to the height of the ribs, and with a coat of Portland cement. In the sections beneath the two branches of the Seine the metal tube of the tunnel is to be constructed as described above, but surrounded by a metallic framework which shall serve as the caisson, thus enabling the tube to be sunk vertically into place. The sides of the caisson are composed of sheets of iron attached to the framework surrounding the steel lining of the tunnel. These sheets rise to the level of the foot of the arch and form a water-tight box which can be transported by floating. The entire space inclosed between the sides of the caisson and the tunnel will be filled with cement concrete, in which the framework will be buried and which will form a layer of strong and indestructible masonry surrounding the metal lining of the tunnel.

Three caissons will be used for the larger and two for the smaller branch of the Seine. The ends of these caissons are closed temporarily with sheets of steel which must be removed when the sections carried by the several caissons are joined to form a continuous tunnel. These junctions will be effected by small caissons operating in the intervals, 1.50 meters (5 feet) long, which will be left vacant between the ends of the sections of the tunnel. By sinking two of these small caissons two masonry walls will be built, connecting the bases of the large caissons and rising to the level of a horizontal ledge at the end of each. Upon these ledges and walls will rest a third small caisson, within which the sections will be connected and the temporary sheet-iron ends removed.

The two stations included in the plan, situated at the "Cité" and the Place St. Michel, will also be sunk by means of caissons similar to those employed for the tunnel under the Seine, but of greater dimensions.

The execution of the entire project of crossing the Seine will involve the employment of three very different methods of working:

(a) Compressed air and a shield will be used for the construction of three sections of the running tunnel.

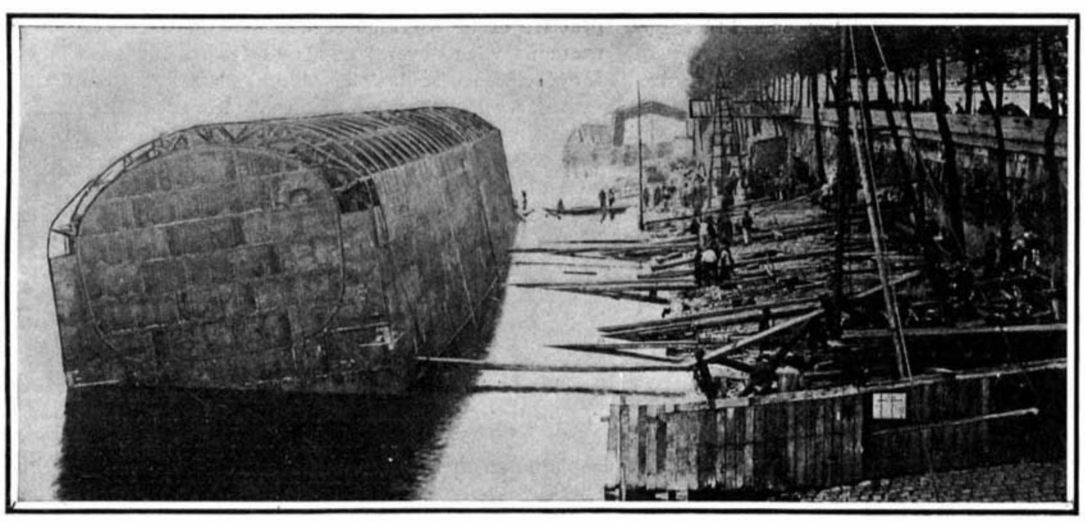
(b) Compressed air caissons will be employed for the tunnel under the Seine, part of the underground tunnel and the Cité and Place St. Michel stations, with their entrance shafts.

(c) Excavation by freezing process will be employed in the passage under the Orléans railway, in order to avoid the possibility of an interruption of traffic due to settling.

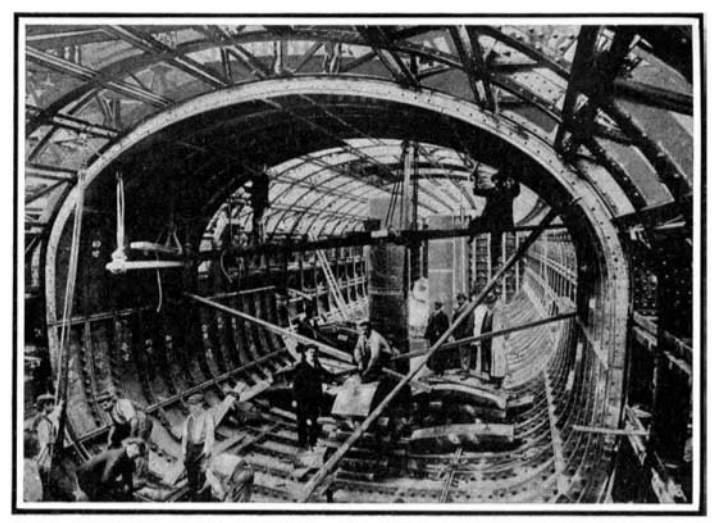
Of these three methods of working the second alone is in full operation. At present the first caisson, on the right bank of the larger branch of the Seine, is entirely submerged and has been sunk to within about half a meter of its final level.

The caissons for the stations will be built on the ground and, when completed and ready for sinking, will present the appearance of huge iron frames, 12.50 meters (41 feet) high, 16.50 meters (54.12 feet) wide, and 68 meters (223.64 feet) long.

As no suitable ground for the construction of the river caissons was available near the points where they are to be submerged, a construction yard has been established at the Quai des Tuileries. One of the illustrations shows the first caisson at the moment when the framework was completed. Its construction was effected quickly by the employment of improved methods, particularly the method of riveting with pneumatic hammers. The caisson having been built and the plates which make it water-tight riveted around it, it was launched sidewise—an operation which was facilitated by the elevation of its site, 40 centimeters (1.6 feet) above the level of the Seine. The caisson, which weighed 280 tons, was then towed to the point where it was to be sunk. Here the stream had been dredged to a depth of 5 meters (16.4 feet) in such a manner that the caisson could be sunk upon a perfectly horizontal bed. On the downstream side of the emplacement guiding piles had been driven, against which the caisson rested. These piles formed the first part of a solid stockade of piling serving, on the one hand, to protect the caisson and, on the other, to support a broad platform. The first work done after the caisson was in place was, of course, the construction of the iron lining tube of the tunnel. Then concrete was poured between the tube and the exterior envelope until the caisson rested solidly on the bed of the river. Then the shafts which give access to the working chamber and the air locks which surmount them were put in place and the sinking by means of compressed air commenced. When the final level is reached the working chamber will be filled with concrete, the tunnel will be emptied of the water with which it was filled in order to ballast the caisson and facilitate its descent, the shafts will be removed and the openings through which they communicated with the interior of the tunnel will be carefully closed. In this caisson the telephone has been employed—for the first time to the writer's knowledge



The First Caisson Launched Sidewise.



Construction of Iron Lining Tube.

THE TUNNEL UNDER THE SEINE RIVER.

—to assure permanent communication between the interior and the exterior. One instrument is placed in the working chamber, the other in the superintendent's booth on the platform of the caisson.

Engineering Notes.

What is probably the highest dock in the world has recently been completed at Port Florence, on the Victoria Nyanza, in Uganda, at an altitude of 3,700 feet above sea level. The dock has been constructed to accommodate the Nyanza fleet plying on the lake in conjunction with the Uganda railroad. It measures 250 feet in length by 48 feet wide and 14 feet deep. It is excavated out of the solid rock by native labor, and occupied twelve months in construction, at a cost of $20,000. Both the time occupied and the cost of the undertaking were increased owing to plague visitations, which seriously interfered with the work.

After an accident which occurred to a flywheel in a large European electric station, the superintendent designed and had constructed a flywheel of wood more than 35 feet in diameter and 10 feet wide at the rim. The thickness of the rim is about 12 inches and is constituted of 44 thicknesses of beech planks with staggered joints. The boards are glued together and the whole is bolted. The inside of the flywheel is formed of a double wheel with spokes and the latter are fastened to two hubs. The twenty-four spokes and the hubs are of cast iron. The weight of the flywheel is nearly 50 tons. On the first trial it attained a speed of 76 revolutions per minute, which corresponds to about 120 feet per second at the rim. It is probable that this is the highest peripheral speed which has yet been obtained with a wooden wheel, and it is one of the highest even from an absolute standpoint. As to size, the flywheel seems to hold the record.

In European countries the development of canal traffic is receiving special attention from the various governments, according to a recent report, published by the British Foreign Office. In Germany these waterways are to be brought up to date, for which purpose an expenditure of $83,643,750 has been sanctioned this year. Of this total, $62,687,500 is to be devoted to the construction of a canal from the Rhine to the Weser, including the canalization of the Lippe, and various other accessory works. The balance is to be expended upon the construction of a large canal for barges between Berlin and Stettin, the improvement of the waterway between the Oder and the Vistula, and the canalization of part of the Oder. In France the modernization of existing, and the construction of new, canals will absorb $41,200,000. The new works include the Canal du Nord, one from Cette to the Rhone, and another from Marseilles to the Rhone. A similar development is being carried out in Belgium, Austria-Hungary, and the Netherlands, for which large sums have been appropriated by the governments.

Owing to the success that has attended the inauguration of the steamship service with the vessel "Coya" on Lake Titicaca in Peru, the highest navigable sheet of water in the world, another and much larger boat "Inca" is now in course of erection upon the shores of the lake. This latest acquisition is 220 feet in length by 30 feet beam and 14 feet draft, of 550 tons displacement, and propelled by twin-screw engines developing 1,000 I. H. P., capable of giving a speed of 12 knots. The vessel was erected in England, complete in every detail, and was then dismantled, every section being packed and carefully numbered, and shipped in 3,000 cases to the port of Mollendo. From the seaport the parts were conveyed to the shores of the lake by railroad—a distance of 150 miles, and involving a climb of over 12,000 feet. The "Inca" is modern in every respect, being complete with elaborate passenger accommodation, electric lighting, and steam heating. There is accommodation for 24 passengers and every possible arrangement and facility for working freight.

At the last annual meeting of the Gas Association known as the Markischer Verein at Berlin, two interesting papers were read by Messrs. Pfudel, of Charlottenburg, and Bremer, of Berlin, concerning the replacing of cast-iron by wrought-iron pipes in the Berlin system. The cast-iron pipes, owing to the frequent breaks which occurred, gave rise to serious accidents, and they were then replaced by wrought-iron pipes without, however, taking the necessary precautions against rusting. At the end of a few years the pipes were entirely eaten through, and in their place was found an envelope which was mostly made up of rust. Then the company tried protecting the pipes by a coating formed of a mixture of tar, sand, lime, powdered clay, and pitch. A very good result was obtained with this coating, and it is found that pipes which have been buried for twelve years are perfectly preserved. The municipality of Berlin, after the disastrous explosion which took place in Handelstrasse, had the proprietors replace all the cast-iron branch pipes by the new system, so that soon there will be little danger of explosion.

THE SIZE OF MOLECULES.

By the term molecule the smallest possible particle of a chemical substance is understood. For example, if a piece of cane sugar is broken into smaller and smaller fragments, a point is finally reached beyond which the subdivision cannot be carried without producing something different from cane sugar. At this point we have reached the cane-sugar molecule.

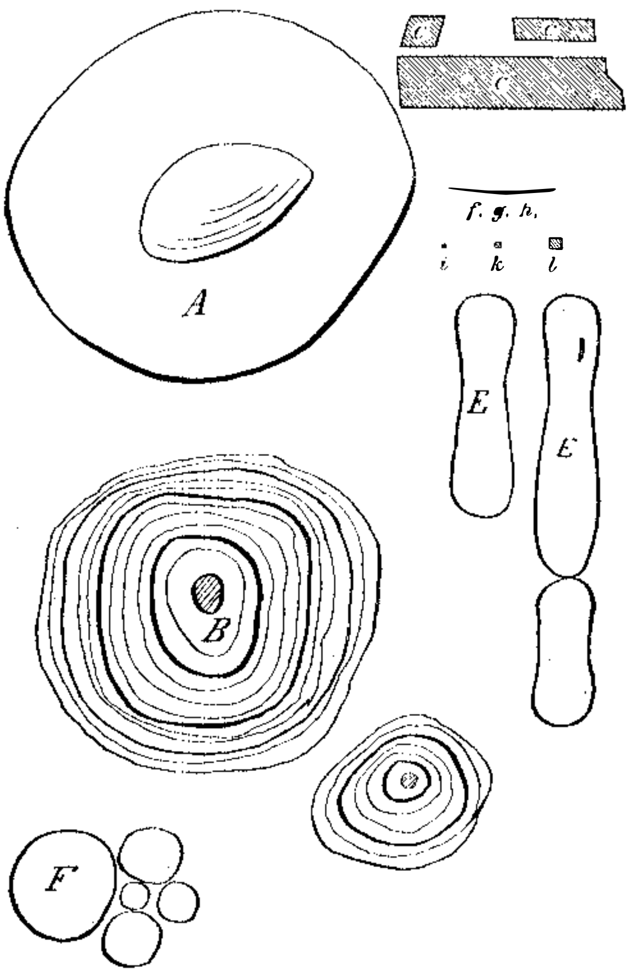


Fig. 1.—MAGNIFIED TEN THOUSAND TIMES.

A. Human blood corpuscle. *B*. Rice starch grain. *C*. Kaolin suspended in water. *E*, *F*. Bacteria. *f*, *g*, *h*. Particles of a colloidal solution of gold. *i*, *k*, *l*. Particles of a gold solution in the act of precipitation.

Now, molecules are composed of atoms, which are the smallest possible particles of the chemical elements, and the dimensions of molecules vary greatly according to the number and character of the atoms of which they consist. The hydrogen molecule is a very small one, for it is composed of only two atoms of hydrogen. The molecule of cane sugar is comparatively large, containing 12 atoms of carbon, 22 of hydrogen and 11 of oxygen. But there are molecules of much greater size. The molecule of albumen is believed to contain nearly 1,000 atoms.

The subdivision of a lump of sugar, described above, is purely hypothetical, but many substances can be so divided very easily by dissolving them in water or

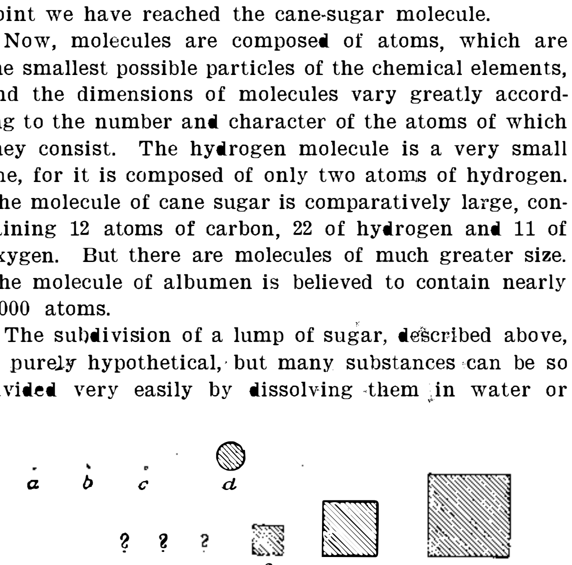


Fig. 2.—MAGNIFIED ONE MILLION TIMES.

a. Molecule of water. *b*. Molecule of alcohol. *c*. Molecule of chloroform. *d*. Molecule of soluble starch. *e*-*h*. Particles of colloidal solution of gold. *i*. Particle of gold in the act of precipitation.

some other liquid. In solution they are resolved either into separate molecules, as is the case with cane-sugar, or into larger or smaller groups of molecules. In the case of substances with very complex molecules especially, it must not be supposed that all the particles in the solution are equal in size; on the contrary, there are many reasons for believing that the groups of molecules are in various stages of disintegration.

The "ultra microscope," invented by Siedentopf and Zsigmondy, has made it possible to detect, in a solution, solid particles of a diameter of 4 millionths of a millimeter. (The limit of the best microscopes is 75 times as great, or 3 ten-thousandths of a millimeter.) This new optical instrument has brought the largest molecules, such as those of albumen and soluble starch, into the realm of visibility. The accompanying diagrams, from a recent publication* of Dr. Zsigmondy, may serve to give a vague idea of the dimensions of this ultramicroscopic world. If one of the largest of molecules, that of soluble starch, could be actually magnified 10,000 times in every direction, so that its volume would be multiplied 1,000,000,000,000, it would still be smaller than a pea. One of the five million corpuscles which are contained in a cubic centimeter of blood would, if enlarged in the same proportion, fill a large room, for its diameter would measure six meters.

In the Scientific American of November 11, 1905, some account was given of inorganic colloidal solutions, which consist of metals and other insoluble substances, in a state of extremely fine subdivision, held in suspension by water or other liquids. Zsigmondy has studied one of these solutions, colloidal gold, with especial care and has found that the suspended particles of gold differ very greatly in size.—Dr. Bechhold in Umschau.

The Current Supplement.

The current Supplement, No. 1572, opens with a description of some new bogie transport cars which were especially constructed to transport traction engines and motor-driven plows. Excellent illustrations accompany the article. Rear-Admiral George Melville's splendid paper on liquid fuel for naval and marine uses is concluded. For experimental purposes it is often desirable to have at hand an alternating current of low voltage. To secure this from a line circuit a transformer is necessary. Edmund S. Smith describes a small transformer that any one at all familiar with tools can easily build. The total cost of materials will not exceed $3.50, while the only machine tool necessary is a small drill. T. R. Hopper writes on some simple experiments with currents of high frequency. The general question of solution has always been of importance to the metallurgist. J. H. Stansbie gives his views on the solution of solids and solid solutions in a way that cannot but be of help to metallurgists. F. M. Feldhaus gives an illustrated description of some old inventions. Among these may be mentioned a very early magic lantern, a lamp with a glass chimney invented in 1500; Leonardo da Vinci's parachute; a very modern-looking diving suit, dated 1500; a diving bell attributed to Alexander the Great; a paddlewheel boat of 1430, a turbine which bears the date 1575, and a rapid-fire gun which goes back to the fourteenth century. How natural and artificial patinas are produced is told by B. Setleg. The practice of the cyanide process of gold extraction presents us with several new and interesting aspects of the problem of solution. These Mr. G. F. Beilby has considered in an article that bears the title "Gold Molecules in Solution." "Recent Foreign Methods for the Production of Celluloid and Similar Substances" is the title of an article which has been compiled and translated from French, German, and Italian periodicals. Alexander W. Roberts presents graphically some idea of the sun's distance.

A New Sweet Compound.

A new compound described by Dr. T. Gigli has appeared in the European chemical trade which is designed to imitate saccharine. It is known as "banana essence." The taste of this syrup liquid is at first caustic and then bitter, but soon after very sweet. Its specific gravity is 1.188 at 20 deg. C., and it gives an acid reaction. Analysis shows it to contain 54 per cent of saccharine in combination with a base analogous to pyridine. Heated on platinum foil it gives white fumes, then burns with a bright flame, leaving a thin layer of carbon. When the latter is burned, the ash is negligible. The syrup gives a precipitate with Nessler's liquid and most of the alkaloid reagents. Adding dilute mineral acids we can separate the saccharine as a white crystalline precipitate, and ether dissolves it again. By evaporating the ether solution we have white crystals which melt about 225 deg. C. The author tried to prepare a solution of saccharine in pyridine, but did not obtain a product identical with the above.

M. Poincaré, the learned French mathematician and member of the Academy of Sciences, has carried off the John-Boulyai Hungarian prize of 10,000 crowns, or a little over $2,000. This is the first award of the prize which is granted every five years to the author of the most notable mathematical work produced during that period.

* Zur Erkenntniss der Kolloide. Jena, 1905, G. Fischer.