Glass and Alchemy

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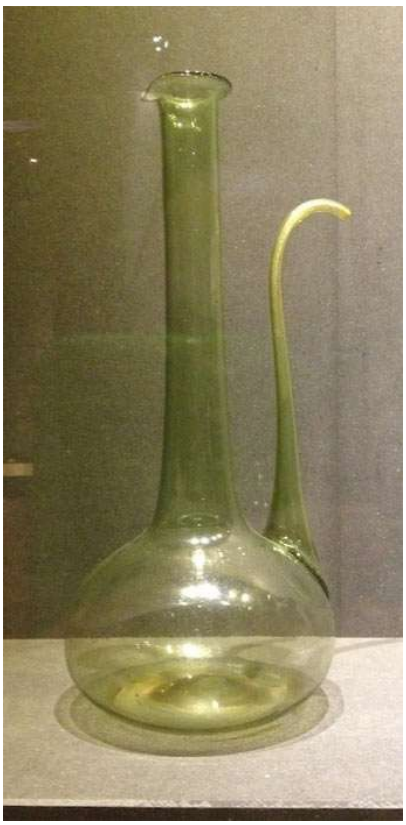
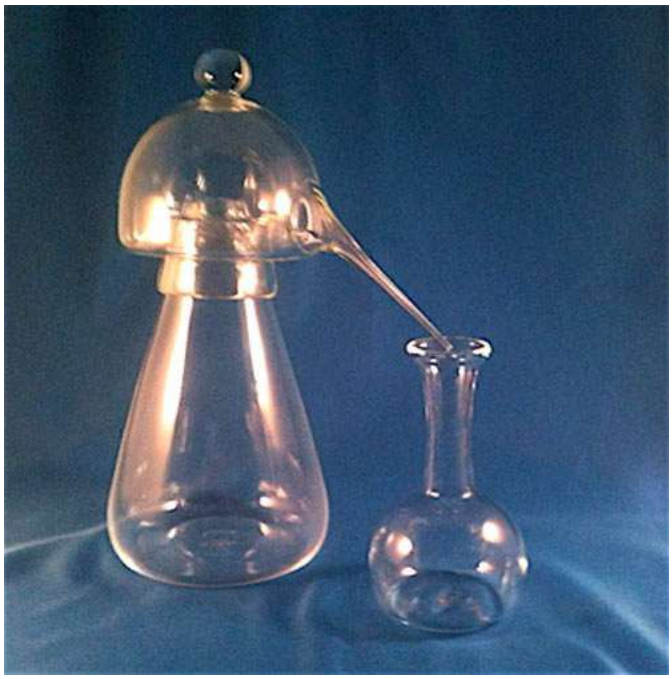


Ampulla Of the type used in alchemy and alchemical practice, Florence, Italy, 17th century

Glass Instruments of the Alchemists

Ceramic vessels were used for sublimation (transition directly from the solid to the gas phase), calcination (heating a solid chemical compound to high temperatures in absence or limited supply air or oxygen, generally for the purpose of removing impurities or volatile substances and/or to incur thermal decomposition) and for melting of substances.

Glass was needed for distillation, an important procedure in alchemy. For distillation alchemists used alembics (stills consisting of two vessels, a flask and a cucurbit, connected by a tube). A retort was also used, which is a cucurbit with long neck instead of a separate tube. It gives a better seal, but is difficult to clean.



Example of an alembic setup

Retort, 18th century, Corning Museum of Glass

Glass making is an old craft. The ancient Egyptians were mastered it well, and it was further developed in the ancient Greek and Roman era. Archaeological digs have turned up sophisticated glass equipment for use by alchemists/chemists.

Mary the Jewess, also known as Mary the Prophetess, lived between the first and third centuries A.D. in Alexandria. She is credited with the invention of several kinds of chemical apparatus and is considered to be the first true alchemist of the Western world. Zosimos of Panopolis, who was a Greco-Egyptian alchemist and Gnostic mystic who lived at the end of the 3rd and beginning of the 4th century AD, mentions that Mary the Jewess wrote a treatise entitled *Perì kaminonkai organon* (On Furnaces and Instruments). This treatise dealt with experimental practice and which was destined to have an enormous influence on the history of alchemy during the following centuries. In this and other works, Mary mentions more than 80 pieces of apparatus, showing the high degree of specialization reached by Alexandrian alchemy. Among the instruments attributed to her, Zosimos mentions the *Trìbikos*, a still used for distillation, connected by three tubes, and three glass *bikoi* "large and strong, so that they may not break with the heat coming from the water in the middle.

Mary's attention to glass apparatus epitomizes ancient alchemists' creativity in exploring new methods of conducting chemical experiments and, at the same time, reveals again the closeness of the connection between the progress of glass making after the introduction of the blowpipe, and the first steps of alchemy. The presence of glass apparatus in the ancient alchemical laboratory showed a surprising degree of specialization.

If you want to know more about the art of glass making in the ancient cultures, read the excellent book *The Alchemy of Glass Counterfeit, Imitation, and Transmutation in Ancient Glassmaking* by Marco Beretta.

The following two pictures give you an idea of the ancient Egypt alchemical glassware:

Glass head of a still, excavated in Egypt. Late Roman Period ? Petrie Museum, University College (London). Inv. UC2213.

Glass alembic. Egypt. University College of London at the Petrie Museum, University College (London). Inv. UC22032.

A 9-Ton Slab of Glass

It was discovered in Beth She'arim, Galilee, northern Israel, in 1956, in a natural cave turned into a cistern. When the floor was cleared of silt, they discovered a large flat, rectangular slab that looked like stone. It measured 6½ x 11 ft. and 18" thick (2 x 3.5 meters, and 46 cm thick). In 1963, members of a joint expedition of The Corning Museum of Glass and The University of Missouri discovered that it was not stone but glass. The place once had been a very large covered tank in which the raw material was poured, and then heated to a temperature of about 1100°C (around 2000°F). It had to be held at that temperature for perhaps 5 to 10 days. The block of glass produced weighs 9 tons (18,000 pounds)! This could have required as much as perhaps 20 tons of wood for fuel. The reason why it was abandoned is that lime from the plastered arch over the tank was breaking down and fell into the molten glass, making it opaque and unusable.

It is the third largest piece of glass in the world, and it was dated to the 9th century. The reason why they were making such large slabs was that it could then be broken up into smaller pieces and be easily transported. The smaller pieces would then be reheated and shaped into glass vessels. Such a 9 ton slab would have produced 50 to 60 thousand small vessels. (Source: Corner Museum of Glass)

Making, blowing and shaping glass is an art by itself, but making a 9-ton slab of glass is quite an achievement. The ancient glass makers/alchemists were quite advanced in their art, and some of their techniques dwindled away and were rediscovered by Western glass makers, often by reading ancient recipe books.

The Beth She'arim slab of glass.

Glass Alchemists in Spain

In the Byzantine empire (5th to 15th century), the progress of glassmaking went hand in hand with the development of alchemy. From there the knowledge was exported to Western European cities. Alchemical glassmakers were also very interested in making imitation gemstones from colored glass.

In the 13th and 14th century, Catalan glass (in Spain) was an important business for the manufacturing of artistically stained glass windows for churches apart from ordinary vases and luxury cups.

Catalan glass vase from around 1500

In the second half of the fourteenth century, a Catalan alchemist and Carmelite friar Guillem Sedacer constructed a theory of matter based on his alchemical experiments. According to Sedacer, glass was a transparent body, artificially brought to the nature of quintessence and it could be transmuted into any other body: hence its name of *lapis convertibilis*. Quintessence was used to describe the mystical fifth element, a pure substance that is the carrier of light. Albertus Magnus (a German Catholic Dominican friar, philosopher, scientist, and bishop), in the third book of his lapidary questioned this conclusion. One of Sedacer's goals was to make gems of various colors, the base of which was a clear glass.

The idea that glass had something to do with transmutation was not a central concept in alchemy, but it does pop up once in a while. It was primarily based on the practice of producing imitation gems by adding metals to glass.

Guillem Sedacer also provided formulas for the production of very transparent glass, that was manufactured in Catalonia. Soda ash from the barella plant was used for this, a salt-tolerant plant that grows along the Catalan coast. This transparent glass was used to make hour glasses, necessary for the navigation at sea. Transparent glass made it also possible to make lenses, giving rise to the fabrication of telescopes, magnifying glasses and corrective glasses.

Sedacer's book, the *Sedacine*, from 1378, was an important glass making work. It dealt primarily with making artificial glass gems. It would be used later by the Murino glass makers in Italy.

Glass Alchemists in Italy

Since the 12th century the glass makers of Florence (Firenze) had already distinguished themselves in the production of luxury glass. They had inherited glass making secrets from the Byzantines and the Arabs, with whom they had close relationships. These works of art were primarily intended to be distributed to other sovereigns as gifts whose inestimable value was conserved only for so long as the Medici laboratories managed to retain the secret of their production. De Medici family was well-known for their interest in alchemy and funded alchemical laboratories.

Drinking Cup from 1550-90 in Transparent glass, Museo Poldi Pezzoli, Milan

The entire outer surface of this Muranese cup is decorated by flower and bird motifs, using a technique introduced to Venice in 1549 by Vincenzo d'Angelo del Gallo.

Milanese glassmakers were known to make imitation rubies and emeralds. Making imitation glass gem stones was a typical alchemical practice. Alchemists took a lot of research and experimentation in order to produce them.

Leonardo da Vinci (1452–1519), who worked in both Florence and Milan, was interested in glass and its connection to alchemy. He had recipes for making imitation precious stones from glass, which were of course in demand by the higher classes. Da Vinci himself was interested in alchemy:

> But of all human discourses that must be considered as most foolish which affirms a belief in necromancy, which is the sister of alchemy, the producer of simple and natural things, but is so much the more worthy of blame than alchemy, because it never gives birth to anything whatever except to things like itself, that is to say lies; and this is not the case with alchemy, which works by the simple products of nature, but whose function cannot be exercised by nature herself, because there are in her no organic instruments with which she might be able to do the work which man performs with his hands, by the use of which he has made glass, etc. (Leonardo da Vinci, in his *Quaderni di Anatomia,* chapter Of Necromancy, page 113v.)

Vannoccio Biringuccio (c.1480–c.1539), a metallurgist and alchemist from Sienna, also made a connection between glass and alchemists:

> Thus in this chapter I shall speak to you of glass, not as a proper semi-mineral, nor yet as a metal, but as a fusible material that is almost made mineral by art and by the power and virtue of fire, born from the speculation of good alchemistic savants [buoni ingegni alchimici], through whose efforts it imitates the metals on the one hand and the transparency and splendour of gems on the other. . . . Certainly, in this art surpasses Nature; for although she has produced crystal and all the other kinds of gems that are much more beautiful than this, no way has yet been found for working with these as is done with glass. (*Pirotechnia*, translated by Cyril Stanley Smith, page 126)

The coloring of glass at that time was well practiced. Alchemists of this period considered glass to be a tool to unlocking nature's secrets. When metal oxides were added to clear glass they produced bright colors: blue and red from copper, green from iron, white from tin, violet from manganese, rich blue from cobalt.

Biringuccio identified the glassmakers of Murano (Venice) as an example of these "ingenious alchemists," who were able "to counterfeit emeralds, diamonds, rubies, and all other gems of any color whatsoever." In his *Questione sull'alchimia: Codice inedito*, he again mentioned the importance of glass in alchemy:

> ...and also glass that is so popular and that is so useful and also mirrors which are more beautiful and marvelous, and for those who can understand, it is nothing else than alchemy.

Around 1575, the grand duke Francesco I set up a glassworks in the Casino di San Marco, Florence, where he employed several glassmakers and alchemists. It was an alchemical research center where where artists and artisans could meet with humanists, scholars, and patrons.

The Alchemist's Studio, by Johannes Stradanus, 1570

Painting illustrating the alchemical laboratory of the Casino of San Marco in Florence.

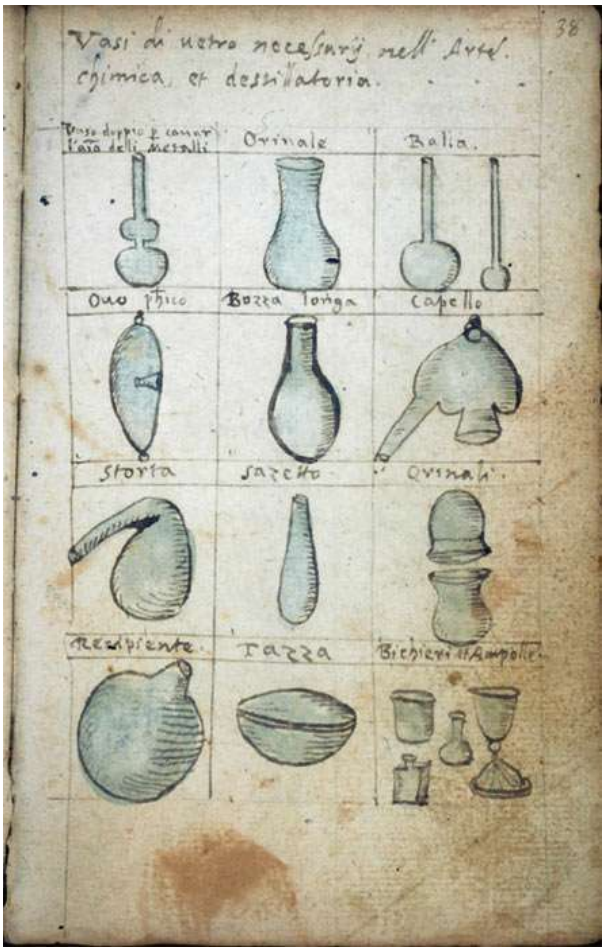
After a short time of inactivity, after the death of the grand duke, it was revived again by Antonio de Medici (1576–1621),who also built a large collection of alchemical manuscripts, among which there were at least twenty-eight recipe books containing secrets on glassmaking.

The first publication of glassmaking was written by a priest in Florence, by the name of Antonio Neri (1576–1614): *L'Arte Vetraria* or The Art of Glass, published in 1612. This book was the first general treatise on the systematics of glassmaking. He became a member of the household of Alamanno Bertolini, where he met the chemist Sir Emmanuel Ximenes, who introduced Neri to the fundamentals of glassmaking. Bertolini was a member of the Medici royal family, what certainly helped in making Neri well-known at his time. It was not exceptional to find artisans recruited by the Medici family for their expertise not only in glassmaking, but also in glazing and the production of porcelain, not to mention alchemy in general.

The publication of *L'Arte Vetraria*, in Florence was driven by the the grand dukes of Tuscany, who were not only interested in the economic value of glassmaking, but also by their interest in alchemy and the extraordinary properties of glass. *L'Arte Vetraria* got widespread recognition, and was translated into Dutch, French, and English. Neri's work was not aimed at ordinary glassmakers. His true audience consisted of highly skilled artisans engaged in the production of rare and expensive glassware for wealthy princes.

Neri, being a successful glassmaker, had a background in alchemy. When Neri was twenty years old, he provided a demonstration of the transmutation of a metal into gold in front of his colleague Agnolo della Casa. Between 1598 and 1600, Neri published *Il Tesoro del Mondo,* The Treasure of the World, which was primarily devoted to alchemical recipes, many of them based on the work of earlier alchemists.

Two illustrations from *Il Tesoro del Mondo (MS Ferguson 67, GB 0247, Glasgow University Library, Special Collections, 1598-1600: left image shows various glassware for alchemical laboratory work; right image shows a typical alchemical scene of the seven planets, with the symbol of Antimony at the top:*



At that time he was not much interested in the art of glassmaking. By contrast, the sixty-one drawings that embellish the manuscript show that Neri had been in Rome to collect information on medical remedies, and at the age of twenty-two was already acquainted with the furnaces, equipment, and tools used by alchemists and artisans. Neri's obsession with the philosopher's stone greatly damaged his reputation in Florence. According to a biography, Neri found a manuscript on the philosopher's stone in the library of the Palazzo Bartolini near the Church of the Santa Trinita, where he was employed, possibly as housemaster, after being ordained a priest. The rumor of Neri's discovery spread rapidly, and he decided to hold a public demonstration of the virtues of his secret recipe, consisting of a green oil and a red powder by which he claimed that he could make gold. To this end he arranged to have an experiment conducted by a goldsmith and in the presence of a few trusted friends. The test was successful, producing a quantity of gold that astonished the witnesses, and Neri's fame as an alchemist soon became the subject of public acclaim throughout the city. The news, however, attracted the attention of "two thugs" who threatened to kill Neri if he did not disclose his secret to them. Fearing for his life, Neri fled Italy and traveled through Spain, Holland, France and Germany until he learned of the death of the two thugs and felt that he could safely accept the many times

repeated invitation of Antonio de Medici to return to Florence.

After the publication of his book *L'Arte Vetraria*, Neri turned his attention once again to his main interests: alchemy and Paracelsian medicine.

In the 1670s and 1680s, Venetian glass became very popular, with its voluptuous, highly colored forms and thin-walled vessels.

Late 17th century Venetian glass ewer, Los Angeles County Museum of Art

German Glass Alchemists

The northern European innovations in the 17th century showed a shift in interest from glassblowing, as in the Venetian style, to the material itself. This led to the creation of vessels with walls thick enough to carve and cut in their decoration. Critical to these advancements were new glass formulas, an improved treatment of raw materials, and innovations in furnace technology. All of these came straight from the laboratories of alchemists. Repeated experiments, coupled with a deep knowledge of material science, allowed the alchemists to both select the right raw materials to produce the new variety of glass and to understand the potential interactions, both desirable and not, of the component elements. Such experimentation could not have happened in a large glassworks factory, where the focus was on production.

Johann Rudolf Glauber (1604–1670) was a German-Dutch alchemist and chemist. He became famous for his discovery of sodium sulfate, or *Glaiber's salt.* He worked first manufacturing mirrors and later as Apothecary to the court in Giessen (Germany). He left Germany for Holland because of the Thirty Years War. In Amsterdam he built up a business manufacturing pharmaceuticals (including chemicals such as Glauber's salt). This led great financial success. As with so many alchemists, he was also an apothecary, supplying medicines. He was known for providing free medical treatment to the poor.

Glauber was the most important promoter of glass experimentation during that century, although it was not his main area of research. In Amsterdam he colored glass, using metals and achieving green with copper, blue with cobalt, yellow with iron, purple with manganese and red using colloidal gold. As we have mentioned before, colored glass was linked to alchemy. It was believed that the metals will reveal their soul or true color towards glass and then the alchemist could extract it to possess the spirit of the metal and affect real alchemical transmutations.

Johann Daniel Crafft (1624–1697), who had worked as Glauber’s assistant for about 10 years. Crafft became a glassmaker himself, and introduced milk glass, produced with bone ash. He also invented a hard crystal glass resembling quartz that could be carved by adding lead or ground flint. After 1673, he worked with Johann Kunckel (1637?–1703) in Dresden, Germany.

Gold Ruby Glass

Kunckel was a competent chemist, and he became a very successful glassmaker. He became an alchemist by studying the prince of Saxony’s library of alchemical writings in Dresden. Kunkel experimented with adding gold to glass, producing a deep red color.

Although this *gold ruby glass* was already known to Glauber, it was only produced in small quantities. Glauber thought it would lead to the philosopher’s stone essential for transmuting base metals into gold and silver, probably because it was believed since the ancient Greek times that a red stone was the key to the

transmutation of metals. Finding a way to produce red glass was intimately connected to the alchemical ideas of the philosopher's stone. The alchemist Lully mentioned it under the name of Carbunculus, which was red in color. Paracelsus says that it was like a ruby, transparent and brittle as glass; Berigard de Pisa that it was of the color of a wild poppy, with the smell of heated sea salt; Van Helmont that it was like saffron, with the lustre of glass.

Friedrich Wilhelm (1620–1688), Elector of Brandenburg and Duke of Prussia, hired Johann Kunckel to produce vibrant, raspberry-red gold-ruby glass at his glassworks in Potsdam. Frederick William instructed that the alchemist, "should not cease, to obtain the honor that the first red glass be made here (at the Potsdam glassworks), no matter how much it may cost." For Frederick William, the prospective renown brought to his court for being the first to produce an innovative material through alchemical/artisanal processes far outweighed its development costs. On view in the elector's collection, radiant gold-ruby goblets would signify to well-educated guests the alchemical knowledge fostered at Frederick William's court.

Gold ruby glass is one of the most difficult colors to achieve in glass because it consists of gold that has been added to the solution of the glass, where it dissolves into small particles, so-called colloids, during the heating and forming processes. Colloids have to have a very specific shape and an equal distribution within the glass in order to produce an even ruby color. The principle of coloring glass with gold was known since early antiquity, but Johannes Kunkel was the first to achieve the difficult process of producing very large gold ruby glass vessels. He published a recipe for producing red ruby glass, but intentionally omitted that small amounts of tin need to be added to to produce e dependable red color. Deep transparent ruby glass requires only miniscule amounts of tin and gold, and the freshly made glass object (which has a gray color at this stage) is cooled then reheated to bring out the deep red color. Secrecy to protect one's own trade is always paramount.

Goblets made from gold-ruby glass were some of the most fashionable collectors' items in the seventeenth century, and examples could be found in nearly every major European collection.

Covered ruby goblet. Kunckel's shop, Brandenburg before 1691. Hamburg, Museum fur Kunstund Gewerbe.

God ruby glass specimen from around 1700, from Staatliche Museen zu Berlin, Kunstgewerbemuseum

Other alchemists tried to produce a red colored glass, such as the Hamburg physician, Andreas Cassius, who in 1676 reported his discovery of the red coloring properties of a solution of gold chloride, subsequently called purple of Cassius. This was a beautiful purple-red color, which was also highly regarded as since ancient times purple was a royal color, and sometimes also associated with the philosopher's stone.

The secret to the beautiful color of red ruby glass was certainly known before Kunkel. We find a citation in the Benvenuto Cellini's *The Treatise on Goldsmithing*, published in 1568 in Florence, page 15, about an alchemist who discovered a red glass that was used as a enamel:

> "But all I need tell of it is that this alchemist, while engaged in the search of how to make gold, had mixed together a certain composition, and when his work was done, there appeared among the stuff in the metal rest of his crucible a sediment of the loveliest red glass, just as we see it to this day. After much time and trouble, & by many mixings of it with other enamels the goldsmith finally discovered the process of making it. This enamel is far the most beautiful of all, and is termed in the goldsmiths' art 'smalto roggio', red enamel, or in French 'rogia chlero' (rouge claire) that is to say, and which means in other words, red and clear or transparent."

We can go even back further and find that deep red glass was made by the ancient Egyptians and Romans. The color was produced by a colloidal gold solution prepared by dissolving gold in Aqua regia. An example of this is the famous Lycurgus cup, a late Roman (4^{th} century) glass cup that is made of cut glass and is displayed in the British Museum in London. This cup looks green in reflected light, but appears red when light is shone through it. This effect is due to the colloidal dispersion of gold and silver nanoparticles.

The Lycurgus cup

Crystal Glass

Glass art reached perfection in crystal glass, but many centuries of searching and trying preceded it. Various causes lie at the sometimes distant origin of its discovery. Many centuries ago, an attempt was made to artificially create diamond and rock crystal, which according to the alchemical maturation theory were in fact the same. In a Book of Gems (Jawahir-nameh, 1195–1196) they are distinguished only by a difference in 'age'. Diamond is ripe (pakka), rock crystal is not (kacha).
The alchemists, attempting to imitate these stones, managed to produce several types of translucent glass. However, these were not completely white, but rather greenish. He therefore continued to search tirelessly for a product to purify it completely, but also for raw materials that could give him the density and hardness of rock crystal.
For a long time his efforts were fruitless, he limited himself to softening the natural crystal, either to rework the translucent paste or to make gemstones with it by coloring. Numerous studies report processes that seem as important and secret as those dealing with transmutation. To soften rock crystal, the alchemist had to immerse it in a liquid consisting of tuna brine, Cyrenacia juice and vinegar for several days. It could also be soaked in a mixture of vinegar, alum and a copper salt. To purify the crystal, he boiled it in a copper bath for seven days, after which it was coated with a paste of lime kneaded in urine. After this treatment, the rock crystal could be colored as emerald, ruby, topaz or sapphire. Well polished it could also resemble diamond.

However, the alchemists never succeeded in making glass clear enough so that it could pass for natural quartz crystal. The glass remained impure throughout the Middle Ages, despite adding manganese black (manganese dioxide) to purify it. Albertus Magnus wrote that manganese black, "which does not tolerate fire, evaporates and takes with it the impurities of the glass, as happens "just like linen in the wash". The use of this product undoubtedly explains why glass was whiter in the 12^{th} century, especially in Germany and northeastern France. Manganese black was commonly used in the 13^{th} century, the golden age of stained glass.

The Greco-Egyptian and Arab alchemists also knew manganese dioxide, which they sometimes called "brown stone". This term, however, has very different meanings to them, including a magnetic iron ore that the glassmakers used to color glass. The manganese-treated glass still retained a bit of color.

Greco-Roman Period, from Egypt in Roman imperial time 3rd-4th Century

It is probable that for the first time glass that came closest to rock crystal was produced in Murano, Italy. It was also called "crystalline glass" (vetco eristalino), to avoid confusion with real crystal. In the 13th century, the Italian process was known in Bohemia, where materials required for manufacture were imported from the Mediterranean region. The German craftsmen succeeded to make a sodium and alum glass that was, however, less malleable than Murano's.

In 1463 the Angelo Barovieri found a very transparent product, which immediately aroused great envy. They undoubtedly succeeded in improving a kind of crystalline glass that had been made in Venice for at least two centuries, without ever reaching a crystal quality. In the 13th century, this glass, which was made with crushed rock crystals and silicon sand, or with a paste of ordinary glass decolorized with a "soap", was made into *cristalleri*, or *cristallo*. It must have looked very different, because the statutes made a distinction between two techniques for imitating rock crystal: the "little art" and the "great art" (arte minuta and arte grossa). A certain quality of glass was probably a very good imitation of glass quartz, because the Venetian government threatened fines for those who dared to sell one for the other. The glassmakers and traders were obliged to indicate whether it was glass or natural crystal. It was thus the Barovieri who gave the crystalline glass all its brilliance, whereby we want to emphasize that the founder of this famous company got several secrets from an

alchemist.

Enameled cristallo stem glass, around 1500

According to Garnier, the crystalline glass of the Barovieri owend its "whiteness, purity and translucency to the use of Egyptian or Syrian soda, together with smelting with crushed Tessini boulders." This soda was obtained by burning an herb, "al-kali", which came from the East via Alexandria. Interestingly, according to Glauber, a 17th century German alchemist, "Alkhest" or Universal Solvent was required in the achievements of the great work. Apparently Alkahest was any sort of solvent. As can be seen, the alchemistry remains close.

Research was also carried out elsewhere to discover the secret of the Barovieri or to improve the quality of their glass. Grand Duke Francesco II de' Medici, for example, tried to imitate rock crystal, whose knowledge of alchemy was already mentioned. At that time, many glass makers from Murano had already left for other horizons to use their secrets to make money elsewhere. Just about all over Europe they set up factories for "crystalline glass after the model of Venice" or "glass in the Venetian style". Neri also recommended the use of "al-kali" soda and Tessini pebbles. Both products had to be fried together to form a glassy mass

which then had to be washed with Piedmontese manganese. The alchemists continued to search to find imitations of crystal. Btittger, who discovered porcelain for the Elector of Saxony, promised to also make "masses of crystal".

Glassmaker-alchemist Haudicquer de Blancourt (1650-1704) still believed that he could transmute crystal into diamond or ruby with the help of an elixir, which had been the dream of the alchemists from the very beginning of their science. The invention of genuine crystal is credited to an English chemist, Ravenscroft. George Ravenscroft (1632–1683) was an English businessman in the import/export and glass making trades. He added lead oxide to the glass paste. After cooking on coals and in a reducing medium, this produced a more brilliant and firmer result than the Venetian crystalline glass. His style of lead crystal glass became fashionable in England and within 20 years of his patent some 100 glass makers in England were producing lead crystal glass. Ravenscroft did not actually invent lead crystal glass, as others had already discovered the advantages of adding lead oxide to glass, but he did improve the process.

Roemer, or drinking glass, by George Ravenscroft, 1677-1677