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


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:

$$4 \text{Fe} + 3 \text{O}_2 \rightarrow 2 \text{Fe}_2\text{O}_3$$

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).
Ceramics Making Raku

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 firebars 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 smoky 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.

\[ 2 \text{C} + 4 \text{CuO} \rightarrow 2 \text{Cu}_2\text{O} + 2 \text{CO} \]

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:

\[ \text{Fe}_2\text{O}_3 + \text{CO} \rightarrow 2 \text{FeO} + \text{CO}_2 \]

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

<table>
<thead>
<tr>
<th>Oxide</th>
<th>Color</th>
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<tbody>
<tr>
<td>( \text{Fe}_2\text{O}_3 )</td>
<td>Ferric iron red</td>
</tr>
<tr>
<td>( \text{Fe}_3\text{O}_4 )</td>
<td>Ferrous-ferric yellow</td>
</tr>
<tr>
<td>( \text{FeO} )</td>
<td>Ferrous iron black</td>
</tr>
<tr>
<td>( \text{Fe} )</td>
<td>Metallic iron no color</td>
</tr>
</tbody>
</table>

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 a copper glaze will give a red color due to the now present copper or a luster glaze due to metallic copper forming.