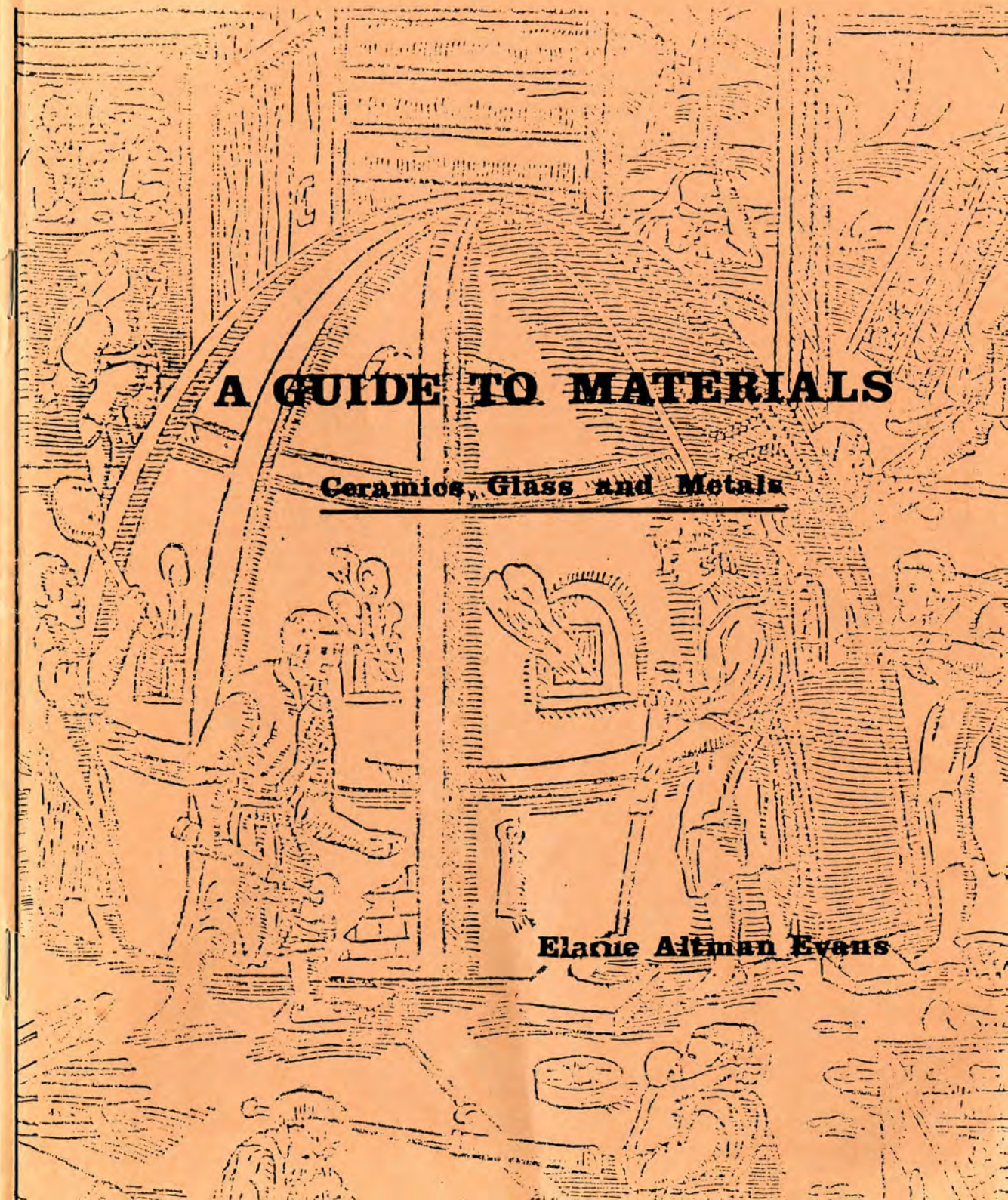
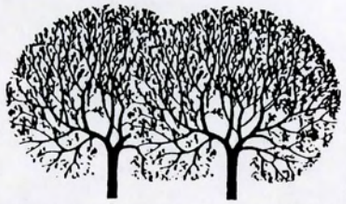


A GUIDE TO MATERIALS

Ceramics, Glass and Metals

Elaine Altman Evans

On Cover: Illustration from George Agricola 'De Re Metalica" (Froben Publishers, 1556).
Glass is being melted in pots in a large kiln. Glass workers are removing glass from the openings and shaping the molten mass with their tools as can be seen in the front and in the right rear where a glass blower is using a blowpipe. A wooden case filled with glass objects is at the right.



Museum-School Partnership
of East Tennessee

A GUIDE TO MATERIALS

Ceramics, Glass and Metals

By

Elaine Altman Evans

Curator of Collections

The Frank H. McClung Museum, College of Liberal Arts
University of Tennessee, Knoxville, Tennessee
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FOREWARD

The purpose of this booklet is to provide students, school group leaders and museum visitors with a brief but informative reference on the subject of ceramics, glass and metals. This information should prove useful towards a better understanding and appreciation of the material components of the objects that are on exhibit in the Museum. Often what appears to be an ordinary object turns out to be of complex construction when the materials and methods of its manufacture are examined. Knowing something about the composition of ceramics, glass and metals will provide a truer sense of their quality and value.

The contents of this booklet have been designed to enable visitors to more fully understand and enjoy the objects on exhibit by gaining an awareness of some of the raw materials, technology and manufacturing processes that were employed in making them. It is hoped that this endeavor will be useful and serve a practical need for the museum visitor.

March 23, 1985 Elaine Altman Evans

Frank H. McClung Museum
University of Tennessee
Knoxville, Tennessee

ACKNOWLEDGEMENTS

In the preparation of this booklet the writer wishes to extend appreciation to the members of the Museum-Partnership of East Tennessee without whose enthusiastic cooperation this booklet would not have been possible. I would like to thank in particular Mrs. Jinx Bohstedt, Education Subcommittee member, who provided many helpful ideas and support, and Dr. Paul W. Parmalee, Director of the Frank H. McClung Museum, for reading the script and offering valuable suggestions.

The booklet is intended to be used in conjunction with the Frank H. McClung Museum's participation in the program "The Community: A Classroom All Around Us," which is part of a Regional Workshop Program sponsored by the Smithsonian Institution, Saturday, March 23, 1985 in Oak Ridge, Tennessee. This program will provide an opportunity for school teachers and administrators "to survey the range and breadth of educational activities available in their community" so that the "bonds between local school systems and community resources which serve as auxiliary educational institutions" will be strenghened.

E.A.E.

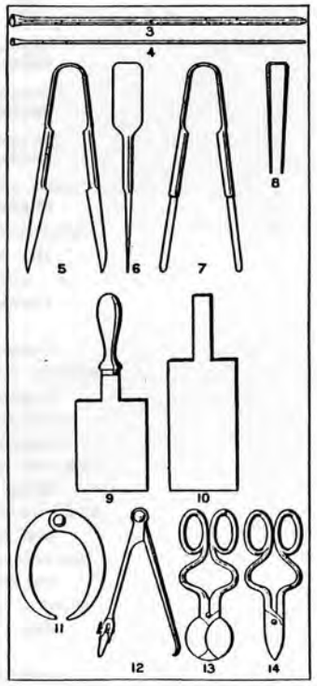
WHAT IS GLASS?

Glass is a hard, brittle, shiny material, usually translucent but not always transparent, and either colorless or colored. It may be noted that although differing combinations of raw materials to make glass have been used since early times, basically glass is a compound made with silica (sand, flint or quartz) and an alkaline substance (sodium or potassium or both) as the essential ingredients. The sodium or potassium is added to the silica as flux to promote fusion when these ingredients are liquified by high heat, a necessary procedure before the glass can be worked into shapes. The sand for glassmaking should have a high silica content (not less than 99.6%) and a very low iron oxide content (less than 0.02%) for good quality crystal glass. Colored glass is created by adjusting the atmosphere in the furnace or by mixing various metallic oxides with the basic ingredients such as copper or iron for green glass, tin oxide for white, animony and lead for yellow, or cobaltic oxide for blue.

In the 17th Century a tougher, sturdier glass compound was developed by the addition of small quantities of lead oxide, chalk or limestone to the basic ingredients. The calcium (chalk) gave more clarity and purity to glass as is found in examples of the vastly popular Bohemian "crystal glass." In 1676 in England, a significant contriubtion to glassmaking occurred. The addition of lead produced a Flint Glass or Lead Glass that had a higher refractive (heat resistant) strength and so brilliantly reflected light when cut.

How Is Glass Produced?

Glass must be in a fluid or malleable state before it can be shaped into an object. To reach a finished condition the basic ingredients of glass are heated at a high temperature causing them to combine into a



GLASSWORKING TOOLS

Top row: for shaping
Middle: for flattening
Bottom: for measuring and cutting

plastic mass. As this mass cools it hardens into glass.

A "batch" of glass mixture is placed in large pots or a furnace and melted, the normal range of melting temperature being about 1300°C.-1500°C. The resultant fluid glass is "refined" or freed of its tiny gas bubbles, a result of normal development during the melting process. Sometimes this is accomplished by blocks of wood soaked in water that are plunged into the fluid glass to create steam bubbles that dispel the minute gas bubbles from the mass. The temperature is slowly lowered, producing a proper consistency in the glass so that it may be worked. However, the cooling off period must be carefully estimated to avoid any crystallizing of the glass.

When Was Glass First Made?

Glass is very old and as yet its true origins are unknown, but Egypt is believed to have been its birthplace. A type of glass from which true glass eventually developed was used as a glaze on predynastic pottery in Egypt as early as 4000 B.C. The oldest pieces of true glass so far found, however, seem to date at circa 2500 B.C. in Egypt and Mesopotamia, and appear as glass beads and tiny amulets. By circa 1570 B.C. glass objects that included vessels, mirrors, plates and artificial gems were being produced on a large scale in Egypt.

Although glass was known in ancient Greece, it was not until the Roman Period that it reached an extraordinarily high degree of excellence. Egypt was the most important source for glass until the Roman era of glass production; the Romans owed much of their knowledge about glassmaking to the Egyptians.

According to some ancient writers including the Greek historian Herodotus (484?-425? B.C.) and the Greek philosopher Theophrastus (c. 372-c. 287 B.C.), the glass industries at Thebes, Sidon, Tyre and that great trade center of Alexandria, Egypt, were the most important sources for glass in the ancient world. By the 1st Century B.C., glass goblets were replacing gold and silver ones and colored glass was being made into a variety of ornate containers that were elaborately decorated by scratching, engraving, layered colored glasses, facet cutting and gold leaf.

What Are Some of the Ways Glass Is Shaped and Decorated?

Core Shaped Glass: In ancient Egypt and Mesopotamia, vessels were formed around a shaped sand or clay core. Molten glass was taken from a crucible and wound around

CORE SHAPED VESSEL
2nd Century B.C.
Syria; 13.5 cm. h.

A typical type made in blue opaque glass with white combed or waved decoration.

a shaped core attached to a metal rod. The malleable glass was then further shaped with various tools, and contrasting colored threads of hot glass were pressed into the hot surface and often pulled up and down to create a waved decoration. To rid the vessel of any rough areas and give it a slicker finish, the surface was "rolled" on a flat, smooth marble slab. After the glass had cooled the core was removed, producing a hollow glass vessel.

Mold Shaped Glass: A later development in ancient glass production involved vessels that were formed by pouring molten glass or packing ground glass into a mold with a positive and negative side. When the mold was heated the glass inside fused and took on the shape of the interior of the mold. After the glass cooled it was removed from the mold and any rough places or mold seams on the glass vessel were ground or polished off.

Free-Blown Shaped Glass: One of the great advances in glassmaking was the emergence of the blowpipe for free-blown glass production. This technique seems to have begun in the second half of the 1st Century in Syria and is still used today.

The knob-shaped end on a long metal tube is dipped into a mass of molten glass. As the glassmaker blows through the blowpipe a hollow bulb is formed at the knob end. This bulb of malleable glass is enlarged or shaped while it is still on the pipe or it is shaped by simple tools for additional form and detail after being cut free of the pipe. While the glass is still plastic, any decorative studs and bosses or separate parts such as a foot on a goblet, colored glass threads, handles or spouts may be added.

Mold-Blown Shaped Glass: Examples of mold-blown glass are known in Syria from the 1st Century B.C.-1st Century A.D. A glass blower blew a bubble of hot glass into a dampened wooden mold with patterns carved in its interior surface. The moistened wood created steam that cooled the molten glass and as the glass cooled the impressed pattern was set in the glass.

Pattern-Pressed Shaped Glass: In this method molten glass is poured into a patterned cast iron mold and a mechancial plunger presses the mass against the interior design. The final pattern edges of the glass are soft and rounded, not sharp as when glass is cut with a wheel. This method was developed as the need for a cheaper type of cut glass became necessary to satisfy the demand. By the late 1820s pressed glass production was flourishing in American glasshouses.

GILDED GOBLET, c. 1910
Italy; 19.7 cm. h.

The gilding on this mold-blown shaped Venetian glass goblet has been painted on the wavy pale green bowl, foot and other areas.

Cut Glass: Cut glass has been known since at least the 8th Century B.C. as evidenced by a cut glass vase that had been carved and hollowed out from a glass block. The vessel has an engraved lion and the name of Sargon II, King of Assyria, carved in cuneiform on its surface. Later, in the 1st Century A.D., facet-cut cups and bowls worked on a wheel-lathe were being produced by the Romans as was "cameo" glass made of two or more layers of colored glass.

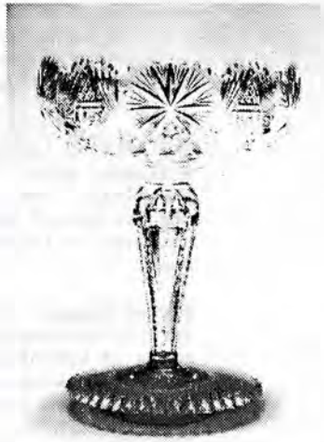
Today cut glass is made in a similar manner. A molded thick undecorated lank glass form is made and a design for the glass cutter to follow is penciled on the surface. The glass is then ornamented by a craftsman who cuts the decorative facets and grooves in the blank glass by hand with a metal wheel on a lathe, using an abrasive of sand and water. later the glass is made smooth by rubbing with powdered pumice and polishing with a very fine powder. The beauty of true cut glass is in the deep sharp cuts around its outer surface that glitter so brilliantly.

Another way in which cut glass is processed is by a fire-finished pressed blank, or part-molded glass. The blank carries the first deep incisions of the design so that the refractory surfaces can be re-established and sharpened or smoothed by heat. This method saves the cost of hand labor and the loss of glass from the usual primary rough cutting. The finished piece lacks, however, the essential brilliance and sharpness of true cut glass.

It is interesting to note that several factors led to a more refractive brilliance in cut glass, particularly in the 19th Century. In the 17th Century, the addition of a considerable quantity of lead to the composition of the glass had produced a clearer and lusterous material for cutting and polishing, thus permitting a superior refraction of light. A deeper cutting of the glass was attained as the composition of glass and its potential became better understood.

A further improvement was better control of the process called "annealing." This process eases fracture-causing stress or brittleness from an excellerated rate of shrinkage in the glass, by heating and then slowly cooling the glass. This allows the thicker glass sections to be deeper more dramatically cut. By the 19th Century improved industrial facilities, higher speed wheels and better abrasives created a peak in high quality cut glass production, both here and abroad.

Engraved Glass: There is little difference between cut glass and engraved glass. Essentially, deep facets are cut in cut glass, while in engraved glass the



CUT GLASS DISH, c.1890-1910
United States; 26 cm. h.

The clear glass compote is cut in hob-stars, star bursts and a bull's eye motif. A graduated diamond pattern decorates the foot.

ETCHED GLASS, 20th Century
United States; 16 cm. h.

A wine glass with tapered and flared cup decorated in acid etched flowers and leaves.

cutting is shallow and has delicate pictorial and ornamental motifs.

The cutting is done with a minute copper wheel or with a diamond point. The wheel engraves a depression in the glass. The diamond point scratches or stipples the surface of the glass, producing a gossamer quality compared to the deeper cross lights produced by the wheel.

Etched Glass: It was probably not before the 17th Century in Germany that designs were etched on glass by means of hydrofluoric acid. In this method the glass is covered with a resinous paint or wax as a protective seal and a fine steel point is used to cut a design through this coating. Acid is applied to the exposed surface to eat away the glass, producing an etched decoration.

Enamelled Glass: Enamel used to decorate glass is a compound of glass that has been colored by various oxides. Generally it consists of 50% sand or flint, 35% lead and 15% sodium or potassium.

The enamel is applied to the surface of the glass piece to be decorated. As fluid enamels can only withstand a small amount of heat, they are applied to finished glass or fused to it at low temperatures.

The technique of enamelling on glass was perfected by the Saracens of Arabia in the 13th Century A.D. Evidence of enamelling on glass, however, has been found in much earlier periods in the ancient world.

Cased Glass: Probably the most famous example of cased glass, also called "cameo" glass, is the Portland Vase in the British Museum in London. Carved with mythological scenes in white relief against a dark-blue background, the vase is believed to have been made in the Roman Period of the 1st Century A.D. The white glass, fused to the blue glass beneath, was carved away to expose the color below.

In recent times ornamental cased glass has been composed of as many as five different layers of colored glass that have been cut through, creating a marbled effect. Examples of this method can be seen on a variety of glass pieces, including cased glass toilet bottles and decanters so popular in the 19th Century.

Stained Glass: A stained glass window can be defined as a mosaic of shaped translucent colored glass pieces held together by narrow strips of lead. The leadings

ENAMELED BOTTLE, c. 1900
Near East; 20 cm. h.

The clear glass bottle is decorated in hand painted enamel and gold luster swirls.

serve as a binding as well as an important part of the design. The first stained glass windows with pictorial ornamentation have been dated to the 10th Century A.D. in France. However, it was not until the 12th Century that large stained glass windows were made that were to reach such high levels of development in the ensuing centuries.

A number of techniques have been used in the production of stained glass. One early method of coloring the glass was to dye the glass throughout by melting the basic ingredients in a crucible and adding metallic oxides for color. After the colored glass had been cut into the desired shapes from a pattern or "cartoon," they were juxtaposed and held together by lead, plaster or cement.

Another method to color the glass employed the use of colored enamel paints which were used to either entirely coat the finished glass or highlight details such as garment folds, facial areas and symbols. Opaque brown was an early color used to tone down the light and for outlining figural and ornamental details on the glass. In the 14th Century, a golden yellow glass was achieved by applying a silver compound to it.

Modelling was achieved by removing some of the paint with a brush, highlights by painting a thin coating of enamel on the glass and scratching line details in the paint with a pointed tool, and shadings by stippling areas with a brush. After the glass pieces had been painted the enamel paint was fused to the glass in a kiln, after which the pieces were cooled. The leading was prepared and fitted over the edges of the finished glass and soldered. This patchwork of glass was now ready to be fitted into the window opening and fastened to the window frame by lead and iron "saddle bars." Although the painted methods did not provide quite the jewel-like brilliance of color and light associated with the early glasses, it allowed for more dimensional details.

Other methods used to make stained glass included fusing two or more thin sheets of different colored glass together to produce different colors and colored layers. Another technique, known as "flashed" glass, involved dipping clear glass into a molten mass of colored glass; this left a thin coating on the glass and thereby provided more translucency.

FLASHED GLASS VASE, c. 1910?
Czechoslovakia; 29.9 cm. h.

Scrolls, trees, deers, clear bullets and rectangular motifs and other designs are etched through the thin red glass coating to the colorless glass beneath.

WHAT IS A CERAMIC?

The word "ceramic" is the term used to categorize all forms of fired clay. All ceramic objects are formed from moist clay heated to a hard state. A number of steps are involved in producing ceramics, including the preparation, shaping, drying, glazing and often decoration of the clay before or after it is fired. There are three main ceramic types; each has its own unique characteristics and variations in the quality of pastes and decorations. These are earthenware, stoneware and porcelain.

WHAT IS EARTHENWARE?

Earthenware is a soft, heavy, opaque, granular and porous ceramic made of clays that contain no fusable ingredients such as are found in stoneware and porcelain. In general, earthenware refers to all low-fired pottery.

How Is Earthenware Made?

To produce earthenware the clay is mixed, shaped either by hand, potter's wheel or mold and dried and fired in an oven at low temperatures no less than about 350°C. to 400°C.; this process frees the "combined water" from the clay. During the heating, clay particles adhere at some points and not at others so that the clay does not completely fuse or vitrify, leaving the pottery porous. For the earthenware to be completely non-porous or waterproof it must be sealed.

In some cultural groups the clay is prepared and shaped, perhaps as a container, and sun-dried to rid it of its "free water." If, at this point, the clay vessel is left uncoated and filled with liquid it would readily absorb the liquid and fall apart. To prevent this from occurring, the pot is treated with resin, oil, plant juice or a combination of substances to seal it and make it moisture repellent. In general, however, a glaze, a coating of liquid glass, is applied to the object as a seal and then it is fired again at about 1050°C. to fuse the glaze to the pot.

What Are Some of the Types of Earthenware?

There are numerous varieties of earthenware; the most well known are maiolica, faience, delftware and slipware.

EARTHENWARE BOTTLE
c. A.D. 1000-1500
Tennessee; c. 19 cm. h.

This unglazed pottery bottle was made by a southeastern Indian during the Mississippian Period. The vessel represents an owl.

Maiolica

Maiolica is a soft, porous earthenware that is fired and then coated with an opaque tin-glaze (lead glaze with tin ashes added) either by imersion or by squirting.

By one method, the piece is refired and the resultant milky opaque white surface, resembling hard white enamel and so well suited for painted decorations, is decorated with metallic oxide dyes or enamels and fired again to set the colors. In many examples the entire surface is hand painted with patterns and scenes in combinations of the early maiolica colors of yellow and orange (from iron oxides), green and blue (from copper oxides) and manganese purple (from manganese oxides), sometimes called aubergine.

The term maiolica was first used by the Italians around the 15th century to describe a tin-enameled Hispano-Moresque earthenware that came by trading vessels from Valencia, Spain; the Italians who mistakenly believed the intricately patterned pottery came from the island of Maiolica (now called Majorca) retained the word as the name for their own pottery. Evidence seems to indicate that the art of maiolica originated in the Near East,spread to Spain and Italy and then to other sections of northern Europe. The ware is sometimes anglicized as "majolica," a word also used for all tin-glazed wares produced in the Italian manner by other countries.

Colorfully decorated vases, large platters, jugs and tiles are some of the principal objects produced by the early maiolica-artists who delighted in elaborately painted ornamentation, special symbols and detailed mythological and religious figure groupings and portraits as their subjects. Some of the highest artistic achievements in European maiolica were produced in such Italian centers as Gubbio, Faenza and Deruta. Each factory had its master painters with their own particular style of decorating the wares. By the mid 16th century, maiolica had taken a firm hold on the market and was being made in some 50 Italian centers, some of them continuing production well into the 19th and 20th centuries.

Delftware

Essentially, delftware is the maiolica of the Netherlands. This Dutch faience, known to have been produced there by refugee maiolica-potters in the early part of the 16th century, is named for the city of

MAIOLICA PLATTER, c. 1915
Italy; 32 cm. dia.

Earthenwwre with under-the-glaze hand painted decoration.

Delft, near Rotterdam. Imitations of delfware in England started in the early 18th century, no doubt due to its wide spread popularity.

Delftware is usually found in blue and white and in the polychrome colors in imitation of the fine Chinese porcelains of the late Ming and K'ang Hsi periods of 1644 to 1722. To approximate the thinness of Chinese procelain, delftware was generally made with a more refined clay or paste than that of maiolica. Other popular motifs employed in the ornamentation of delftware were borrowed from Japanese Imari ware, Italian Renaissance art forms and indiginous Dutch works of art.

Faience

Faience is a French term probably derived from the name of the Italian town Faenze. As has already been mentioned, Faenze was a center in the 16th century for maiolica production, whose potters strongly influenced early French ceramic artisans such as those of Lyon, France. The term faience is also used in Germany, Scandinavia, Spain and other countries. Faience, like maiolica and delftware, is covered with a tin-enamel glaze.

It may be noted that in ancient times faience was sometimes not what the term implies, although it may be called faience. The so-called faience of ancient Egypt is not a true faience, as it was made from powdered quartz coated with a vitreous alkaline glaze, or made of a single self-glazing mixture; therefore it cannot be considered a glazed pottery at all.

In France, around the mid 17th century, Rouen was the leading center of the thriving faience industry. However, the importation of English wares soon struck a fatal blow to this once flourishing center toward the end of the century. In northern Europe, Spain and Portugal, influxes of refugee Italian potters were responsible for the establishment of successful and long lived faience factories in those areas. Befor porcelain arrived on the scene in Europe, the priviledged classes used faience and silver for tableware while the less fortunate used common earthenware or pewter dishes.

Faience Fine

Mention should be made about the distinction between French faience and faience fine, the latter being a French type of English creamware. Faience fine is a lead-glazed, cream colored earthenware that was

first made in Staffordshire, England. This ware became so popular in 18th century France it nearly toppled the production of French faience and porcelain. In order to halt their commercial rival and stay in business, French manufacturers copied the English creamware and methods of decoration.

The thin, hard-bodied pottery with a soft cream color is known by different names, depending on the country where it is made. Developed in the 18th century by the English potter Josiah Wedgwood, the ware was known as "Queen's Ware," named after Queen Charlotte while Wedgwood was under her patronage. Later, Wedgewood introduced a much whiter ware called Pearlware. Wedgwood had stopped tin-glazed faience production in England and Europe in its tracks with the development of this light, durable, white glazed pottery.

Slipware

In general, slipware is a word for slip (liquid clay) decorated pottery. This semi-liquid of creamy consistency is made from white or colored clays diluted with water. Slip is poured over the entire surface of the usually buff or reddish pottery to conceal the body, or it is applied as contrasting colored trailings, dots, combed lines, waves or detailed brush-worked ornamentation.

Slip-decorated earthenware requires only one firing to set both the body and the slip, whereas other ceramic wares need a separate firing or additonal firings to set over-glaze enamel colors or gilding.

In 17th and 18th century England a variety of techniques with slip were used to decorate earthenware, including, for example, coating or painting coarse red pottery with white slip or using the Italian "sgraffito" method of scratching patterns into the slip to the body beneath. Slip was also used for joining separate sections of the pottery together such as handles, spouts or finials.

STONEWARE TANKARD, c. 1915
Germany; 30.4 cm. h.

Typical of the type of stoneware from Westerwald, Germany with cobalt blue painted on the impressed, incised relief designs on the grey body and handle.

WHAT IS STONEWARE?

Stoneware is the term given to all types of pottery made from a mixture of clay and a natural fusible quartz or flint that is fired at high temperatures. Midway between earthenware and porcelain, stoneware is a hard, opaque and occasionally semi-transparent ceramic that is non-absorbent and almost non-porous.

How Is Stoneware Made?

After the clay is properly prepared, it is fired at a temperature of around 1200°C. to 1400°C. so that the non-clay elements are fused enough to produce a waterproof body that essentially does not need a glaze. In any event, a lead or salt glaze is generally applied to enhance the object or for utilitarian reasons.

How Is Stoneware Glazed?

The most common glaze used on stoneware is a salt-glaze. This thin, glassy glaze is formed on the ceramic body surface by the sodium in the salt. In a one-firing process, the glaze is produced by throwing rough salt in the kiln fire while it is at the highest point of temperature. The chlorine in the salt escapes from the kiln chimney and the sodium combines with the silicates in the body of the pottery to form a thin glass-like glaze on the surface of the ware. If a thicker glaze is desired an amount of red lead is added with the salt in a one-firing process, unlike lead-glazed stoneware where a second firing is required.

Salt-glaze ware is often ornamented with cobalt blue under the glaze that is applied to molded relief or incised motifs for decorative emphasis. When a brown colored stoneware is desired, a liquid clay containing a lot of iron oxide is washed on the surface of the object before firing. If a black color is necessary, then iron rust is used, or when a blue color is desired, cobalt is used.

When Was Stoneware First Made?

Stoneware was probably produced in China before the 7th century and no doubt was the ancestor of porcelain due to its hardness and density. The porcelain-like stoneware only lacked the true whiteness and translucency of porcelain. Around the 12th century, it is believed a stoneware was developed in Germany, in or near Cologne, Bavaria, as well as in northern Europe and Flanders. However, it was not until the 16th century that stoneware was of much artistic value; particularly fine pieces were produced in Siegburg and Westerwald, Germany. In the 17th and 18th centuries, some of the best examples were produced in England at Brampton, Nottingham, Belper and other areas. Popular utilitarian stoneware vessels included acid containers, vinegar jugs, drain pipes and fine tableware decorated in low relief and piercing.

Some of the handsomest examples of the high fired ware were developed by Josiah Wedgwood, famous for his unglazed, tan colored stoneware called Caneware, variously colored stoneware called Jasperware, and black basalts.

WHAT IS PORCELAIN?

True porcelain, a word perhaps derived from the French pierre de pourcelaine or the Spanish term porcella, is usually a fine white grade of ceramic that is translucent and has a transparent glaze. When the porcelain is unglazed it is called biscuit or Parian porcelain.

The ingredients for true or hard-paste procelain are a refractory white clay called "kaolin" (from the Chinese word for "high ridge") and feldspathic rock called "petuntse" (from the Chinese term pai-tun-tzŭ or "white stone"). Basically, kaolin is a nonfusible silicate of aluminum while petuntse is a fusible silicate of aluminum and silicate of potassium.

How Is True Porcelain Made?

Kaolin does not melt and feldspar melts only at high temperatures causing it to become glassy. When the kaolin and the powdered felspathic rock are fired at high temperatures around 1450°C. they produce porcelain, the powdered rock acting as a kind of cement; that is, when being fired the plastic clay holds the piece in shape while the feldspathic rock fuses into a type of natural glass. As the molten feldspar cools it keeps the kaolin suspended and this is what gives true porcelain its delicate and translucent texture as well as its hardness. Basically, there are two types of European porcelain: a) soft-paste porcelain; b) hard-paste or true porcelain.

What Is Soft-Paste Porcelain?

Soft-paste porcelain, often called "artifical porcelain," was made in Europe well before the advent of true porcelain. The ingredients that were used to make it greatly varied in attempts to imitate true porcelain. Many types of powdered glass were fused, ground up and added to clay or other ingredients, to make as close a resemblance to true porcelain as was possible.

Usually, soft-paste is fired at about 1200°C. and a glaze added before the second firing at a lower temperature. Lead was generally added to the glaze mixture so that the glaze would better fuse to the porce-

PORCELAIN SET, 19th Century China; 5.1 cm. h.

An octogonal shape cup and scalloped edged saucer hand painted in over-the-glaze enamels in the Rose Medallion pattern.

lain. Unfortunately, such glazes were easily scratched. Since soft-paste lacked the special refractory quality of true porcelain and was easily broken, the production of soft-paste ware was gradually abandoned almost entirely in England and France by the 19th century.

How Does Soft-Paste Differ From Hard-Paste Porcelain?

The principal differences between the two types of porcelain is found in the firing temperatures, sometimes called soft and hard firing, and in the consistency of the wares. When true porcelain breaks the fracture is smoothly textured with edges like egg shell. Soft-paste, on the other hand, breaks with a rough edged fracture and has a granular texture. Also, soft-paste can be stained by the acids from fruits and dyes and cut by a knife or file along an unglazed section. In contrast, hard-paste is impervious to such substances and cannot be cut even with a steel blade, it is so hard. True porcelain is often tested for a special resonant sound it emits when struck, attesting to its thinness and thereby its translucency.

Where Was Porcelain Discovered?

The art of making fine true porcelain has had a long tradition and for centuries was a well kept secret of China, the country believed to have been the first to know how to make the hard-paste ware. The Chinese may have made a type of porcelain earlier, but the creation of porcelain "thin as paper, white as jade,bright as a mirror with a ring like a bell" was made during the T'ang Dynasty, A.D. 618-906.

The Japanese no doubt learned about porcelain from the Chinese by the early 16th century. Deposits of the necessary clays were located near Arita,Hizen Province, in Japan. Porcelain made at the Arita kilns were shipped to Europe from the nearby port of Imari, thereby creating the name "Imari Ware." Kakiemon porcelain was also made in the same area. These fine and very popular porcelains were copied by Meissen decorators in Germany, and in England and elsewhere.

In Europe in 1708, true porcelain was developed by Johann Friedrich Böttger who used kaolin from deposits located near Dresden, Germany. Böttger started the well known factory at the nearby town of Meissen, so famous for its fine porcelain that has been erroneously called "Dresden china." The new ware took some years, however, to become established and it was not until the middle of the 18th century that any large scale production took place in Europe by procelain manufacturers.

PORCELAIN STATUETTE, 20th Century
China; 40.7 cm. h.

A Blanc de Chine figurine of the goddess of Mercy Kuan Yin. The hands and plants were separately applied to the piece.

At Sèvres, France from about 1753 to 1772, some of the most exquisite soft-paste porcelain was produced; it was said to have greatly enhanced the reputation of the ceramics made there. Germany and France produced procelains of the finest quality in the world, renown for delicate shapes, figure groupings, beautifully painted flowers, landscapes and other subjects, and distinct and exceptional taste in decoration.

By the mid 18th century in England porcelain factories were at Bow, Chelsea, Worcester and Bristol as well as in other areas of Britain. A type of porcelain known as "bone china" was being produced, made by the addition of bone ash as an ingredient to the clay. This resulted in a harder porcelain than soft-paste, yet not as hard as hard-paste or true porcelain.

Around the mid 19th century in Ireland, the production of a thin, translucent,hard-paste porcelain had begun. The ware, called "Belleek" after the town in which it was made, is about the thickness of eggshell and has a special lustrous iridescent type of glaze due to the use of the metallic element bismuth.

How Are Some Porcelain Objects Made Today?

If a statuette is to be made, for example, it is first sculpted or formed with a type of prepared plastic material such as clay. The completed clay model is divided into separate component parts and a mold is made for each of the separate sections. A slip (liquid clay mixture) is poured into each mold. A thin shell of unfired clay in each mold is removed for further drying; before the pieces are thoroughly dried they are assembled into one piece with a slurry (thickened slip), the connecting seam lines are removed and all detailing is completed on the piece.

After the assembled object has dried for two to eight weeks under a controlled environment, it is fired at a temperature that gradually reaches about 1315°C. for some 12 hours, after which it is allowed to slowly cool to room temperature for an additional 12 hours. The fired piece is then hand painted and refired, often in several stages at temperatures from 871°C. to 982°C. as some colors require more heat than others to fuse.

WHAT ARE METALS?

Metals have different properties from stone or wood; they are chemically different from non-metals because they form positive ions, basic oxides and hydroxides. Metals belong to the class of chemical or electro-positive elements such as gold, silver, iron, aluminum, copper, etc. Usually whitish, lusterous, relatively dense, cohesive, malleable and ductile, metals also have a high tensile strength, particularly in the transition metals, and are excellent conductors of heat and electricity. When molten metals are mixed together in differing proportions and are slowly cooled they form homogeneous close-packed crystals.

A metal alloy is formed when one metal is combined with other metals. In general, metals form salts when they are combined with non-metals and basic oxides if they are combined with oxygen. Metals are also used in ceramic and glass production.

In the process of metallurgy, metals are separated from their ores by smelting and refining in order to prepare them for use. In the metallurgical process, metals are extracted from the ores and rid of impurities. As almost two thirds of known elements are metallic, only a few of the major metals will be discussed here.

WHAT IS COPPER?

Copper is a yellowish-red metal that is soft, very malleable and ductile with a high tensile strength; it is one of the most important nonferrous metals. Although copper cannot be corroded by dry air due to its chemical inertness, nevertheless in moist air a greenish film of basic carbonate is formed on it that contains carbonic acid.

Why Is Copper Alloyed?

One of copper's most valuable assets is its ability to combine with other metals to form a great variety of different alloys. The oldest and most useful of these are the many brasses and bronzes. Not only are such alloys excellent candidates for cating, but they are easily soldered or brazed. Copper alloys have a wide range of color including decorative reds, subtle pinks and shades of yellow and white. When copper is alloyed with nickel, in certain proportions, the alloy is used to produced coins. If copper is combined with zinc then a brass alloy is produced.

COPPER AX, c. A.D.1000-1500
Tennessee; 38 cm. l.

A cold hammered copper ax blade made by a southeastern Indian and probably carried as a symbol of honor in ceremonial functions.

How Is Copper Used?

Pure copper makes a poor metal for casting, mainly due to its difficulty in reaching a sufficiently flowing state. Therefore, detailed or intricately shaped objects are seldom cast in copper.

However, as pure copper is very malleable it can be easily worked into sheets. In one process, the copper is rolled out from cast copper blocks with annealing (heating and slowly cooling) to adjust the temper and prevent brittleness. Although a surface grain results it can be modified in size by the temperature and time of heating and cooling, making the copper sheet easier to polish. The flat copper sheets can be shaped into objects when they are hammered over shaped wooden forms. Edges can be secured by brazing or joined by folding them together and then flattening them by tapping with a hammer. Early copper kitchen and housewares such as kettles, saucepans, pots, containers for measuring food stuff, coal-scuttles and ale jugs have been made from hammered copper.

When Was Copper First Worked?

Copper was probably the first metal to be used by humans. As early as the Neolithic Period, it seems that copper was evolving as a useful metal, followed soon by bronze and iron. Metallurgy was known in the Near East around 3000 B.C. At that time copper oxides were being reduced to metallic copper. In order for this to have occurred, knowledge of high temperature furnaces and methods for the reduction of copper must have been known. In addition, copper ore in its natural state was plentiful.

In ancient Egypt many copper tools have been uncovered. There is evidence that the copper contained arsenic or small amounts of beryllium or glycine which combined with the copper oxide. When the metal was hammered, hard copper was produced that was sturdy enough to be used for tools.

WHAT IS TIN?

Pure tin is a soft, silver-white metallic chemical element that is weak and brittle, heavier but softer than zinc and with a hardness between lead and gold. Tin melts at a low temperature, is highly fluid when molten, and has a high boiling point; it is corrosion resistant to many substances. There are two types or forms of tin: a) soft white tin; b) brittle gray tin.

The most important tin bearing mineral is cassiterite or tinstone (natural tin oxide). Normally, very high grade cassiterite concentrates contain 70% to 75% tin with very small amounts of metal impurities as compared to cassiterite from low grade deposits which have large amounts of impurities in the ore.

How Is Tin Processed?

The melting point of tin is 232°C., it is malleable and ductile at 190°C. and it is powdered at 200°C. In the processing, the ore is crushed to a powder and heated to remove any sulphur and arsenic; it is then smelted further with carbon which acts to separate out the zinc, copper, bismuth and iron that may be present. During the refining process, salt is sometimes added. The salt forms volatile or soluable chlorides that assist in removing, for example, lead and silver from the tin ore.

What Are Some of the Advantages of Tin?

Under ordinary circumstances tin does not greatly oxidize when exposed to air nor is it affected greatly by water. Upon exposure to air, a thin coating of stannic oxide forms that acts as a protective film. Some acids such as sulphric acid and nitric acid attack tin; however, diluted ammonium hydroxide and sodium carbonate do not. Also, most oils, alcohols or chlorinated hydrocarbons have very little or no effect on tin. Other advantages of tin, in addition to its use in making bronze, is its non-toxic nature, corrosion resistance and its strength when combined with other metals.

What Is Tinplate?

Tin can be extremely useful in protecting surfaces that tend to oxidize or corrode. Tinplate is made from thin sheets of steel or iron which are coated with tin. Although tin cans made of tinplate may first come to mind, kitchen utensils such as cups, knives, pots and hardware items are also often tin-plated but with a thicker tin-coat produced by electroplating.

When Was Tin First Used?

As in the case of previously mentioned metals, tin was known in antiquity but the exact date of its discovery has not yet been firmly established. From present evidence the origins of tin seem to have been in western Asia or possibly northeast Persia or in Syria. The earliest occurrence of tin in ancient Egypt seems to be from a ring and a bottle found in Egyptian graves of the Eighteenth Dynasty, c.1580-1314 B.C.

TIN CANDLE MOLD, c. 1890
Tennessee; 27.5 cm. h.

The two rows of four cylinders are soldered at the cylinder tops and along the seams. The shallow pan base has a folded edge.

The metal may have been discovered by accident while tin ore was being heated with charcoal or wood by the ancients. Tracing its origins, as those of other metals, has been complicated due to the similarity in color between tin and lead, often confused by ancient writers. Although the Greek poet Homer (c.1000 B.C.?) may have been the first to mention tin, by the first century A.D. expressions for the metal are clear and the metal was identified for certain by the Roman naturalist and writer Pliny (A.D. 23-79). Nevertheless, little is known about how tin was extracted from the ore at that time; it probably involved a reduction process of heating the ore over a wood fired furnace until the metallic tin was smelted out.

WHAT IS BRASS?

Basically, brass is an alloy of copper and zinc, but sometimes other metals such as tin are added. By adding zinc to copper, a harder and stronger metal is produced but one that is still malleable, ductile and resists corrosion.

How Is Brass Alloyed?

The melting point of brass depends on the ratio between the copper and zinc. If the mixture is 5% zinc and 95% copper, the melting point is about 1065°C., but when the ratio is 50% zinc and 50% copper it drops to about 880°C.

When zinc in the ratio of 10% to 40% is added to 60% to 90% copper, brass is produced. The resultant metal varies in hardness and color depending on the ratio of the two elements. Brasses that contain 75% to 85% copper are red-gold in color and malleable with a high tensile strength; those containing less than 50% copper are silver-white in color, brittle, are less malleable and have a low tensile strength. Certain ratios of the two elements often make brass look like bronze, particularly if the zinc content is about 10%.

After the brass has been processed by smelting and refining, it is ready to be shaped. Brass is formed into sheets or wires or it can be machined, beaten hammered or wrought.

When Was Brass Discovered?

Pure zinc, as a separate metal, was unknown in very ancient times, but it is fairly certain that during the Roman Empire zinc ore in the form of calamine was combined with copper to make brass. The exact

origins of brass are still clouded in obscurity and are debated by scholars. There is some difficulty in unscrambling terms used by ancient Greek and Roman writers.

Through the centuries brass has been a popular metal for many of the crafts made by less affluent societies; it is low in cost and can be easily worked, therefore it is more likely to be used for lesser works of art and utilitarian items. Bronze has been preferred for the more important works due to its excellent casting qualities.

WHAT IS BRONZE?

Bronze is usually considered an alloy of copper and tin, but varying amounts of lead, zinc, silver, phosphrous and other metals may be added in making special bronzes. Tin bronze, for example, contains from 2% to 20% tin and is used mainly as a statuary bronze. When compared to the brasses, tin bronze is harder, strong and more corrosive resistant.

Although bronze may be defined as an alloy of copper and tin, the term bronze may also apply to many copper alloys that have crystalline or bronze-like structures, have a bronze color, or because they also contain amounts of tin. Generally, when bronze is cast varying amounts of lead are added to increase the fusibility and therefore facilitate casting. General purpose bronze is Normally a combination of 90% copper and 10% tin.

How Is Bronze Colored?

As is the case with other alloys, the range of bronze colors varies depending on the ratio and type of metals that are combined. If the bronze is a light golden yellow more zinc has been added, or if a substantial amount of lead is added then a grey-blue color results.

Bronze becomes a dark brown if it has been kept dry and has had a minimum exposure to atmospheric pollutants. However, the surface of bronze can turn a light green if the metal has not been protected by a coating. A blue, green or black discoloration can form on bronze when the metal contacts certain acids such as carbonic acid, nitric acid and sulphuric acid that are found in the air or in soils. Ancient bronze objects exhibit such discoloration, as well as corrosion, either from their having been buried in the earth or sea or standing in the open air for centuries. Many bronze works of art are exposed to the weather.

BRONZE BUST, 1936,
United States; 56 cm. h.

A cast bronze portrait bust of the Knoxvillian Louis B. Audigier by the sculptor Lampert Bemelmans.

As a protective measure a false patina may be formed on them followed by a spray of wax in a solvent, as a coating.

How Is Bronze Worked?

Bronze is particularly suited to casting in its ability to seep into every space after the molten metal has been poured into a mold of the object to be made, and the fact that it shrinks after it has cooled allowing easy removal from the mold. Furthermore, bronze has a relatively low melting point which is between 786°C. and 900°C. Bronze can also be shaped when cold if it contains less than 5% tin. Ancient bronze contained 10% tin and was mainly used for tools, but when the bronze contained more than 15% tin, its hardness and brittleness made it ideal for casting purposes.

A casting method to form solid objects from bronze called the cire perdue or lost wax method was used extensively by the ancient Greeks and Romans and was revived in the Renaissance Period. Briefly, this process involves shaping a beeswax model of the object to be molded and then coating the model with a clay mixture that forms the actual mold. Holes are provided in the clay mold so that when it is heated the wax melts and runs out of the holes. The dry and hard mold is now ready to receive the molten bronze, which is poured into the now hollow mold. After the bronze has cooled the mold is broken away from the metal object. Any rough edges or mold seams are chiseled and smoothed off in the finishing and polishing process.

Hollow casting is accomplished in much the same way, mainly for reasons of economy, however. Less bronze and less wax are necessary as the finished product is hollow. In this method, a shaped core of quartz sand, mixed with amounts of another material to give it malleability for shaping, is coated with beeswax and then covered with a clay mixture, just as in solid casting. However, in this method the molten metal that is poured into the mold falls between the inner quartz core and the outer shell. After the mold cools the outer mold is removed.

Where Was Bronze First Used?

Bronze tools and implements are known from the Bronze Age, a prehistoric period that preceded the Iron Age. The discovery of bronze was no doubt by accident, a chance mixing of "oxide ores" of copper and tin.

Bronze has been found at the Sumerian city of Ur in Mesopotamia, dating around 3500 to 3200 B.C.; in China a multitude of bronze weapons, mirrors, vessels and

household items were produced there more than 3500 years ago. For centuries China has been well known for its bronze work, so well perfected during the Shang Dynasty around 1500 B.C. In ancient Egypt, the Middle Kingdom is believed to be the period of the first bronze making in Egypt. During the New Kingdom many bronze objects were made. Bronze is so well suited for casting sculptural pieces and for repousé and other relief work that it has never lost its appeal as the most preferred metal.

WHAT IS SILVER?

Silver is a chemical element with the symbol Ag, from the Latin argentum, a lustrous white metal, softer than copper but harder than gold. As a conductor of heat and electricity silver is superior to all metals. After gold, it is the most malleable and ductile of metals. As silver cannot survive constant use due to its softenss, it is generally combined with another metal to make it harder. The melting point of silver is 960°C. and its boiling point is 2000°C.

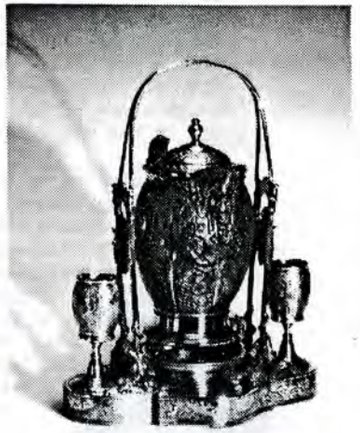
What Are Some of the Uses of Silver?

Silver has long been used to decorate wearing apparel in such forms as buttons, metallic thread, jewellery and walking canes and as table silver, trays, candelabra and many other ornamental objects. Silver is also used to decorate ceramics and glasswares. Silver does not oxidize when heated, therefore it can be used to apply electrically conductive coatings to ceramics or glass. A paste that contains a combination of silver and certain additives can be applied to a ceramic, either entirely or in a decorative pattern. After the paste is heated, the silver becomes bonded to the ceramic or glass. Silver is also used in the processing of photographs in the form of silver chloride, silver bromide and silver iodide. Silver nitrate is used for making mirrors.

What Is Silver Plate?

Silver plate was known by the Aztecs and Incas in the New World and by the ancient Egyptians, Greeks and Romans in the Old World. The ancient Egyptians knew how to plate silver as early as Dynasty II of the Old Kingdom; this is evidenced by a ewer made of copper sheet coated with silver and hammered to shape.

Although this technique was known by people of several ancient civilizations, it seems that the art



SILVER PLATE SET, c.1875
United States; 51.5 cm. h.

The water cooler on a swivel stand is flanked by goblets and decorated with plants, animals and figures in high relief.

of silver plate disappeared until the 18th Century, when, in an effort to reduce costs, a method of bonding silver to copper was devised. In 1742 in Sheffield, England, objects were again made from silver plate by fusing a thin layer of silver to a thin layer of copper.

This composite material called "copper-rolled plate system" or Sheffield plate was nontheless overshadowed by the introduction of "electroplating" which caused the demise of the earlier plating method. Essentially, a coating of silver was electroplated to a base metal such as nickel, brass or copper. Nickel, a particularly ideal base metal for silver plate, is an alloy of nickel, copper and zinc and is referred to as German silver or nickel-silver. It is interesting to note that German silver contains no silver. However, the sterling silver used in some table silver and jewelry is about 92.5% silver and 7.5% copper.

What Causes Silver To Tarnish?

Silver is tarnsshed by various sulfides that pollute the air. The black tarnish that forms on silver is called silver sulphide. Although silver is not usually affected by air or water at ordinary temperatures, at 200°C. a thin film of silver oxide forms on the surface of the metal. Silver is highly resistant to either liquid or fused alkalis and organic acids that are often found in foods and skin; silver resists corrosion.

When Was Silver Discovered?

Silver was known during the prehistoric periods; it can be dated to 2500 B.C. in China and is was also known in ancient Egypt, Greece and Rome.

In ancient Egypt, silver objects have been found dating from the Predynastic Period . Beads, amulets and other tiny items made during the Old Kingdom have been uncovered in Egypt. Nevertheless, silver was a scarce commodity there until the Eighteenth Dynasty; in later periods it was extensively used for beads, jewellery, bowls and vases as well as for silver foil and thin silver leaf to decoratively cover parts of furniture.

WHAT IS GOLD?

Gold, the most precious and well known of the costly metals, is deep yellow in color, soft, extremely malleable and ductile. The chemical symbol for gold is Au, from the Latin word aurum which means "glowing

dawn." Gold remains unchanged by heat, moisture and most corrosive substances. It is an excellent conductor of heat and electricity, does not tarnish or burn in air and is impervious to most pure acids.

Gold is a relatively rare metal. Small quantities of it can be found in veins in rocks, various telluride minerals in the earth and in ores such as quartz or pyrite, or it may occur in alluvial gold in the form of nuggets. Most gold ores contain very small amounts of the metal; for example, much of metallic gold contains from 1% to 50% silver. Gold has always been a favorite metal for the backing of currency and for this reason it has had a long and fascinating history.

When Was Gold Discovered?

For thousands of years gold has been prized for its beautiful color, lustre and the ease with which it can be worked, and throughout history it has been cherished for its lasting quality. Certainly, from earliest times gold has been used for personal adornment in nugget form.

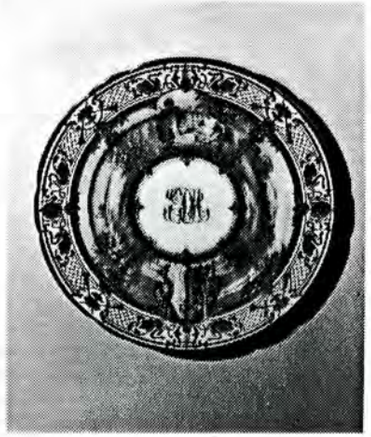
The ancient Egyptians as well as other ancient civilizations were familiar with the metal. In Egypt it was used in the manufacture of vases, cups, plaques, jewelry, either solid or gold overlay form. The Egyptians were skilled at the craft of working gold as is evidenced by the outstanding gold funerary mask and sarcophagus found in the tomb of the Eighteenth Dynasty pharaoh King Tutankhamen in the Valley of the Kings.

How Is Gold Colored?

For gold to be hardened it must be alloyed with other metals. Copper, silver or nickel or small amounts of zinc is added to gold to better prepare it for use. Various combinations and proportions of these metals create the color of gold, making it reddish, yellow, pink, greenish or white.

How Is Gold Measured?

The purity or "fineness" of gold is measured in carats: 24 carat is pure gold; 18 carat is 75% gold and 14 carat is 58.3% gold. The higher the unit of fineness the softer the metal; almost pure gold can be hammered into gossimer thin sheets of about 0.000005 inches in thickness. This gold leaf or foil is used on such diverse things as picture frames, architectural decorations, paintings, furniture and illuminated manuscripts. Gold leaf can also be welded to nickel or brass to make "gold-filled" or "rolled-gold plate" to imitate fine gold for jewlery, statuary and personal accessories.



PORCELAIN PLATE, c. 1913
Germany; 26.4 cm. dia.

A monogrammed plate ornamented with hand painted scenes from Parsifal by Richard Wagner, in under-the-glaze enamels and gilding fired on the ware.

Gold compounds called "liquid bright gold" can be applied to ceramics and glass, then dried and heated to a metal hardness.

WHAT IS IRON?

Iron is a silver-grey, lustrous, easily polished, strongly magnetic, malleable and ductile metallic element. It easily oxidizes in moist situations, but remains stable if little moisture is present. Although iron compounds are very abundant in nature and found in many minerals, metallic iron is scarce and generally occurs only in small amounts.

Pure iron is difficult to obtain; therefore, it must be obtained from iron oxides through the use of heat and reducing agents derived from coal, wood or other carbon or organic substances. This extraction process involves the conversion of natural iron-bearing minerals into metallic iron, usually by the blast furnace method.

How Is Iron Alloyed?

There are two categories of iron-carbon alloys that may be mentioned here: a) pure iron or wrought iron and b) cast iron. Wrought iron contains no more than 0.035% carbon and sometimes very small amounts of other substances; it remains unchanged due to the low carbon content. Cast iron, however, contains from 2% to 4% carbon and various amounts of other substances such as silicon, manganese, phosphorous and sulfur, in addition to alloying elements in varying proportions that range from trace amounts up to more than 30%.

How Is Iron Used?

Iron can be hammered and shaped while at a red or white heat. However, iron is not particularly good for casting because of its high shrinkage tendency and therefore it loses much in clarity of detail. Nevertheless, hardware, very fine ornamental gates, fences, furniture and architectural decoration have been sucessfully cast.

When Was Iron Discovered?

Meteoric iron was known in prehistoric times, perhaps as early as 4000 B.C. However, it is believed that the actual process of extracting iron from ores was not practiced until around 3000 B.C., probably in the Near East.

IRON LAMP, 19th Century
Tennessee; 20.5 cm. l.

The heavily encrusted oil lamp has a perforated curved handle and pinched nose.

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