Project: Making Raku

Student Learning Objectives

At the end of the activity students will be able to:

- make a clay pot using the pinch pot method
- describe the change in the pot after vitrification
- coat the pot with a raku-type glaze
- perform the raku technique upon the pot to observe the reduction and/or oxidation resulting from this technique.

Materials

- Clay, low-fire type
- Glaze, low-fire type
- Copper carbonate or other glaze metals as interest and budgets allow (see attachment)
- Paper cup or other container for glaze, 6 oz.
- Sawdust
- Nail for scratching initials
- Paint brush for applying glaze

Equipment

- Oven or kiln
- 5-gal metal bucket with lid
- Large pail for water
- Nylon string or wire
- Heat-resistant leather gloves
- Goggles
- Long-handled, 80 cm, tongs

Procedure

1. Cut a softball-sized piece of clay from the brick, and work it into a ball shape.
2. Work the clay into a cup (pot) shape as demonstrated by the instructor. Try to make it a uniform thickness (see Figure 6.8.).
3. Set the pot aside to dry over night (or longer).

Figure 6.8. Pinch Pot (Raku)

4. Turn the dry pot over, and scratch your initials into the bottom.
5. Turn the pot in to the instructor to be bisque fired, or bisque fire the pot at cone 4.
6. Observe and record the differences in the pot after it has been bisque fired.
7. Fill a 6-oz. paper cup 1/2 full of raku glaze. This is equal to about 100 g of dry glaze. To the glaze, add between 1 and 5 g of either of the two metal carbonates. Mix thoroughly. If the glaze becomes too thick, a little water may be added to maintain original consistency. It should be about as thick as heavy cream or cake batter.
8. Coat your pot with the glaze using a brush. Do not coat the bottom 0.5 cm of the pot. Use several thin coats. The glaze should be between 2 and 3 mm thick. Allow the glaze to dry completely.
9. Place the glazed pot into the kiln. Turn on the kiln, and allow it to heat until the pot is glowing cherry red and the outer surface is bright and shiny. The time will depend on the number of pots in the kiln. It will take about 3 hours. Once the pot is ready, you must have the pails with the sawdust and water close by and ready to use.
10. Put on the heat-protective leather gloves. Have a partner quickly open the kiln. Using the long-handled tongs, quickly grasp your pot, and immediately drop it into the pail of sawdust. You may push the pot into the sawdust if you wish. Place the lid on the pail, and leave it on for about 3 min. As soon as your pot has been removed, your partner should close the kiln.
11. After 3 min take the lid off of the pail. Watch out for a flare up! Using the long-handled tongs, remove your pot, and drop it immediately into the pail of water. Once the pot has stopped steaming, carefully remove it using a pair of tongs. Be careful, the water may be quite warm. Take the pot to a sink and clean it up. Be careful. Gentle scrubbing will remove black carbon deposits. On the cobalt pots the cobalt appears as a dark metallic coating. Don't scrub it off.
12. Observe and record the differences in the pot in your journal after the raku process.

Extension Activities

1. Compare raku pots to conventionally fired pots with the same glaze.
2. Discuss the terms “oxidized” and “reduced.”
3. Measure pots for firing shrinkage, i.e., measure the diameter of the pot before firing and after firing. Record the results in your laboratory notebook. Theorize what is occurring. Discuss these results in your class or with your teachers.

Using the Raku Glazing Process to Show Oxidation-Reduction in Chemistry

(Whitaker, G. 1983. Prepared as a master's thesis, Western Washington University, Bellingham, Washington)

Introduction

The art of raku was conceived and developed in Japan during the last quarter of the sixteenth century, specifically for the production of ceramic wares for use by the Zen Buddhists in the Tea Ceremony. The name "raku" meaning "pleasure or enjoyment," was given to the descendants of the famous sculpture-potters. Raku applies solely to the art and products of the raku family masters but it has also come to mean a ceramic technique that has been traditionally used by them. Raku is committed to the basic premise that the pot is the product of a process of mutual interaction and refinement between man and nature and that through this involvement man discovers his own significance. Raku places great reliance on maintaining a close and intimate relationship between the pot and its maker at all stages of production, and particularly so during the moments of truth when the pot is subjected to severe and sudden changes (Cooper).

The Making of Raku Ware

Raku wares are made by carving and refining forms down from larger leather-hard ones, which have been raised by a pinching technique. The Raku forms made by the joining techniques must have particular attention paid to welding the parts into a totally unified structure. Otherwise the wares will later split apart under the stresses of thermal shock. After drying the wares should be bisque fired, (bisque firing is the initial firing to vitrify (harden) the form) to a temperature of 850° to 900° Centigrade. It is important that raku bodies never approach their maturation temperature during firing. After the forms are removed from the kiln (see Figure 6.9), they are placed in a safe place to cool.

Oxidation and Reduction

Simply, oxidation is the addition of oxygen. Thus, when iron and steel are allowed to become wet and are exposed to the air, the subsequent process of rusting, in which the metallic iron acquires oxygen from the air, is known as oxidation. An example of this process is:

$$4\,Fe + 3\,0_2 \longrightarrow 2\,Fe_20_3$$

The metallic iron becomes an oxide and is said to have been oxidized. In ceramic firing, processes of oxidation are commonplace. Most ceramics and most metal enamels are fired in an oxidizing atmosphere with a copious air supply, so that all materials actively seeking oxygen can acquire it during the process (Shaw).

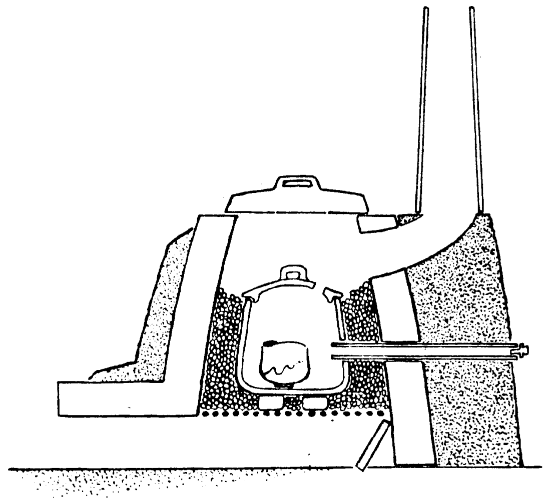

Figure 6.9. Small circular raku kiln burning coke or smokeless fuel. The saggar is the heart of the kiln and the main wall follows its profile. The walls may be made of common brick for a temporary kiln or of firebrick for a more permanent structure. The belly of the kiln is transversed by a number of fire-bars that both support the saggar and contain the fuel. The rectangular air intake tunnel may be used to direct fire from a flame gun to the center of the kiln if fast firing is desired. The kiln may be lit either with wood and the coke gradually added from above or by means of the flame gun. The chimney is a commercial chimney pot, and the whole kiln has an insulation of banked earth. The development of the glazes within the saggar may be observed at intervals through the viewing tube that may be made of metal or clay. The kiln will reach glazing temperature in 2 to 3 hours.

Reduction

There is an old Chinese legend that tells of a potter who lived many centuries ago. One day he was firing his kiln and was having a lot of trouble. It was one of those days when everything goes wrong. The fire wouldn't burn properly, the chimney wouldn't draw, the place was full of smoke, and the air was filled with a horrible odor. The potter was afraid that most of the ware, which he had glazed with a lovely green copper glaze, would be ruined.

When he opened the kiln he found his fears were justified, for piece after piece came out blistered, blackened, and dull. But in the very center of the kiln, there was one vase that was a beautiful blood red. Such a color had never been seen before on any piece of pottery. The potter's neighbors and co-workers marvelled at it. It was so beautiful that it was sent to the emperor as a gift. The emperor in turn admired the color so much that he had the vase broken and the fragments set in rings as though they were precious stones. Then he sent the potter an order for a dozen more red vases.

The potter's troubles began. He tried again and again but he could not reproduce that red color. He checked his glaze formulas carefully and used exactly the same ingredients that he used that day, but all the pots came out green. The emperor grew impatient. Messengers arrived from the palace, saying *produce or else!* Finally our potter was in despair. He decided to fire one last kiln and loaded it with vases covered with glazes as before. But during the height of the fire, his courage failed him. He opened the door of his kiln and jumped in.

His assistant ran up quickly. The kiln fire was smokey and there was a bad smell in the air. They shut down the flames and allowed the kiln to cool, and when they opened it, what did they find? No trace of our poor potter, but yes, you've guessed it—the kiln was full of beautiful red pots.

And there, according to the legend, was discovered the secret of reduction. The potter's assistants reasoned that if a human body produced such results, maybe a dead pig would work and they tossed a pig into the next fire. Again they got beautiful red pieces. Then they tried substituting such things as wood and straw, and still the trick worked.

Reduction results when the fire is overloaded with carbon. When this happens, the green oxide of copper loses some of its oxygen and becomes a red oxide.

$$2\ C + 4\ CuO \longrightarrow 2\ Cu_2O + 2\ CO_2$$

Likewise, a red oxide of iron loses some of its oxygen and becomes a black oxide. This reduction process is shown by the chemical equation:

$$Fe_2O_3 + CO \longrightarrow 2\ FeO + CO_2$$

Iron oxide exists in several different combinations, and each proportion of iron to oxygen has a characteristic color as follows:

Fe_2O_3	Ferric iron	red
Fe_3O_4	Ferrous-ferric	yellow
FeO	Ferrous iron	black
Fe	Metallic iron	no color

Red oxide of copper produces the *sang-de-boeuf* or ox blood color, while the black oxide of iron produces the gray-green color known as celadon (see Table 6.2).

Reduction is obtained in the down draft type of kiln by closing the damper and adjusting the burners so that the flame does not get enough air and burns yellow (see Figure 6.9). This sends free carbon into the kiln. There is loss of heat during this process, so in high fire work the potter has to alternate periods of oxidation and reduction. With the muffle type of kiln, it is not so easy to produce controlled reduction, for the flames do not touch the ware, and, if the muffle is tight, even though the flame releases free carbon it will not get a chance to act on the pieces. Reduction can be produced, however, by putting some organic material such as sawdust, straw, or dry leaves, which will ignite instantaneously inside the muffle. In the case of low fire luster glazes, organic material is actually mixed with the glaze itself (Kenney).

An American version of the classic Japanese raku technique also involves a reduction process. A specially prepared glazed pot is fired to a deep red color, then while still glowing red hot, it is quickly plunged into a container filled with organic matter such as straw, sawdust, or oil. The pot will acquire a smoked appearance, and I a copper glaze will give a red color due to the now present copper or a luster glaze due to metallic copper forming.

Table 6.2. Coloring Action of Oxides In Glazes*

Oxide	Percent	Color in Lead Glaze	Color in Alkaline Glaze	Color When Reduced
Chromium oxide	2%	Vermilion at cone 012 Brown at cone 06 Green at cone 06		
Cobalt carbonate	0.5%	Medium blue	Medium blue	Medium blue
	1%	Strong blue	Strong blue	Strong blue
Copper carbonite	0.5%			Copper red
	1%	Green	Turquoise	Deep red
	2-3	Deep green	Turquoise	Red and black
	8%	Green with metallic areas	Blue-green with metallic areas	
Ilmenite	3%	Tan specks	Gray-black specks	Spotty brown
Iron chromate	2%	Gray-brown	Gray	
Iron oxide	1%			Celadon
	2%	Pale amber	Pale tan	Olive green celadon
	4%	Red-brown	Brown	Mottled green
	10%	Dark red	Black-brown	Saturated iron red
Manganese carbonate	4%	Purple-brown	Purple-violet	Brown
Nickel oxide	2%	Gray-brown	Gray	Gray-blue
Rutile	5%	Tan	Gray-brown	
Vanadium stain	6%	Yellow	Yellow	
Cobalt carbonate Iron oxide	0.5% 2%	Gray-blue	Gray-blue	
Cobalt carbonate Manganese carbonate	0.5% 4%	Blue-purple	Aubergine	
Cobalt carbonate Rutile	0. 5% 3%	Gray-blue	Gray-blue	Textured blue
Copper carbonate Rutile	3% 3%	Textured green blue-green	Textured	
Ilmenite Rutile	27% 2%	Textured brown	Textured gray-brown	Spotty brown
Iron oxide Cobalt carbonate Manganese carbonate	8% 1% 3%			Black
Cobalt carbonate Iron oxide Manganese carbonate	3% 2% 2%	Mirror black		
Manganese carbonate Iron oxide	6% 3%	Luster brown		

*Source: Nelson, G.C. 1957. *Ceramics Reference Manual*, Burgess Publishing Co.

Raku Glazes

Raku glazes are usually better applied thickly, and the relationship to glazed and unglazed areas carefully considered as the blackened reduced body can be very attractive. The pots are put into the kiln when it is estimated to have reached a sufficiently high temperature that can be judged by color—a rich red orange—or measured by a pyrometer. During the firing, the glazes will begin to bubble as they melt and when they have settled evenly and have a shiny reflective surface, the glazes have matured. Depending on the efficiency of the kiln, this will take about 20-40 min. When the pots are taken from the kiln, they will oxidize as they are brought into the air, and, if reduction is required, it should take place now. Burying the pot inside a metal dustbin full of sawdust or other material and then covering the bin with a reasonably well fitted lid will ensure a well-reduced glaze. Dark gray acrid smoke will be given off indicating a good reducing atmosphere. If copper is present in a glaze or in painted decoration, a rich lustrous surface will result from this heavy reduction. The body will be turned black by carbon.

After about 15 to 20 min, remove the pot and quench it immediately by placing it quickly into water to prevent reoxidation in the atmosphere. If the glaze is still molten when placed into water it will froth to give an unpleasant surface.

(A frit is a glaze that has been fired in a crucible and once cooled has been ground into a powder form for use. This process is used to seal in toxic glazes such as lead because of the high toxicity of this substance.) Alkali frit, lead frit, and borate frit, can be combined with about 10% whiting and 10% ball clay to give glazes that will work well. Additions of 5-10% tin oxide will give a rich white glaze that will usually crackle to give a large network of black lines. This contrasts well with the black matte body. Additions of coloring oxides will give the following results:

Copper	2-3%	turquoise
Cobalt	0.5%	blue
Manganese	1-2%	purple-brown
Iron	2-6%	creams-ambers

(Also see Table 6.3 for other coloring metals.)

After the pots have cooled, the glaze surface needs to be cleaned to remove soot and dirt with a stiff brush, wire wool, or an abrasive cleaning powder. Care should be taken not to remove the reduce metal if you have strived to get that appearance.

Now we come to an area where almost anything goes and daring experimentation is half of the fun! Because of the low temperature of raku firing, potters can use such things as lead all alone to make a glaze, but because of the hazards of raw lead, it seems wiser to use colemanite, (a natural mineral containing both calcium and borate) and various frits as fluxes (a substance that promotes melting).

Borax mixed into a paste with water and brushed thickly on a piece will form a glaze; so will Boraxo.

Interesting lusters often develop during reduction in glazes containing copper. Metallic lusters can be achieved by adding 1-3% silver nitrate or 2-5% tin chloride (see Table 6.3).

Table 6.3. Suggested Additions of Coloring Oxides to Reduction Glazes*

Cobalt carbonate	1/2%	medium blue
Cobalt carbonate	1/2%	light blue
Cobalt carbonate Chrome oxide	1/2% 1%	turquoise
Cobalt carbonate Rutile	1/2% 3%	warm textured blue
Cobalt carbonate Nickel oxide	1/2% 1%	grey-blue
Nickel oxide	1%	grey or grey-brown
Manganese carbonate	4%	brown
Manganese carbonate Rutile	4% 2%	Textured brown
Ilmenite	3%	spotty brown
Ilmenite Rutile	2% 2%	textured yellow-brown
Iron	1%	celedon
Iron	2%	dark olive celedon
Iron	4%	mottled green or brown
Iron	10%	saturated iron red
Copper	1/2%	copper red
Copper	1%	deep copper red
Copper	3%	red to black
Cobalt Iron Manganese	1% 8% 3%	black

*Source: Nelson, G.C. 1957. *Ceramics Reference Manual*, Burgess Publishing Co.

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