

The Production and Identification of Artificial Gems—II*

How They Are Made and How Distinguished from the Real

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It will, of course, be well understood that the experiments I have briefly indicated toward the artificial production of corundum had as their immediate objective the formation of ruby, that being by far the most valuable variety. It had long been known that the color of the ruby was due to a trace of chromium, and by adding a small proportion of potassium or ammonium chromate to their mixture, Fremy and Feil reproduced accurately the color of the ruby in their crystalline flakes.

The process of producing reconstructed rubies by means of the oxy-hydrogen blowpipe is, roughly, as follows: The residue from cutting rubies and small worthless stones is broken into coarse sand, a small quantity of which is placed on the center of a disk of platinum; this is then carefully brought to the fusion point, care being taken at this stage not to raise the temperature to such an extent as to melt the platinum support. As soon as this mass is fused it serves to protect the platinum, and the reconstructed ruby can be built up on it by adding the fragments of ruby one at a time by means of small platinum forceps. These pieces have to be dropped on with great care in order to secure incorporation with the mass and prevent as far as possible the formation of air bubbles. It will be readily understood that this process is a tedious and laborious one, and, in fact, the formation of masses of sufficient size to yield large stones on cutting is a matter of such difficulty that the cost of production is very high.

Just about seven years ago, however, Verneuil† overcame this restriction when he hit on the extremely ingenious idea of introducing the raw material through the blowpipe, and thus placing it on the support automatically. The diagram (Fig. 2) shows the principle of his apparatus. The blowpipe is arranged vertically over a small insulated chamber containing the support on which the mass is to be built up. The oxygen tube communicates at its upper extremity with a funnel-shaped hopper, in which is suspended a small sieve filled with raw material, which is rhythmically shaken by means of a small hammer actuated by an electro-magnet or cam. Each time the hammer taps the support of the sieve, causing it to vibrate, a small quantity of the powder falls through into the tube below, and, carried along by the gas, passes out at its lower extremity into the zone of flame, where it is immediately raised to the fusion point, and falls as a melted globule onto the support below.

As seen in the diagram, this support is arranged with a screw adjustment, so that as the mass of corundum is gradually built up by the constant addition of fresh globules the surface can be kept at a constant level, and the portion already formed removed from the zone of heating so as to allow it to stiffen. When the apparatus is first started the blowpipe is adjusted so as to give a comparatively cool flame, and the powder is admitted slowly. By this means a small "stalk" is formed, which insulates the mass from the support and prevents the fusion of the latter. When this has been formed the full pressure of the blowpipe is put on and the rate of admission increased, with the consequent formation of a "boule," as the pear-shaped mass produced is termed.

With this apparatus a boule weighing some twenty to thirty carats, and capable of yielding two cut stones of about six carats each, can be prepared in about half an hour almost automatically, a single operator being able to control several machines. The boules, on cooling, very often split in half in the direction of their growth, and this is a convenience rather than otherwise, as the resulting shape can be cut to greater advantage.

In the first instance reconstructed rubies were made in this way after the manner introduced by Gaudin, the material fed into the blowpipe being pulverized rubies and chips, and this method is still employed by some workers. But more commonly nowadays the corundum is produced direct from amorphous alumina by using pure ammonium alum as the raw material. On reaching the flame this decomposes, the ammonia and sulphuric acid volatilizing, leaving the alumina. Stones made by this process are generally known as "synthetic," as distinct from "reconstructed," although, of course, to the pedantic, the process is one of

decomposition rather than one of absolute synthesis.

The "synthetic" corundum produced in this way, if pure ammonium alum is used, is, of course, colorless, and can be used as artificial white sapphire. If a small proportion of chrome alum is added, the resulting stones are rubies, and other colors may be produced in the same way. For a long time all attempts to reproduce the fine blue of the sapphire failed, because, following the apparent analogy of silicates, cobalt was invariably employed as the coloring agent. This, however, does not readily form an aluminate in the same way that it does a silicate, and, in consequence, it is impossible to produce a satisfactory coloration in the corundum by its means; it is possible to

should not only be crystalline but possess all the characteristics of a single crystal. Crystallographers are agreed that each boule is a single crystalline individual, with the axis roughly perpendicular to the plane of formation—that is to say, running from the point of attachment of the pedestal to the top of the mass. On the top of the boule one invariably finds a mass of symmetrically-arranged facets, which Dr. Herbert Smith has found to correspond with the fundamental rhombohedron of corundum. Judging by analogy with other materials, one would expect at first sight that a fused mass formed in this way would be either a heterogeneous mass of minute crystals, or entirely amorphous, possessing the structure characteristic of glass. It is well known, for example, that under similar conditions pure silica yields "quartz glass," which is extensively manufactured at the present time.

Then, again, there is the matter of coloration. One would like very much to know what is the state of combination of the chromium in a ruby, and whether the color is produced by chromium aluminate in solution or metallic chromium in molecular suspension. In glass, as is now well established, this color is produced by the optical effect of ultra-microscopic spheres of metallic gold or copper, but there seems to be no parallel between the two cases.

A point of more practical interest is the fact that although the artificial corundum is a true crystal it possesses the shape and formation of a congealed liquid or glass. The practical interest of this lies in the fact that it affords the only means of distinction between this artificial corundum and the naturally-formed gem-stone. Being of exactly the same composition and crystalline structure as the natural mineral, it cannot be identified by any of the physical tests I briefly referred to above. For all practical purposes the artificial ruby is a ruby, and one can only deny that it is a "genuine ruby" if this word is held to connote essentially a product found in the earth and not made by man.

And yet, owing to the curious anomaly of its structure, the artificial product can almost invariably be distinguished from the natural with the greatest ease. In the naturally-formed stone any foreign matter which may be present is coerced into following the lines of growth of the crystal, and more particularly bubbles of gas which may be present in the liquid are distorted from their natural shape so as to accord with this symmetrical growth. It is the great exception to find a natural ruby entirely free from such inclusions, which generally form irregular cavities with a decided tendency to geometrical shape.

It is very common also to find the structure technically known as "silk" caused by microscopic bubbles drawn out into a series of parallel canals, all lying in one plane. Any variation of color in different portions of the stone also follows the lines of growth in this manner.

In the artificially-produced corundum, on the other hand, although the particles arrange themselves symmetrically, any air bubbles that are entangled in the successive globules remain undisturbed, and appear as naturally spherical bubbles in the finished product; and, moreover, if one globule differs slightly from another in the proportion of chromium, the resulting difference in color follows the form of the mass as a whole, the zones of color being circular.

As some of the air entangled between the fine particles fed into the blowpipe almost invariably fails to make its escape during the brief fusion, the presence and form of the bubbles is in this way sufficient to identify the artificial process of formation.

In the great majority of cases examination of the cut stone with a lens is sufficient to decide the point, but in doubtful cases a more minute examination may be made by placing the stone in a little cell filled with highly-refracting liquid, in order to secure regular illumination, and examining it under the microscope by transmitted light, when the minutest trace of structure can be detected. In the case of an absolutely flawless stone it would be impossible to decide whether it were natural or artificial, but such stones are so rare that this case is almost theoretical.

It is claimed in some quarters, it is true, that "experts" can invariably distinguish the artificial product merely by reference to the color, which is said never to be exactly the same as that of the natural stone,

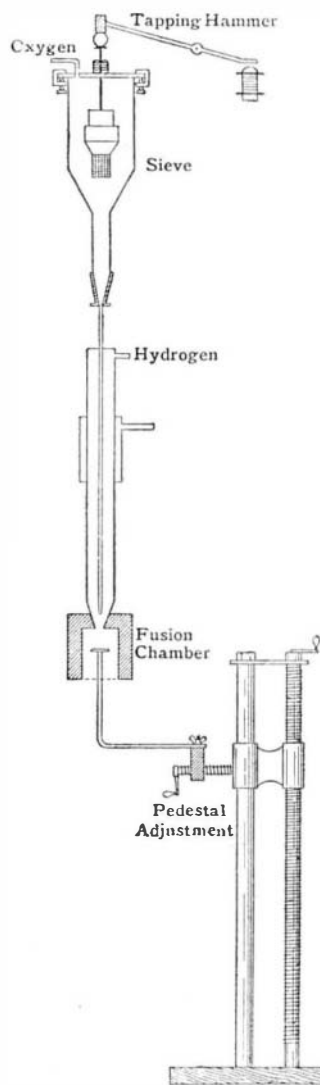


Fig. 2.—Apparatus for "Reconstructing" Rubies.

get the cobalt in a state of combination by adding a large proportion of magnesia to the alumina, but then the product formed is not a crystalline alumina but magnesium aluminate, and its properties are fundamentally different. Its refractive index is lower, its refraction single, and its hardness lower. In fact, the result is blue spinel instead of sapphire. Moreover, such blue stones have the characteristic absorption of cobalt, and appear purple in a light that does not contain a large proportion of blue rays.

In 1908 Paris attempted to avoid this latter difficulty by preparing a calcium aluminate colored with cobalt, as it is found that in this case the transmission of the red rays is less pronounced. But the calcium aluminate so formed is not crystalline at all, but amorphous. A year or so ago, however, the problem of producing synthetic sapphire was finally solved by the use of titanium oxide, a very unexpected result, considering the chemical position of this element. With this last advance the artificial production of the corundum gem-stone may be considered to be completely solved, and cut stones can now be obtained in every variety of color, from pure white to ruby and sapphire, at prices ranging from \$1 to \$2.50 a carat, according to color, quality and size.

Whatever may be their economic importance, a very much debated question, there can be no doubt as to the scientific interest of this group of artificial gems. In the first place it is a matter of some interest that a mass of fused material formed in this way

* Paper read before the Royal Society of Arts.

† "Mémoire sur la reproduction artificielle du rubis par fusion," M. A. Verneuil, *Annales de Chimie et de Physique*, Sept., 1904.

much as this latter varies. Personally, however, I am rather sceptical on this point, as one knows that experts claim in a similar manner to distinguish between one species of natural gem-stone and another by color alone, and their results are not *always* in accordance with scientific tests. At any rate such dexterity can only be acquired by a life-time of specialized experience.

As I have already indicated, spinels may be produced artificially by the same process as corundum, adding the necessary magnesia to the alumina, and the same remarks apply to the production and identification of this species as to corundum, the artificial stone being identical with the natural in all respects except those to which I have just referred.

As regards the remaining transparent gem-stones, which fall into a group by reason of the fact that they contain silica as an essential component, their artificial production is of little importance. They cannot be produced by the same process as corundum, owing to the fact, already alluded to, that under such conditions both pure silica and compound silicates yield an amorphous product, which has not the optical properties of the natural stone. One is constrained, for the artificial production of the crystalline material, to fall back upon methods similar to those employed in the earlier attempts to obtain ruby—obtaining the requisite composition by chemical reaction and maintaining the mass at a temperature just above its fusion point for a sufficient time to allow the silicate to crystallize out.

Topaz, garnets, and zircon have been produced in this way experimentally as a matter of scientific interest, but the small stones produced have no commercial value. The majority of these stones are of such common occurrence in nature, and consequently of such little value, that their artificial production in this manner is not a commercial proposition.

An exception, however, must be made in the case of the emerald, which ranks next to value to corundum, and many attempts have been made to produce it artificially. Reconstructed emeralds have been made by the Verneuil process, but these are, of course, amorphous, and do not possess the double refraction and other properties consequent upon the crystalline structure of the natural stone. The problem of producing this stone artificially has not as yet been solved in fact. I am quite aware in saying this that recent newspaper reports lead one to believe otherwise, but, as in the case of the diamond, such reports indicate either remarkable foresight on the part of the writers or show that their imagination is developed at the expense of their powers of accurate observation.

There remain now to be considered those precious stones which are opaque, and owe their beauty entirely to color and structure.

Turquoise is a stone formed under conditions which are easy to reproduce, and its artificial production was successfully accomplished, many years ago, by precipitating hydrated phosphate of aluminium with the requisite proportion of copper phosphate to give it the color, and subjecting the precipitate while still damp to hydraulic pressure for a considerable time. Prepared in this way the artificial turquoise is so nearly identical with the natural that its identification is a matter of considerable difficulty. There is, however, generally a slight difference in the specific gravity, hardness, and index of refraction (when this can be measured), which will serve to distinguish it on careful examination. The only point in which there is any decided difference between the two is the behavior on heating, but as this involves the destruction of the stone it cannot be offered as a practical test.

Opal consists essentially of what is known as colloid silica, that is, silica in the amorphous state and combined with water. The play of color one associates with it is entirely an optical effect, due to an accidental structure of the stone, which is permeated by a number of minute fissures, between which a thin film of air penetrates, the extreme thinness of this film causing the optical effect known as interference. If a piece of opal is powdered it is no longer colored, as would be the case with a ruby or sapphire, but yields a dirty white powder, and generally a specimen of opal, as found, only shows the structure in parts, the remainder being dull and lusterless like flint.

This peculiar structure is, moreover, by no means confined to opal, but may occur in any mineral deposited under similar conditions. In the mineral known as Lumachello, or fire-marble, for example, the same effect is seen in a lime-stone. But opal is the only mineral which combines this structure with sufficient durability for use as a gem-stone, and in this connection it should be remembered that, as a matter of fact, it only just possesses sufficient hardness for this purpose, and is one of the softest and least durable of all the precious stones. This fact, combined

with the fragility consequent upon its structure, has involved the opal in a mass of superstition and romance from time immemorial.

Although it has this unfortunate drawback, opal is, at any rate in my estimation, the most beautiful of the precious stones, and when one appreciates the reason of its beauty it will be readily understood that its artificial production, or even successful imitation, presents almost insuperable difficulties.

It is true that a somewhat similar play of color can be imparted to glass by rendering it translucent by a slight addition of arsenic or tin in the making, and by etching the surface in various ways, and such iridescent glasses are often found naturally as the result of decomposition, but this is merely a surface effect, and such specimens cannot be cut to advantage; moreover, they lack the beauty caused by the fire permeating the entire substance of the gem. The opal ranks with the diamond, therefore, in resisting attempts at artificial production, and is even superior to it in that it cannot be really successfully imitated.

I come finally to the pearl. This, of course, differs from all other precious stones in being entirely of organic origin. The peculiar luster of the pearl, like the color of the opal, is due rather to its structure than its composition. It is formed in the oyster by the deposition of successive layers of calcium carbonate round some central object, and consists of an innumerable number of thin overlapping laminae of the crystalline variety of this substance known as aragonite. These layers being semi-transparent, the light falling on the surface is partially reflected from the surface and partially transmitted into the stone, where it suffers reflection from the surface of lower layers.

To produce this complicated structure artificially is practically impossible, unless one can describe as an artificial pearl that formed by the oyster in response to the deliberate introduction of irritant foreign matter by human agency. But in this case, who shall decide where nature ends and human ingenuity begins? Perhaps the well-known Japanese pearl may be correctly described as artificial pearl, although the oyster has a great deal to do with it.

Such pearls are formed by introducing a mother-of-pearl shape between the shell and mantle of the oyster and then leaving the oyster alone for a time to allow it to convert this into a pearl by the deposition of several layers of nacre. The mass is then removed from the shell and converted into the semblance of a true pearl by supplying a back of mother-of-pearl. Such pearls, however, never have the fine orient of those produced under normal conditions, and they can readily be detected by examining the back, when the lustreless mother-of-pearl and the line of junction can be detected.

Of course, wonderful imitations of pearl are made in various ways, which are difficult to distinguish from the natural article by casual examination. One method of preparation is as follows: Small hollow spheres are blown in opalescent glass, coated inside with a preparation of fish scales, and then filled up solid with wax. Such imitations are identified by examination of the hole or by putting a spot of ink on the surface, when the reflection from the inner surface of the glass is seen. These empirical tests are usually sufficient, and it is rarely necessary to resort to testing the specific gravity and hardness, which provide further means of identification. It is worthy of note, however, that such imitation pearls are unique among imitation gems in that, in some respects, they are actually superior to the natural article. They are considerably harder for instance, and their luster is not affected by constant wear.

In conclusion, I would like to refer very briefly to the present position of gems from the economic point of view. It is, perhaps, natural that the considerable influx of artificial gems in recent years, more particularly of the corundum species, has led to a great deal of controversy and difference of opinion as regards their merits. On the one hand the vendors of the artificial stones often publish extravagant statements as to their defying identification, which, as I have shown you, is all nonsense. On the other hand, those interested in maintaining the prestige of the natural article make equally unreasonable statements, to the effect that such artificial productions, to quote a recently published circular, "are as worthless as the jewelry from a Christmas cracker." I have, I hope, clearly shown you the immense difference that exists between the imitation and the artificial ruby, taking an example; the former, it is true, depreciates rapidly in use, and deserves such a description, but the latter has absolutely all the essential qualities of the natural stone, and to place the two on the same plane as worthless trash is unfair to modern science and ingenuity. It must be clearly understood that there is no essential difference discernible between nat-

ural and artificial ruby as regards their beauty and their durability, which, as we have seen, are the two great items in the intrinsic value of a stone. But, of course, the price of a stone is chiefly determined by that third factor, which I have not so far taken into account—namely, rarity. Personally, I must confess that I have never been able to see why one should value a thing for no other reason than that it is difficult to get, although I suppose here I am in a hopeless minority, and that it is and always will be human nature to take this view.

It would serve no useful purpose to enter into that fruitful subject of controversy, the price of an article due to extrinsic causes, but I may say this—that while to me personally one is as good as the other, if any man is prepared to pay £100 for a natural stone when he can obtain essentially the same thing, artificially produced, for five, he is absolutely entitled to get it; and I would not wish you to think that I would defend for a moment the man who attempted to supply artificial as natural. But if this is so, it is still more the case that nobody has any right to supply anyone with paste under the name of artificial (or synthetic, or scientific, if these names are preferred) gem. I do think that the distinction between the two should be clearly recognized, and that it should not be permitted to use the term artificial indiscriminately. At present this is being widely practised; every day one sees offered for sale "rubies, emeralds, sapphires, and pearls artificially produced and having all the properties of the natural stone." Now, as I have indicated, such a thing as an artificial emerald answering this description is unknown, and, as a matter of fact, the stones supplied under this title are, as a rule, nothing more nor less than paste imitations, the public being deliberately led to believe otherwise. There is in this case, as I have indicated, a real practical difference between the two articles, not merely a question of opinion.

Again, one must deprecate the custom that has sprung up of arguing that, because "a rose by any other name will smell as sweet," a "scientific" stone will be as good by any other name than its right one. When synthetic yellow sapphire is called "scientific topaz," perhaps no serious fraud is perpetrated, although it is misleading, but when artificial white sapphire is openly and deliberately sold at a fancy price as "synthetic diamond," with the support of the press, I for one consider that matters are going too far, and that this is being done at the present moment anyone can verify for himself. All these misrepresentations may bring wealth to individuals, but they tend to bring into disrepute the artificially-produced gem, and instead of allowing it a place of its own as a distinct achievement, cause it to be looked upon as a spurious make-believe.

Curiosities in Needles.

NEEDLES are articles of such common use and of such small dimensions that one hardly expects to find them present any features of artistic or personal interest. Yet there are one or two instances of this kind on record. Queen Victoria possessed a needle, the stem of which was covered with beautiful designs representing incidents in the life of her late majesty. So small and intricate was the pattern that it could be seen only by the aid of a magnifying glass. Moreover, the needle was hollow and within it was placed another still smaller needle.

The German Emperor, William I., grandfather of the present occupant of the throne, also possessed a very remarkable needle. The story of the circumstances is as follows: In 1883 the Emperor visited a large needle factory in Kreuznach, and one of the workmen, whose task it was to bore the eye of the needles, requested the Emperor to give him one of his white hairs. The Kaiser complied with the request in some astonishment, and was still more surprised when he saw the deft workman bore a hole through the hair, draw a fine thread through the eye, and hand the threaded needle back to the venerable monarch, who kept it as one of the most interesting souvenirs of his long and varied life.

Progress Made by the Metric System.—According to the *Comité International des Poids et Mesures*, the following countries have adopted the metric system: Since January 1st, 1912, it is compulsory in the five Central-American republics and in Greece. In the last named country it was legally introduced since 1836, but its use had been confined to legal commissions. In Bosnia and Herzegovina the metric system will come into general use after September 1st, 1912. In the Anglo-Saxon countries there are still too many opponents against its introduction, although a bill has been introduced in England to adopt the system in the Australian colonies.—*Mechaniker-Zeitung*.