stroyed by the exposure is difficult to say, for histological examination showed the tissues to be so abnormal that it is possible the plants could not have stood erect even if they had been able to detect the stimulus of gravity.

All attempts to obtain a curvature of growing organs or plants toward or from a radium tube or radium-coated rod proved unsuccessful, but when a sealed glass tube of radium bromide is suspended horizontally in tap-water, or in nutrient solution, in which radicles of white lupine seedlings are growing verti-

cally, the tips of the roots may be made to curve toward the radium. Such a result is illustrated in Fig. 13. In this experiment the radium tube was originally about 5 millimeters distant from the root-tips. Whether this result was due to the direct influence of the rays, or to some undetermined condition established by them in the liquid can not yet be decided.

The above experiments were all confirmed by repetitions, and clearly indicate that radium rays act as a stimulus to the various physiological processes of

plants. If the strength of the radium, the duration of exposure, and other conditions are suitable, the response is an excitation of function, but if the method of treatment is otherwise, the radium too strong, the exposure too prolonged, the result is a retardation, or complete inhibition of function, or the death of the plant. There are not only differences in sensitiveness between individuals, but also between different species and different tissues. As in the case of animals, embryonic and younger tissues are more sensitive than those that are older and more mature.

ARTIFICIAL GEMS PAST AND PRESENT.

IMITATING NATURE IN THE LABORATORY.

BY EMIL FREUND.

PLINY mentions the imitation of jewels by glass fluxes, and it is sufficiently proved that the ancients were far advanced in this art. Egyptian mummies are provided with glass buttons of green and blue color. During the Roman Empire the use of colored glass was very general. Antique cameos have been found carved in varicolored glass to represent the onyx. Colored glass was also cemented with real onyx, but the combination was never so perfect as to defy detection by the artist and jeweler.

Before dealing with the production of imitation and artificial precious stones, another distinction in terms may be made for convenience, a distinction between the words "imitation" and "artificial." To many this may appear unnecessary, the two terms being more or less synonymous. With the advance of scientific research the chemist can now make in the laboratory not merely glass imitations, but real stones artificially, which are identical in composition with those found in nature. Their artificial production is quite modern, carrying us back only a generation or two. Imitation stones, however, were known in the Middle Ages, if not earlier. They were certainly known to the alchemists; for St. Thomas Aquinas mentions imitation jacinth, sapphire, emerald, topaz, and ruby. In the middle of the seventeenth century pastes were not manufactured according to a different formula for each stone, as had formerly been the case, but according to one general formula, much the same as that in use at the present time. Artificial precious stones are again classified as (1) reconstructed stones, (2) manufactured stones, properly speaking, whether they are made scientifically or synthetically.

The first precious stone which artificially reproduced not only the appearance but also the characteristics of a natural stone was lapis lazuli, the sapphire of the ancients, which is not to be confounded with the sapphire of our modern jewelers. This untransparent stone of a magnificent azure blue color, was most highly prized by the ancient Hindoos, Assyrians, Persians, Jews, Egyptians, Greeks, etc., and this irrefragably refutes the erroneous theory of some archaeologists that the ancients were unable to distinguish the blue color.

PASTES.

The basis of paste imitations is a fine, pure, and white glass composition, called "strass," after its inventor, Strass of Strassburg, in the seventeenth century, who first conceived the importance of imitating the real gems as respects their hardness, specific gravity, and refraction of light. He accomplished the task so admirably that in many instances, either all three, or one or the other of his objects, were attained. The strass is composed of silicon, potash, borax, red lead, and sometimes arsenic.

For imitating colored gems, various colored ingredients are employed. To obtain that intensity of color approaching nearest to the original gem experience alone can guide the manufacturer. In order to imitate the uniform and intense colors, the strass coloring ingredients must be finely divided or powdered, and very intimately mixed. The mass is then to be exposed to a very great heat, and in that state left for nearly thirty hours, so that the cooling may be gradual. M. Feil of Paris was one of the first men to produce a good quality of strass, and as a result imitations are now made so well that their detection is exceedingly difficult.

DOUBLETES.

Imitating real gems by "doubling" takes place when quartz cut and polished is cemented by means of gum mastic to colored paste, whereby the whole stone assumes the color of the lower paste. When a real gem is employed instead of quartz (the surface and the quartz or paste being cemented below) the process is called "half doubling." This adulteration is carried on to a very great extent in the East Indies, where any thin gem is joined to a paste of corresponding color.

The concave doubling is effected by excavating the inside of a quartz or paste. This cavity being filled by a colored fluid, and the other part afterward cemented on it, will, when well executed, present so uniform a color that it is difficult even for a judge to detect the deception. The surest method of detection is to put the specimen in question in hot water or alcohol, so that the gum mastic will be dissolved. When set, the only way of discovering the adulteration is to put it reversely on the nail of the thumb, when the false refraction of light or the rainbow colors will surely reveal its identity.

BURNING.

This mode of adulterating the real gems by coloring cut and polished quartz specimens and throwing them into a solution of permanent pigments, such as indigo, cochineal, or ammoniacal copper, the small cavities produced by the heat will absorb the fluids. The topaz is burnt by itself, with or without the absorption of a pigment, as also spinel and quartz. Chalcedony is, however, frequently burnt to imitate onyx, and to engrave thereon cameos and intaglios. It may be remarked, however, that since the introduction of colored pastes very few adulterations of this kind are practised and we see such doublets and burnt stones but rarely.

ARTIFICIAL GEMS.

Artificial gems are at present of considerable interest and furnish an example of the strides made by modern chemistry. In 1886 there appeared in the Paris market certain stones which had been offered for sale by a Geneva house as rubies from a new locality; subsequently, it was said that they were obtained by the fusion of a large number of small rubies, worth at most but a few dollars a carat, into one gem worth many times that amount. An examination proved that they were not the product of a fusion, which would have resulted in the formation of a substance lower in its specific gravity and softer than a ruby. They were artificial stones and had been formed by heat, not from rubies, but evidently by passing an aluminate of lead in connection with silica into a siliceous crucible, the silica uniting with the lead to form a lead silicate and liberating the aluminate, which crystallized in the form of corundum. The difference between these stones and the true ruby was very apparent, owing to the presence of a large number of spherical bubbles, some pear-shaped, and a stringy internal structure, showing how bubbles had moved. Mr. Ebelman, at Sèvres, over sixty years ago, and Mr. Fremy of Paris, after years experimenting has with the assistance of M. Verneuil succeeded in obtaining large numbers of beautiful crystals, but only after many experiments, and conditioned largely upon the heat, which regulates chemical action. Though the color is excellent, the crystals do not exceed 1/25 to 1/50 of an inch in diameter.

Several decades ago the chemist Gaudin succeeded in obtaining small ruby pellets from pure argillaceous earth, precipitated from dissolved alum and moistened with chromate of potash. The color of these rubies, according to the quantity of chromate which they contained was either that of a rose or bordering purple. The pellets were so hard that they easily cut glass, garnets, and topazes, but they were not crystals and their transparency was by no means perfect. Similar experiments were made by the chemists De Bray, Sainte Claire Deville, Caren Senarmont, Ebelman, and others.

"Reconstructed" rubies are obtained by melting together or fusing small rubies of inferior quality with quartz of the same hardness and specific gravity. They came to America in 1886 and were sold as high as \$80, \$100, to \$150 per carat. Others again were sold for \$20, \$10, etc. Again others could not be used as gems and were even not good enough for mechanical purposes. The inventor of the reconstructed rubies was a Catholic priest who lived in seclusion near Geneva. He furnished this reconstruction rough to a lapidary firm of that city, who introduced the

same to the trade. With his death the formula, which was a secret, was lost. Never since have better rubies been produced. A few can still be found in the hands of gem lovers.

In 1889 a well-known American firm imported an artificial ruby called a "scientific ruby." This ruby was built up or fused together out of small inferior rubies and later split and polished. These stones were all cut in the old Indian cut and after they came to New York they were assorted according to their quality and then recut in the modern style. These scientific rubies were examined by the Columbia School of Mines, and the test showed that they were fused from natural rubies. Only their hardness showed that they were harder than the genuine stone, while the specific gravity, the optical and chemical properties were those of the natural ruby. These rubies were sold from \$60 to \$150 per carat, none less than \$60.

These stones were all of fine color and good quality. Reconstructed rubies, on the other hand, are sometimes brownish and resemble garnets. It was rather difficult for an expert to recognize them at first glance. The stones had the same inclusions as the natural ruby. Through competition these rubies were sold cheaply and now none as good are made. These scientific rubies were a puzzle to the lapidaries. It was in their favor that they were crystallized, while this was not the case with the reconstructed. The rubies sold at present as "reconstructed" or "scientific" are not what they pretend to be. They are all artificial rubies and ought to be called so.

It is reported that as a result of numerous experiments certain French chemists have at length succeeded in discovering a new method of producing artificial rubies, which is more practical and considerably cheaper than the ordinary process. The "machine" constructed for the manufacture of rubies is provided with a blowpipe similar to a glass blower's pipe and a heating pipe. In the latter are sifted finely-pulverized alumina and chromium oxides alternately to form a deposit in strata and in the shape of a conical sugar-loaf. This formation makes gradual heating possible. The mass assumes a spherical form, and on hardening the crystalline character of the ruby appears. Great care is taken to let the mass cool slowly in order that the formation of crystals shall be regular and the stones clear, the formation of bubbles being sedulously guarded against.

With this simple apparatus three or four rubies are made at a time, and they can be distinguished from natural mechanically cut rubies only by skilled experts. The artificial ruby can readily be distinguished from the natural by examination under the microscope. The natural gem contains minute cracks, as seen with the microscope. Even though it seems to be entirely flawless, careful examination with the microscope of 100 diameters will show minute cleavage cracks running through the gem. The artificial gem contains nothing of this sort, but shows very minute bubbles or gas holes. So far as the luster and hardness are concerned, the artificial stone is exactly like the natural, and no one could tell the difference, except by this microscopic test.

Small artificial stones are made after an invention of Boettger of the same material as the genuine, chiefly alumina. The hydrate of alumina is precipitated from the solution of an alumina salt, by means of an alkali; then well washed and mixed with nickel salt, and rolled into small sticks about the thickness of a finger. Any cracks formed during drying must be filled with the same material. When dry, the end of such a stick is held in the intensely hot flame of an oxy-hydrogen blowpipe, whereupon globules are melted off, among which some will be so hard as not only to scratch glass, but even quartz, topaz, and granite. These are then cut and polished like gems. When nickel salts are used the emerald is obtained. For rubies, chromate of potash is used. They may be

easily distinguished from the originals by their want of that perfect transparency which remains the distinguishing characteristic of the natural precious stones.

By another chemical reaction, namely, the use of fluoride to set free the aluminate, fine but small crystals were obtained, and these were finally increased in size by a modification of the process known as "nursing," in which a crystal is kept in the mother liquid at an appropriate temperature until it grows as large as desired. This requires the elevated temperatures (1,500 to 1,800 deg. C.) possible only in recent years. The process, which succeeded only after many failures, is now carried on as follows:

The small ruby to be "nursed" is placed on a turning plate, where, by means of an oxy-hydrogen blow-pipe, it is raised to a temperature of about 1,800 deg. Then, with a pair of pincers, there are added to it successively tiny grains of ruby. If this work is carried on uninterruptedly without losing sight of the crystal, with the dexterous movement of the hand that is quickly acquired by women, it is easy to get fine crystals, all of whose parts, though not homogeneous in origin, are melted together and recrystallized into a single form, which may be cut like a natural crystal. One of the difficulties of the work is that the crystals often break while cooling. The quality of these rubies is very similar to that of the natural stones; they can scarcely be distinguished except under a lens by the presence of air bubbles, but when they are recognized, as the purchase of a precious stone is after all a question of fashion, their value is at least ten times less than that of natural rubies, whose price has also been influenced by this vulgarization of a substance that was formerly sought for its rarity even more than for its intrinsic value. It must be understood that an artificial ruby is not a real ruby, since it is not the natural gem, which alone has hitherto borne the name of ruby in commerce, and since its qualities in jewelry are still inferior, but it is also not a false ruby, since chemically, physically, mineralogically, optically, in all its theoretic characteristics, the synthetic ruby is similar to the natural ruby. The synthesis is not a falsification; it is the reproduction by man of the work of nature.

The synthetic gems introduced and made in the laboratory and lapidary shops of the "Deutsche Edelstein Gesellschaft" are made according to the formula of Prof. Mielche. The formula is a secret. So far it is known only that the production of the sapphire was not a success, while the ruby and especially the spinel were successful. The synthetic ruby is chemically built up at a certain temperature until it crystallizes. The crystals are often very large. On this same method "alexandrites" are made. According to Prof. Mielche, the synthetic stone is not a natural stone, although it looks like a natural stone; experts at first sight cannot recognize the natural from the synthetic. Careful examination is necessary. The crystallization of alumina, which yields, according to circumstances, corundum, ruby, or sapphire, has been accomplished for many years (since 1837) and in many different ways, but it is only since the work of Frémy (with the collaboration of Feil and Verneuil, 1877-1890) that the operation has assumed industrial importance.

The process employed at first by Frémy and Feil consisted in forming a fusible aluminate (generally aluminate of lead) which was then decomposed by a silicious substance, setting free the alumina in crystalline form. The red coloration, which characterizes the ruby, was obtained by adding 2 to 3 per cent of bichromate of potash. By this process rubies were obtained that were often very large, but always friable and consequently of no use.

Artificial crystallization of alumina was accomplished several years ago. The color in the resulting mineral was superb, but the individual crystals were so minute that a microscope was needed to distinguish their angles. They were united by their bases to a crust of amorphous alumina, and sparkled like tiny red stars whenever the light played upon them. The natural ruby doubtless took years, and very likely centuries, to form. The chemical ruby, which is precisely the same as the natural ruby, is made in a few weeks. It is almost pure alumina, the red color being due to a fraction of one per cent iron. The sapphire is the same as the ruby, except for its coloring matter. It has a wide range of color, varying from yellow, purple, pink, and gray to white. Corundum is the common variety of alumina, and is much used in the arts. The ruby is the most costly of all gems, a stone of deep color far outranking the diamond in value. Hence the discovery that it can be made in a laboratory is disquieting to dealers in precious stones. The artificial ruby, to use an incorrect term, is as durable and beautiful as the best product of the Burma mines, and it is only the magnifier that shows the little bubbles.

EMERAUDE SOUDÉE.

There has been sold in Paris for some years, and from Paris distributed in the markets of the world, a

stone which is called "*emeraude soudée*." The color of this stone is yellowish or bluish green, its specific gravity 2.70 to 2.71. It is as hard as quartz. As quartz can be scratched with a good English steel point, so can the *emeraude soudée* be scratched. A genuine emerald cannot be scratched at all by steel. As soon as this *emeraude soudée* comes to a red heat in an alcohol flame, a light brown material appears on the girdle. If this stone is split, the cleavage surfaces of the upper and under parts are also colorless. The green layer that lies between these two parts is no emerald at all, but a green chromo oxide containing fluid substance, which at a high temperature very strongly connects the two parts. As the quartz is very porous, the coloring substance percolates through and can be seen on the cleavage surfaces. The *emeraude soudée* is nothing more than quartz with a chromo oxide coloring substance which stands cooking in alcohol and heating. It has only the name and color of the emerald.

ARTIFICIAL SAPPHIRES.

Mr. Paris of the Pasteur Institute and his teacher, Mr. Lacroix, of the French Academy of Sciences, are said to have been successful in making artificial sapphires. Until now all the investigations and experiments of chemists proved fruitless. Should the French scientists have succeeded in making an artificial sapphire having the quality of the natural sapphire and the same physical, chemical, optical properties, hardness, specific gravity, etc., the discovery certainly deserves all praise. Much has been written about this invention, but reports of mineralogists or gem experts have so far not been published. It is known that Lacroix about twenty years ago scared the Parisian Jewelers' Syndicate with the ruby crystals of 1/5 inch diameter made of kryptolith, which he had heated for an hour, but this product was only a laboratory curiosity. As the diamond is nothing else than crystallized carbon, so the sapphire, like the ruby, is merely crystallized corundum mixed with chromium and oxide of iron and other pigments.

A SIMPLE VAPOR PRESSURE APPARATUS.

After the chemical composition of natural precious stones was known, chemists attempted to reproduce it in the laboratory. Mr. Paris's method (according to the SCIENTIFIC AMERICAN, December 17th, 1908) of making artificial sapphires consists in introducing foreign elements into the combination. Alumina and oxide of cobalt are theoretically all that is necessary to form the sapphire. The latter serves to produce the yellow color and is a small fraction of the whole amount. Mr. Paris conceived the idea of adding 2 per cent of lime and magnesia. The whole mixture was melted at the usual high temperature. The effect of this combination is surprising. Formerly the melted alumina crystallized upon cooling and eliminated the coloring matter, but in the present case this crystallization does not take place. The mass becomes colored and remains permanently in this state. At the moment of the highest temperature the lime and magnesia are driven off and the aluminate, colored by oxide of cobalt, remains. This substance is therefore the artificial sapphire, and it is chemically identical with the stone found in nature.

An artificial, reconstructed, scientific, or synthetic precious stone may be as fine as a natural stone. But microscopic examination always reveals internal regular inclusions, clouds, etc., while in the natural stone these formations are irregular.

Our knowledge of the subject has been added to by the investigations of such men as Gustave Rose, Heintz, Manross, Dumbree, Senarmont, Hautefeuille, Berthier, Forchhammer, Wöhler, Becquerel, Wibel, Moissan, Ebelman, Franke, Crookes, Noble, Fouque, Sorbey, Levy, Mielche, Goldschmidt. A few American chemists have also contributed (Fischer) a little to the practical solution of the problem.

A SIMPLE VAPOR PRESSURE APPARATUS.*

By E. J. RENDTORFF.

A HIGHLY desirable experiment in the physical laboratory is the determination of the vapor pressure of various liquids at different temperatures. This experiment is not given in the numerous secondary school manuals and consequently no satisfactory apparatus for this purpose is sold by our various supply houses. In Prof. Millikan's book, "Mechanics, Molecular Physics and Heat," a simple form of apparatus for this determination is described, but it has the disadvantage of being non-transportable when filled.

The accompanying illustration presents a similar type of apparatus that is transportable and can readily be filled with any liquid whose vapor pressure is to be studied. To a bulb *D*, about 6 centimeters in diameter, is attached a graduated tube *E* some 85 centimeters long and 4 millimeters internal diameter. Above the bulb is attached a stopcock *B* and a small cup *A*.

The tube *C*, of small internal diameter, is sufficiently long to prevent the stopcock from coming in contact with the water in which the bulb is immersed.

To fill the apparatus open the stopcock, attach a Geryk air pump and exhaust the bulb thoroughly. Close the stopcock and fill the cup, *A*, with clean mercury. Allow nearly all of this to enter the bulb. Refill the cup and allow the mercury to run into the bulb until the latter is from one-third to one-half full. Incline the apparatus, allowing the mercury to completely fill the long tube. On erecting the apparatus the mercury in *E* will stand at the same, or a slightly lower level (due to capillarity), than in the bulb.

Now allow a few cubic centimeters of the liquid, whose vapor pressure is desired, to enter the bulb. Totally immerse the bulb in a pail of water, stir constantly, and take the vapor pressure for every increment of 5 deg. C. Plot the curve.

The water in the bulb can now be removed by evaporation under diminished pressure and other liquids introduced.

When the barometer pressure is low, and the boiling point of water consequently below 100 deg. C., a handful of some salt can be dissolved in the water, to increase the temperature of ebullition. In case the glass tube is not graduated the vapor pressure readings can be taken with an ordinary meter stick. Where previous determinations had been made of the relation between boiling point and pressure it will at once become apparent that a liquid boils when its vapor pressure equals the external atmospheric pressure.

When the apparatus was first designed it was feared that leakage of air at the stopcock, due to the expansion of the glass, might seriously interfere with the results of the experiment, but after a test of several weeks no appreciable leakage could be detected. The stopcock was, of course, first coated with a good grade of vacuum wax.

On opening the stopcock a regular barometer results, which can be used during that part of the year when heat is not being studied in the laboratory.

In a paper presented to the Académie des Sciences, Messrs. Courmont and Nogier describe their researches upon the sterilization of water by the mercury vapor lamp with quartz tube. Küch in 1905 showed that when the glass tube is replaced by a quartz tube, the light is very rich in ultra-violet rays. Kromayer constructed a lamp in quartz on this principle for therapeutic purposes. With this lamp there is a great intensity in the ultra-violet rays. Th. Nogier and Thevenot (1908) made researches on destruction of bacteria by the Kromayer lamp, using cultures upon gelose. The present authors use the lamp on the same principle of sterilizing water. They employed a lamp of 4 amperes and 135 volts and found that the microbes were destroyed in water at 12 inches distance from the lamp. They then had made a metallic tank of 115 liters (30.4 gallons) having 24 inches diameter, and suspended a quartz lamp of 12 inches length in the center of the tank, using a current of 9 amperes and 135 volts. The sides of the tank are thus at 12 inches from the lamp. Numerous experiments showed that the water was completely sterilized (ordinary microbes of water, coli, Eberth bacillus) and at the end of one or two minutes, even when the water is very impure naturally or artificially. One minute action is nearly always enough. In these tests the water must be quite clear. It is supposed that the size of the present tank does not indicate the limit of output with such a lamp, but that it can sterilize a large amount of water. It is probable that such a method can be used in practice for sterilizing drinking water, which, however, must be clear. We place lamps either in a tank or in the inlet piping at the proper distance, so that the water is acted upon for one or two minutes. The lamps will last indefinitely, and the operation can be controlled by simply observing the light.

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