

MEISSEN CHYMISTRY

Roald Hoffmann

The art of making porcelain was a Chinese technology known and valued in the West, yet Europe tried—and failed—to emulate this secret for hundreds of years. Porcelain was eventually made in Saxony in 1709, in a successful piece of applied chemical research by the “collaboration” of three men of strikingly different character. One of these, Johann Friedrich Böttger, was an alchemist who, in his life and work, illustrated the scant separation of alchemy and chemistry during that time. Let me tell their story.

My Precious

Merchants first brought Chinese porcelain to Europe overland. And travelers told stories of how it was made. So Marco Polo wrote:

[In the city of Tin-gui ...] cups or bowls and dishes of porcelain-ware are manufactured. The process was explained to be as follows. They collect a certain kind of earth, as it were, from a mine, and laying it in a great heap, suffer it to be exposed to the wind, the rain, and the sun, for thirty or forty years, during which time it is never disturbed. By this it becomes refined and fit for being wrought into the vessels above mentioned. Such colours as may be thought proper are then laid on, and the ware is afterwards baked in ovens or furnaces.

The manufacture of ceramics was well developed in medieval and Renaissance Europe. Yet all attempts to replicate porcelain failed, leaving a legacy of ceramics that imitated the whiteness (or celadon-like coloration), or the hardness, or the translucency of true porcelain. But never all qualities together. Seventeenth-century merchants fanned the ardor for porcelain through the East India trade that brought Asian wares to Europe. As a result, if one could wait three years, one could have any pattern made in fine porcelain. I have seen a Swedish plate in which the European designer's words of instruction were faithfully replicated in classic, cobalt-blue underglaze—the potters in China had treated the instructions as the pattern.

The Right Stuff

Porcelain is a ceramic material. Once it was simple to define ceramics as inorganic, refractory, porous, brittle, and insulating. All parts of this definition have frayed at the edges: It's fun to open a ceramics text, see the authors struggle for a definition at the outset—and then take it all back. There are ceramic superconductors, and brittle is not the word for the stuff of turbine blades. Does one need a definition? Yes: It may be essential for good science, as in the defining moments of thermodynamics. No: It may be merely a refuge for people who want their world clean and neat, this not that. A way the world refuses to be.



Figure 1. The subject of this undated portrait is presumed to be the alchemist J. F. Böttger. The painter is unknown. From the Bavarian National Museum. (Photograph reprinted from Krätz, 1990)

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Perhaps transformation by heat, if not fire, remains the defining essence of ceramics. The chemical and physical changes in the kiln are certainly complex. Porcelain is a high-temperature-fired ceramic with recognizable, if fuzzily defined, properties of whiteness, hardness and resonance—that ringing tone when struck. Its traditional components varied, as there was not one Chinese porcelain but many: Longquan Celadon, Jingdezhen-ware, the products of the Dehua kilns. But the fine, white clay called kaolin was essential. Other fusible materials were added: the mineral sericite (a type of mica called petuntse) by the Chinese, alabaster by the Böttger workshop. The bulk of kaolin is kaolinite, a layered, hydrated aluminosilicate with the nominal formula $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$. Heating expels water, then some silica, which may form its high-temperature form, cristobalite. The remainder of the aluminosilicate exists as mullite, $3\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$. The special qualities of porcelain derive from the development of fine needle-like crystals of mullite, cemented by glassy silica.

The sequence of transformation on firing porcelain is more complicated than this summary. Yet, as in so many things in this world, complexity (or is it our partial understanding?) is absolutely no barrier to reproducibility, whether the porcelain is a fine Chinese export or one's toilet bowl.

The Alchemical Fire

The first of the three men whose talents joined in the development of European porcelain was Augustus the Strong, the Elector of Saxony and King of Poland, who was besotted by Chinese porcelain. Serving him was Ehrenfried Walter von Tschirnhaus, an aristocratic natural philosopher and polymath with a practical bent. He wrote on mathematics, but also learned how to make soft-paste porcelain in France and built giant burning-lenses that reached the highest temperatures yet observed.

The third man was Johann Friedrich Böttger, a young alchemist in the classical vein, who believed in the central philosophy of alchemy (and chemistry), that of essential transformation. He was also a very good, practiced chemist, familiar with metallurgical techniques and the arts of pharmacy. To be an alchemist at this time was a precarious profession, a calling that required great political skill. To gain patronage, one had to promise gold or medical cures. To keep it, one had to practice, with refinement and skill, the art of eternal, creative procrastination: always assuring more, always asking for more. No wonder alchemists were always on the move! As in the story of the goose that laid golden eggs—were the alchemist to succeed, his patron would not want to lose such an economic force—Augustus imprisoned Böttger in the Saxonian capital of Dresden. The incarceration was, in part, punishment for the failure to produce gold, in part, security of the supply, should Böttger succeed.



Figure 2. This statuette of Augustus the Strong was made in Böttger's red stoneware around 1714. (Photograph from the Metropolitan Museum of Art, New York.)

At stake was not just Augustus's displeasure. Figure 3 is a reproduction of a broadside, a contemporary account of what happened to a Neapolitan alchemist, Count Domenico Emanuele Cajetano, who was found cheating. He was hanged. Augustus's mien—you can see why he was called "the Strong"—is captured in a statuette of the King (Figure 2), made in Böttger's lifetime from a marvelous red stoneware the alchemist labored to perfect.

Tschirnhaus convinced Augustus to put Böttger to the task of making "white gold," or porcelain. It took only two years to do so, when so many other attempts had failed, because of a felicitous conjunction of materials and people. First, there were nearby deposits of kaolin that were known to Tschirnhaus. This Saxonian clay lacked the traces of potash mica that lent plasticity to its Chinese counterpart and allowed Eastern potters to experiment with more curvaceous forms. Still, this clay and no other was the essence of porcelain. Next, Böttger could build kilns, in

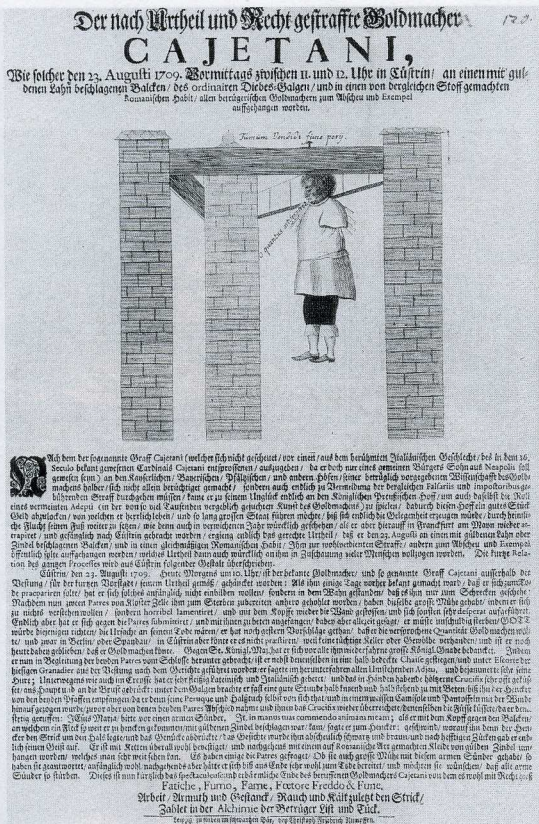


Figure 3. Alchemical failure was often ill-received by one's patron. This 1709 handbill from Leipzig announces the hanging of a false goldmaker. From the Bavarian National Museum. (Photograph reprinted from Krätz, 1990.)

them “the gehennical fire,” that could reach the requisite high temperatures. And finally, talent to decorate the porcelain existed among the artists at Augustus’s Dresden court. Figure 4 shows a Meissen vase that imitates Japanese Arita porcelain (left); in time unique decorative modes and figurines (right) were elaborated.

But most of all, the success of the project was due to the careful experimentation of the alchemist-turned-industrial-chemist. Set on his way by Tschirnhaus (who died in 1708), Böttger first made true, white porcelain in 1709 at the age of 27. In 1710 the porcelain manufactory moved 15 miles down the Elbe River to the city of Meissen and became known by that name. By 1713 it was an economic success.

Crystals of Porphyry and Borax

The story of this rediscovery of porcelain, Böttger’s story, is told beautifully in Janet Gleeson’s 1998 book *Arcanum*. She cites an emotional poem that Böttger wrote to Augustus late in 1709:

The King will yearn for golden fruit,
Which the weak hand yet cannot present.
It puts but crystals of porphyry and borax
Before the King’s throne in place of
such sacrifices.
Yes, the hand extends even the heart,
in vessels of porcelain.

This rings true. Böttger was caught. I sense from the poem that he would have liked to get out of the alchemist’s bind and rest on his great practical synthesis, the making of the translucent “white gold.” But he was not allowed to do so. Although the porcelain was of immense value and eventually contributed to the King’s coffers, it took time to establish a market for it. Meanwhile Augustus did not give up his dream for gold, and Böttger remained a prisoner. Time and again he was pressed to make good on his promises of making gold, and he finally staged a “successful” transmutation in 1713. Böttger was freed in the end, even ennobled. But he was ill and exhausted. He died in 1719, the year porcelain was first made outside of Meissen. It’s not easy to keep an industrial secret.

Chymistry

Did it take an alchemist to make porcelain? Could a chemist of the time have done it? The question assumes a distinction between alchemy and chemistry that I believe did not exist in Böttger’s day. People transformed matter—in metallurgy, in the making of medicines and cosmetics, in cooking, in dyeing fabrics—before there were ever chemists. And these wonderful protochemistries, as I like to call them, are one of many crafty threads into modern chemistry.

Another is alchemy, a unique cultural experiment, which adopted chemical change (as we now know it) as a symbol, a kind of logo, for its philosophy of transformation. Why chemistry? Because chemical transformation was at the same time familiar and spectacular. Imagine fire, or the smelting of ore. Imagine a brightly colored vat of indigo dye reduced by fermented urine to a muddy liquid, then resurrected in its blue glory by exposure to the air!

So the philosophy of change took on a chemical face. And then, I imagine, was co-opted by it. Alchemists became chemists. A strict distinction between the protochemists of the time and alchemists is an *ex post facto* simplification of a world of overlaps, which are beautifully exemplified by Böttger during his short life. In their convincing arguments for a lack of separation, historians William R. Newman of Indiana University and Lawrence M. Principe of Johns Hopkins suggest that the bridging word “chymistry” best describes alchemy and chemistry in the period.

I like the word. And yet, and yet, even as I imagine Böttger keeping careful laboratory notes of his formulae and protocols, I wonder if it could have been done without the underlying alchemical imperative. One could make stoneware and glass, use them in everyday life. But anyone who has held a fine Song or Koryo vessel in one’s hands, rotated it, followed the fine crackle, I think feels that porcelain is something more. It is sublime. To aspire to transform mere clay into that refined essence that catches light and begs to be held as no other ceramic does—that vision takes more than laboratory skill. The synthesis (I have to call it that) of porcelain de-



Figure 4. Two early pieces from Meissen: a vase (left) made during the late 1720s, demonstrating Asian artistic themes (from the Museum Bredius, The Hague) and a 1741 figurine (right) by J. J. Kaendler, depicting a Freemason apprentice receiving instruction from a master (from the Grand East of the Netherlands, The Hague). Note the globe the two figures are examining. (Photographs courtesy of Museum Bredius and the Grand East of the Netherlands.)

mands faith in the possibility of transformation and a conviction that nature can be improved.

I think it took an alchemist. And the knowledgeable naturalist Tschirnhausen. And the forceful tyrant Augustus the Strong (no, please, there's no lesson here for contemporary granting agencies) to make this sublime, applied research work out.

Transmutation

A final comment on alchemy: In the 1968 translation of his remarkable book *Forgerons et Alchimistes*, Mircea Eliade traced the tripartite relationship between metallurgy, alchemy and religion. In conclusion, he writes:

We must not believe that the triumph of experimental science reduced to nought the dreams and ideals of the alchemist. On the contrary, the ideology of the new epoch, crystallized around the myth of infinite progress and boosted by the experimental sciences and the progress of industrialization which dominated and inspired the whole of the nineteenth century, takes up and carries forward—despite its radical secularization—the millenary [*sic*] dreams of the alchemist. It is in the specific dogma of the nineteenth century, according to which man's true mission is to improve upon Nature and become her master, that we must look for the authentic continuation of the alchemist's dream.

You can sense that Eliade will go on to disapprove, not of the alchemist's dream, but of modern, industrial society's twisted reincarnation of

that dream. Even as I worry about the hubris implicit in the ceaseless flaunting of our transformative power, I don't disdain our present state as much as Mircea Eliade. But I do think he is essentially right about chemistry: Modern chemists, screaming to high heaven that they have nothing to do with alchemy, have fulfilled the alchemist's dream—transmuting sickness into health and, with superb ingenuity, changing mud (the raw materials of organic synthesis) into gold (what pharmaceutical companies sell).

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