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Creating Color: Unearthing the Chemistry of Ceramic Glazes

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Introduction

There is something magical about taking lumps of cold clay and turning them into a functional form. The transformation process is what first peaked my interest in ceramics. I turned to this visual art form my junior year of college after being completely overwhelmed by my chemistry major. Not only did Ceramics 1 teach me basic hand building and surface design techniques, but it allowed me to literally pound out my stress. I've gained a strong adoration for ceramics because it relieves my stress and gives me the opportunity to express myself.

After taking Ceramics 1, enrolling in Ceramics 2 was a no-brainer. The second course was all about learning how to throw on a wheel. Using the pottery wheel permitted me to make more refined and symmetrical forms. Ceramics 2 was even more enjoyable for me, because I was able to make functional kitchen ware forms like bowls, mugs, and casserole dishes. However, the part of ceramics that interested me the most was the different glazes. In the second semester, we began to mix glazes and see how they interacted with each other. I was amazed at how you can layer one glaze over another and get a completely different color. For example, Ancient Jasper (PC-53), a reddish-black glaze, over Chun Plum (PC-55), a pinky-purple glaze, combines to form a highly versatile glaze. This combination results in a glaze with lots of blues, yellows,

Top Left: Ancient Jasper; Bottom Left: Chun Plum; Right: Ancient Jasper layered over Chun Plum (AMACO)

reds, and browns. The way the colors run together is different for each piece depending on the form's texture and thickness of glaze application.

After spending a year in Ceramics 1 and 2, I knew that I had to take the third section of the class. Ceramics 3 gave me the time and practice I needed to refine my throwing skills. I got to learn new surface design techniques and focus on my craftsmanship. During this third semester of ceramics, I really began to create pieces that I was truly proud of. It might have taken me one hundred tries, but I finally made a mug that I consider to be perfect. In Ceramics 3, I had the opportunity to work with different clay bodies from stoneware to porcelain. It was intriguing to see how the clay body color affected the color of the glazes. Also, in this course, I had the opportunity to perform many glaze tests on the pieces I created. I got to use different Amaco Potter's Choice glazes and combine them to see how they would react. I tried sixteen different glaze combinations, resulting in some beautiful colors. After doing this research with manufactured glazes, I wanted to try mixing my own glaze and altering the chemical components of it.

I turned to ceramics to get a break from chemistry. But little did I know, they are very intertwined. Seeing how glazes transform during firing made me wonder what causes the different color and texture variations. Ceramics led me to see that the elements, which I've spent the past four years learning about in chemistry classes, have fun and practical applications.

Glaze Testing Basics

Glaze testing can be performed in a variety of ways, but the most common is through the use of line blends. A lot of potters like to create new glazes to get a larger variety of colors in their work. Sometimes the combinations of oxides do not look anything like what was hypothesized. Line blends allow potters to test different glazes on a smaller scale without having to chance a prized creation. Instead, experimentation is done with test tiles, small slabs of clay. This allows potters to try out different color combinations without excessive waste and without being emotionally attached to a piece, in case the combination is not a good result.

The image on the left shows the front of the tile with slip-trailed dots and stamping. The right image shows the back of the tile with my initials carved in.

My test tiles were made by throwing a bottomless cylinder and then slicing it into sections. I carved, stamped, and slip-trailed different designs on my tiles, as shown in the image above. Having the different variations in surfaces allowed me to see how the glaze reacts to different textures. Once the tiles have been bisque fired, a line blend can be performed. The purpose of a line blend is to take a base glaze and add varying amounts of colorants to small samples. Usually, the experiment is performed by altering the amounts of two chemical compounds and analyzing the effects. To perform a line blend, you will need around 10 plastic cups with approximately 100g of the base glaze in each. Make sure that each cup is labeled with the amount and type of colorant to be added. Also, label the corresponding test tile to which the glaze will be applied with red iron oxide. Carefully weigh each colorant and add it to the correct cup. Cover the cup with plastic wrap and let the colorant hydrate for at least one hour. Then, stir each cup thoroughly, making sure all clumps are dissolved. Sieve each glaze to break up any remaining

Test tile with number of dips labeled.

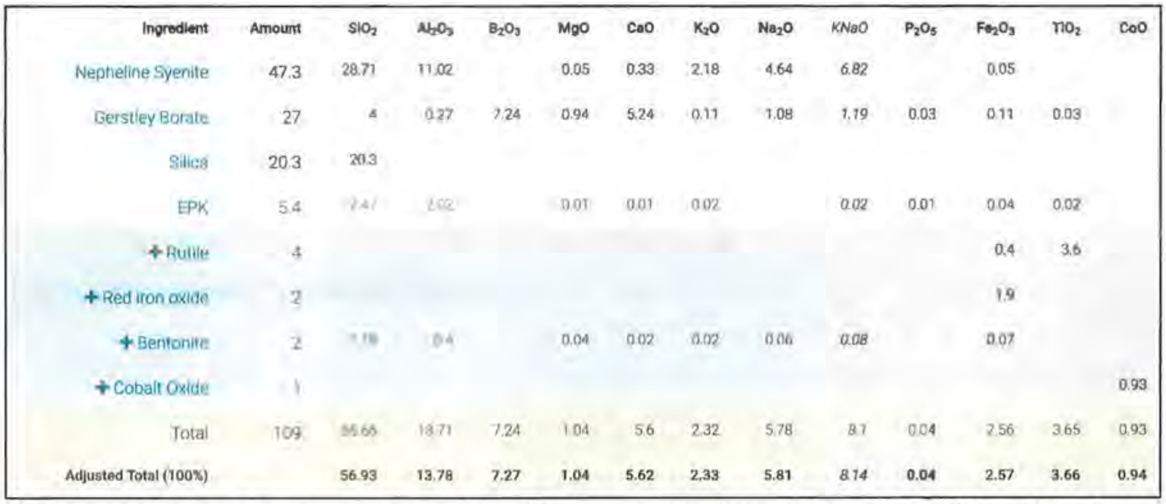
chunks and remove large particles. After all the glazes are sieved, the test tiles are ready to be dipped. It is important to stir each cup before each dip to prevent settling of the heavier compounds. The first dip should be an even coat covering the entire tile except for a ½ inch gap at the base. It's imperative to leave a gap so that if the glaze runs, it will not stick to the shelf of the kiln. The second dip should cover half of the first dip. A third dip can be performed if desired. Having all your tiles dipped at the same level allows for a more accurate comparison between tiles when they are lined up. It is important to note the difference that thickness of application can have on glaze color. The color changes as layers are added; normally they become brighter. However, if the glaze is applied too thick, blistering can occur. For my research, all tiles were fired to Cone 5, approximately 2,167°F, in an electric oxidation kiln. In oxidation firings, the kiln has an adequate supply of oxygen typically resulting in bright, rich colors (Peterson, 2014). In contrast, reduction firings have a limited supply of oxygen and the atmosphere becomes filled with free carbons. These free carbons are highly reactive and can break bonds in the glaze materials to bond with oxygen. When the carbon reduces the oxygen in the glaze materials, the color and the texture of the glaze can change (Peterson, 2014). Oxidation and reduction firings can have very different results as seen in the image to the right.

The same glaze in reduction (left) and oxidation (right) at cone 10. (Hansen, a)

It is also important to note the use of personal protective equipment while working with dry, powdered chemicals. Most of the compounds that I worked with were toxic if inhaled or ingested. To prevent exposure to these harmful materials, I wore a respirator and particulate filter 2091 P100. Gloves were also worn when working with oxides. In addition to the protective measures I took, the ceramics room at Ouachita also has an air filter to remove dust particles from the air.

Floating Blue

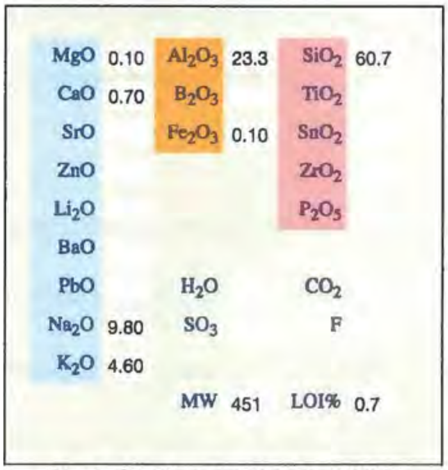
Floating Blue is a popular Cone 6 oxidation glaze because of its large amount of variegation. This glaze has a deep blue background speckled with hints of brown and lighter blues that "float" on the surface (Roeder, 1996). Describing the glaze, Cappell said, "the colors seem to float on a surface of a darker background of great depth, reminiscent of a deep pool of water (Hansen, b)." The glaze color and opacity can vary greatly with the thickness, so it highlights irregularities or designs in the surface. The lighter blue tends to appear in areas where application is the thickest. The brown hues are more visible on areas of thinner application or where the glaze "breaks" on edges and irregularities. Also, small black speckles can be present, resulting from unground particles of iron. The table above shows the traditional glaze recipe for Floating Blue and the chemical breakdown of each component (Rorison, 2015). Previous research performed at Ouachita Baptist University determined the best percentage, 4%, of rutile to yield a vivid blue with lots of variegation.



Ingredient	Amount	SiO_2	Al_2O_3	B_2O_3	MgO	CaO	K_2O	Na_2O	*KNaO*	P_2O_5	Fe_2O_3	TiO_2	CoO
Nepheline Syenite	47.3	28.71	11.02		0.05	0.33	2.18	4.64	*6.82*		0.05		
Gerstley Borate	27	4	0.27	7.24	0.94	5.24	0.11	1.08	*1.19*	0.03	0.11	0.03	
Silica	20.3	20.3											
EPK	5.4	2.47	2.02		0.01	0.01	0.02		*0.02*	0.01	0.04	0.02	
+ Rutile	4										0.4	3.6	
+ Red iron oxide	2										1.9		
+ Bentonite	2	1.18	0.4		0.04	0.02	0.02	0.06	*0.08*		0.07		
+ Cobalt Oxide	1												0.93
Total	109	56.66	13.71	7.24	1.04	5.6	2.32	5.78	*8.1*	0.04	2.56	3.65	0.93
Adjusted Total (100%)		**56.93**	**13.78**	**7.27**	**1.04**	**5.62**	**2.33**	**5.81**	***8.14***	**0.04**	**2.57**	**3.66**	**0.94**

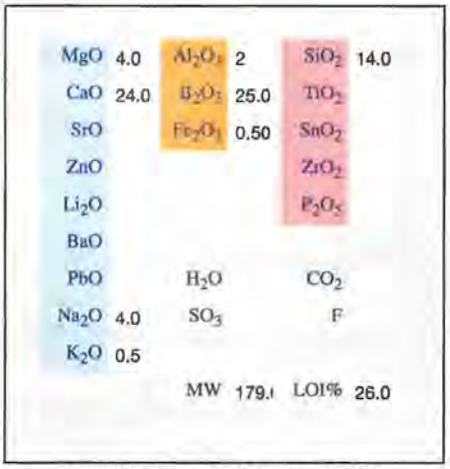
From left to right: 2% rutile, 2% rutile mixed with 4% rutile, 4% rutile, 4% rutile with thicker application

The largest percentage of Floating Blue comes from Nepheline Syenite, a type of soda feldspar with a molecular weight of 451 g/mol. Soda feldspar is derived from albite mineral and contains sodium, aluminum, silica, potassium, and calcium. The specific composition of Nepheline Syenite is shown to the right. The high sodium content makes it a great flux, and the high aluminum content strengthens the glass ("Nepheline Syenite"). Nepheline Syenite can also increase the firing range of low-fire and mid-range glazes. However, the high K_2O and Na_2O content can lead to crazing, because these oxides contribute to a higher thermal expansion ("Nepheline Syenite").



MgO	0.10	Al_2O_3	23.3	SiO_2	60.7
CaO	0.70	B_2O_3		TiO_2	
SrO		Fe_2O_3	0.10	SnO_2	
ZnO				ZrO_2	
Li_2O				P_2O_5	
BaO					
PbO		H_2O		CO_2	
Na_2O	9.80	SO_3		F	
K_2O	4.60				
		MW	451	LOI%	0.7

Nepheline Syenite (Cords, 2008)



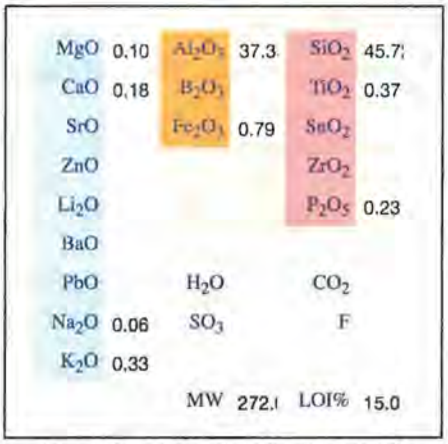
MgO	4.0	Al_2O_3	2	SiO_2	14.0
CaO	24.0	B_2O_3	25.0	TiO_2	
SrO		Fe_2O_3	0.50	SnO_2	
ZnO				ZrO_2	
Li_2O				P_2O_5	
BaO					
PbO		H_2O		CO_2	
Na_2O	4.0	SO_3		F	
K_2O	0.5				
		MW	179.	LOI%	26.0

Gerstley Borate (Cords, 2008)

The next largest percentage of Floating Blue is a flux called Gerstley Borate, which has a molecular weight of 179 g/mol. Fluxes are used to lower the melting point of other refractory materials, so that the compounds melt in the temperature of the kiln. Fluxes can also affect the glaze's opacity, texture, or color. Gerstley Borate can be used as both a high and low temperature flux. Its specific chemical composition is shown in the image to the right. The large percentage of boric oxide, B_2O_3, is what aids in reducing the melting temperature ("Gerstley Borate"). Gerstley Borate tends to develop a milky blue opalescent color in glazes ("Glaze Basics"). It can also be used to help prevent crazing.

Nepheline Syenite and Gerstley Borate, described above, are two partially soluble materials. Because of this, some people had problems with the glaze settling and blistering or crazing during firing. To decrease these problems, it is recommended to use distilled, or water with a low mineral content, sieve all materials using an 80 mesh screen, and stir thoroughly and continually (Hansen, b).

The clay component of Floating Blue is Edgar Plastic Kaolin, also known as EPK. Clays are used in glazes as an inexpensive and non-toxic source of silica and alumina. EPK, with a molecular weight of 272 g/mol is composed of 37.3% aluminum oxide and 45.72% silicon dioxide. The other trace elements in EPK are shown in the table to the right. The clay is also a refractory, a chemical with a high melting



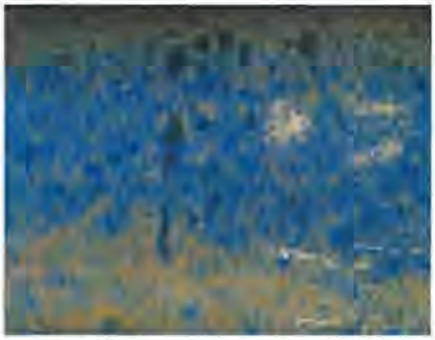
MgO	0.10	Al_2O_3	37.3	SiO_2	45.7
CaO	0.18	B_2O_3		TiO_2	0.37
SrO		Fe_2O_3	0.79	SnO_2	
ZnO				ZrO_2	
Li_2O				P_2O_5	0.23
BaO					
PbO		H_2O		CO_2	
Na_2O	0.06	SO_3		F	
K_2O	0.33				
		MW	272.	LOI%	15.0

Edgar Plastic Kaolin (Cordes, 2008)

point. EPK is a fine-grained, relatively non-plastic clay that fires almost pure white, because it contains very little iron oxide impurities ("Glaze Basics"). EPK is added to glazes when clay is desired, but the color of clay is not.

Flint, also known as silica (SiO_2), is a basic component of all glazes. Flint is a highly refractory compound, melting only at temperatures above 3100° ^{F} ("Glaze Basics"). It is a necessary component of glazes, because it provides the "glassifying" agents that allow the chemical in the glaze to fuse together, forming the glass. Flint is also used to decrease the thermal expansion, counteracting the nepheline syenite. Silica is needed to add hardness to glazes, too.

An additive to the base glaze, rutile, is an oxide combining 90% titanium and 10% iron with a molar mass of 98 g/mol. In oxidation firings, rutile results in a tan color; whereas, in reduction firings, rutile gives gray ("Glaze Basics"). If the glaze is fluid, rutile tends to form opalescent blues. Rutile is often used in glazes to increase opacity and create mottled effects. When combined with metal oxides and stain colorants, rutile can form variegation in the glaze (Willis).



Floating Blue tile showing mottled effects

Red iron oxide, Fe_2O_3, is used to color clays, slips, washes, and glazes. It has a molar mass of 159.69 g/mol and a melting point of 2,849°^{F}. Red iron oxide can lead to tan, earthy red, and brown colors in glazes. Sometimes particles of red iron oxide are not mixed into the glaze well and can create brown specks in the glaze surface. If this speckled look is not desired, a finer mesh screen needs to be used to ensure that the large particles are removed

(Hansen, a). Red iron oxide was also used to label the test tiles, because it does not burn off during firing or stick to the kiln shelf.

For my particular research, I was interested in holding the aforementioned compounds, Nepheline Syenite, Gerstley Borate, EPK, Flint, red iron oxide, and rutile, constant. Without the cobalt in the glaze mixture, a very transparent glaze resulted. The glaze had places that were a translucent tan shade where application was thin. However, in areas of thicker application, a milky blue formed. I was really happy with how the base glaze looked and the variety it provided. It was nice to find out that the base, by itself, was usable.

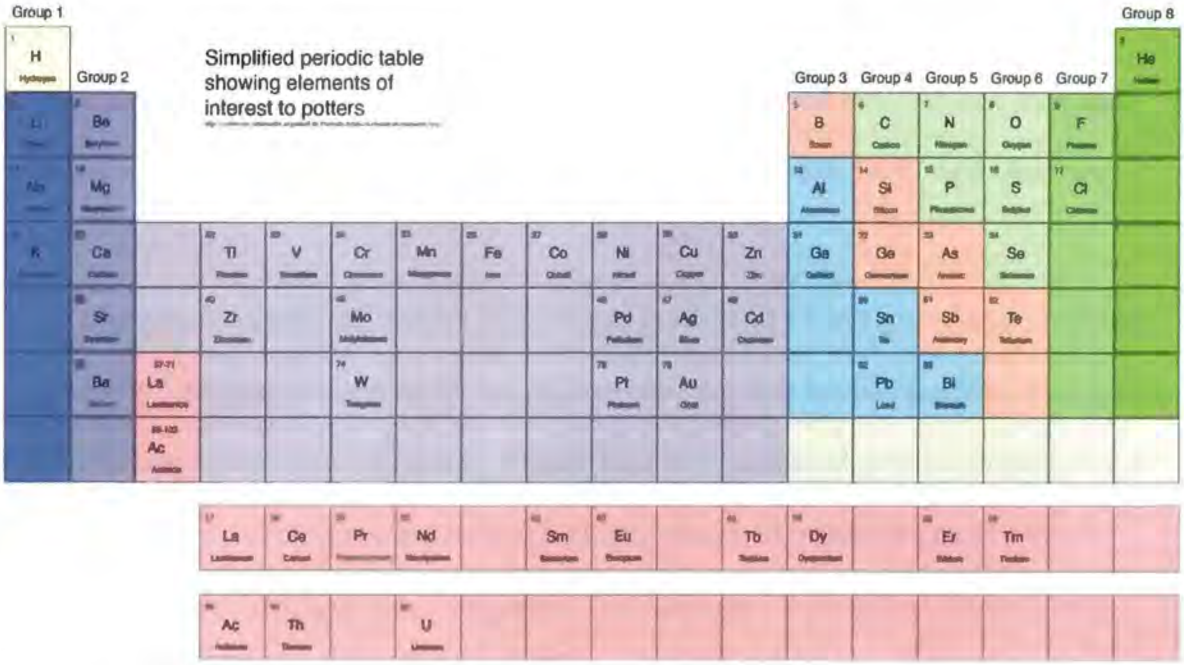
Pitcher with Floating Blue base glaze

Test A: Δ5 Oxidation

Nepheline Syenite	**48%**
Gerstley Borate	**26**
Flint	**20**
EPK	**6**
Rutile	**4**
Red Iron Oxide	**2**

Chemical Analysis

While Floating Blue is a beautiful glaze, I wondered if it would be possible to create different colors by adjusting the additives. Although the majority of the base glaze will be held constant, the type and amount of oxide additives will be changed. Some of the chemicals used in altering the glaze were copper carbonate, tin oxide, strontium carbonate, manganese carbonate, and cobalt oxide. When adding in new compounds, it is important to know the maximum amount that can be added before leaching occurs. It is also important to know the background of the chemical you add to get the effects you want, such as texture, opacity, or color. Below is a simplified periodic table showing only the elements of interest to ceramicists (Bloomfield).



Copper carbonate, $CuCO_3$, has a molar mass of 123.555 g/mol and a melting point of 392°F. The melting point of copper allows the powder to melt during firing, aiding in glass formation. Copper can function as a flux, used to lower the high melting points of the glass formers, which can lead to a glossier glaze finish (Peterson, 2014). Copper carbonate is a green powder that yields green colors in oxidation firings and red colors in reduction firings. If the glaze is alkaline, copper can produce a turquoise blue. Also, if copper is combined with barium, an intense blue or blue-green color can result (Peterson, 2014).

However, copper must be used with caution, as it is considered toxic. Copper carbonate is safe to use if it is less than 5% of the total glaze composition ("Copper Carbonate").

Cobalt oxide, CoO, has a molar mass of 74.9326 g/mol and a melting point of 328°F. Cobalt is a fairly stable colorant that yields blue in both oxidation and reduction firings. The black powder of cobalt oxide is not as finely ground as cobalt carbonate, which can lead to blue specks in the glaze ("Glaze Basics"). Caution must be used when working with powdered cobalt as inhalation or ingestion is toxic. However, cobalt is considered safe to use in amounts less than 3%, and when the glaze components are fully fused together (Finkelnburg, 2014).

Manganese carbonate, $MnCO_3$, has a molar mass of 114.9469 g/mol and a melting point of 392°F. Manganese carbonate is a weaker colorant that creates purples in oxidation firings and browns in reduction firings ("Glaze Basics"). Combined with small amounts of cobalt, manganese carbonate can produce blue-plum hues. Manganese acts as a flux in many glaze recipes, aiding in glass formation. The carbonate form is easier to mix into glazes than the dioxide form and gives a more uniform color. Manganese can cause bubbles or pin-holing in the glaze surface, specifically when used in amounts greater than 5%. Manganese carbonate is toxic in the raw form ("Glossary of Glaze Colorants").

Tin oxide, SnO, has a molar mass of 134.71 g/mol and a melting point of 1,976°F. Tin is used in glazes mostly to make glazes more opaque. Typically, tin oxide is used in amounts of 5-10%, with 5% being the minimum amount needed to produce an opaque white glaze. If used in excess, it can result in a dull matte glaze ("Glossary of Glaze Colorants"). The addition of tin to a glaze recipe can brighten the other colorants added.

Also, combinations of tin and rutile will add variegation to almost any glaze (Hansen, b). However, tin oxide is very expensive and insoluble in glaze ("Glaze Basics"). It is also toxic if inhaled or ingested

Strontium carbonate, $SrCO_3$, has a molar mass of 142.629 g/mol and a melting point of 2,430°F. Strontium begins to function as a flux around 1,994°F, lowering the melting point of silica to form glass. In many glaze recipes, strontium carbonate is used as a substitution for barium carbonate, because barium can be toxic. Strontium produces colors and results similar to barium. While strontium is the safer choice, it does produce a more matte and less reactive glaze (Semler). Addition of strontium increases the strength and durability of the glaze, as well as, making it more scratch resistant. Strontium can form many colors when combined with other oxides. For example, copper and strontium form a dark green, cobalt and strontium form bright blue, and strontium with rutile forms a creamy yellow (Fromme).

Experiments

The first variation to be tested was to add varying amounts and combinations of cobalt oxide and copper carbonate, while holding the base glaze, rutile, and red iron oxide amounts constant. The quantity of each compound added to each line blend cup is summarized in the table below.

	A	B	C	D	E	F	G	H	I	J	K	M*
Cobalt	0g	2.25g	2g	1.75g	1.5g	1.25g	1g	0.75g	0.5g	0.25g	0g	2.5g
Copper	0g	0.25g	0.5g	0.75g	1g	1.25g	1.5g	1.75g	2g	2.25g	2.5g	1g

This line blend was performed on the class clay, which, once fired to maturity, has a taupe color with red undertones. It was hypothesized that combining cobalt oxide and copper carbonate would produce a teal color, with the tiles becoming greener as the percentage of copper increased. Test A did not have any oxide added so that the color of the base glaze by itself could be determined. After firing, there was not a big difference between the individual tiles; they were all approximately the same color. The glaze had a lot more green in it than expected. However, the glaze did have a nice variegation to it. To try to make a more teal color, more cobalt was added to cup E, creating a combination of 2.5 g CoO with 1g $CuCO_3$. This new test didn't result in the teal color as expected; the color is more of an olive green-gray color.

Results of Line Blend #1

The second line blend performed was to combine manganese carbonate and cobalt oxide with the base glaze, rutile, and red iron oxide. The amounts of each oxide added to in the line blend is shown in the chart below. This test, and all subsequent tests, was performed on Cino Blanc MC210 porcelain, produced by the Alligator Clay Company. The clay body was switched to get a more consistent and standardized clay composition. It is

	A1	B1	C1	D1	E1	F1	G1	H1	I1
Manganese	6g	5g	4g	3g	2g	1g	0g	4g	5g
Cobalt	0g	0.5g	1g	1.5g	2g	2.5g	3g	2g	2g Cu:1g

important that the clay color remains constant because the clay color affects the final color of the glaze. For this test, it was hypothesized that the glaze would be brown with the higher amounts of manganese, but transition to purple as the amount of cobalt increases. A slight blue color might also result from the interaction of the red iron oxide with the manganese. Test I1 is a combination manganese carbonate, cobalt oxide, and copper carbonate. The results of this second line blend had a much greater variation in color than the first line blend had. Test A1 had a very taupe color with hints of purple and dark brown. Tests B1 and C1 were an olive gray color. Tests D1, E1, and F1 began to show a blue hint with an olive background. Test G1 showed a really nice blue color. H1 was an olive brown color. The last test, I1, was a rich chocolate brown. In all of these tests, running seemed to be an issue. If these glazes were to be used again, more silica would need to be added. Out of this line blend, G1 produced a color that would likely be used in the future. A closer image and the recipe for G1 are shown below.

Results of Line Blend #2

Test G1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	3

The third line blend was a combination of copper carbonate and tin oxide with the Floating Blue base glaze. The amounts of each oxide added to in the line blend is shown in the chart below.

	A2	B2	C2	D2	E2	F2	G2	H2	I2
Copper	4g	3.5g	3g	2.5g	2g	1.5g	1g	0.5g	0g
Tin	0g	0.5g	1g	1.5g	2g	2.5g	3g	3.5g	4g

From this test, it was hypothesized that a turquoise or pale blue color would result as the amount of tin oxide increased. The glaze would have a green hue with the higher amounts of copper carbonate. The hypothesis was completely off base for this test. The results don't show any type of blue color, but instead exhibit a gradient from green to yellow-orange. Tests A2, B2, and C2 showed a nice olive green color. Test D2 had a bright green hue. Tests E2, F2, and G2 had a yellow orange base with hints of green in the areas of thicker application. H2 was similar to the previous three tests except the green was more of pale mint color. The final test, I2, was a matte speckled cream color. This line blend produced many glazes that are likely to be used in the future, specifically tests G2 and I2. The recipes for these two glazes are shown below.

Results of Line Blend #3

Test I2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Tin	4

Test G2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Tin	3
Copper	1

The final line blend performed combined copper carbonate, strontium carbonate, and the base glaze. Strontium carbonate was used as a less toxic substitute for barium carbonate. The additive amounts are shown in the table below.

	A3	B3	C3	D3	E3	F3	G3	H3	I3
Copper	4g	3.5g	3g	2.5g	2g	1.5g	1g	0.5g	0g
Strontium	2g	3g	4g	5g	6g	7g	8g	9g	10g

It was hypothesized that this line blend would result in turquoise hues, with some possible crystalline effects from the strontium. The results of this line blend were beautiful. All of the glazes had a wonderful iridescent sheen to them. Tests A3 and B3 have a nice light green color. Next, tests C3 and D3 have beautiful turquoise colors with hints of darker blues and greens. Tests E3, F3, and G3 formed a more translucent olive green. Tests H3 and I3 formed translucent browns and creams, respectively. From this glaze, C3 and E3 are likely to be reproduced for future use. Closer images of these two tests, along with their recipe, are shown below.

Results of Line Blend #4

Test C3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Strontium	4
Copper	3

Test E3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Strontium	6
Copper	2

After the four line blends, there were some extra test tiles and base glaze leftover. I decided to try a few different combinations to get a basic idea of how the oxides interacted with one another. The combinations tried are summarized in the table below.

O	P	Q	R	S
Tin 2g	Manganese 4g	Cobalt 2.5g Strontium 3g	Strontium 6g	Strontium 5g
Cobalt 2g	Copper 2g	Copper 1g	Manganese 3g	Cobalt 2g

For test O, it was hypothesized that the tin and cobalt would combine to form a lighter blue. It was thought that test P would combine to form an olive colored glaze. Test Q was hypothesized to form a bright turquoise hue. It was thought that test R would produce a purple color. For test S, it was hoped that the resulting glaze would be a teal color. The opposite of the hypothesis occurred in test O; a dark slate color with a hint of blue resulted instead of a light blue. The hypothesis was proven to be true for test P as a olive colored glaze was produced. Test Q lead to a glaze with a lighter blue "floating" on top of a darker green color. Test R formed a transparent red iron colored glaze, with a hint of purple forming in the areas of the runs. The final test, S, formed a rich blue. Tests O,R, and S are likely to be used in the future. The images and recipes for these tiles is shown below.

Results of Extra Tests

Test O: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Tin	2
Cobalt	2

Test R: Δ5 Oxidation

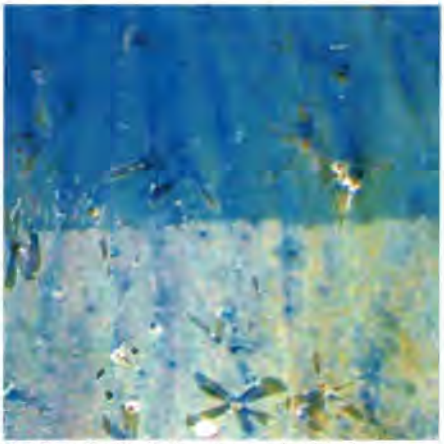
Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Strontium	6
Manganese	3

Test S: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Strontium	5
Cobalt	2

LEACHING TEST

Not all glazes are suitable for use on surfaces that come in contact with food. Sometimes glazes can leach chemicals, which can potentially poison any food placed on the ware. Since I was planning on using my glazes on pieces that would come in contact with food regularly, I decided it was necessary to perform a few simple leaching tests. The first test involved placing a slice of lemon on the surface of the glaze for 24 hours. If the texture or color of the surface changes where it was in contact with the acid from the lemon, the



Bottom half of tile was soaked in lemon juice and leaching occurred (Hansen, a)

glaze is leachable. An example of how the tile can change from leaching is shown to the right. I didn't test every tile, but I did test the glaze I thought I might make again. I checked the tiles at 24 hours, and there were no signs of leaching. I left the lemon on for a total of 36 hours and still, no leaching occurred. To make sure that leaching was not occurring, I performed another test using vinegar. This time, the tiles were left to soak in vinegar for 24 hours. Again, if any texture or color changes occurred, the glaze would be considered unsafe for food. After this second test, there were still no signs of leaching occurring. The glazes tested were determined to be food safe.

Lemon Leaching Test

Results after both leaching tests

Application

I have really enjoyed making different colors from the base glaze, Floating Blue. From this glaze, I now know how to make a variety of different colors ranging from blue and purple to green and brown. My favorite oxide combination was 3g copper carbonate with 4g strontium carbonate that produced a glaze that had lots of turquoise shades in it. This glaze also had a very iridescent quality.

Images of Glaze C3

Holding the base glaze constant, I was able to create a wide variety of colors by changing only the oxide additives. It is economically beneficial to create a variety of colors from a single base glaze. This way, you only have to purchase the base materials for one glaze and a few different oxides. It helps cut down on costs by not having to buy multiple types of clay bodies, fluxes, and feldspars. It is also easier to make just one big batch of the base glaze, divide it up, and add the oxides to get different colors than to make multiple batches of different glazes.

By completing these line blend tests, I have learned so much about the glaze process and the different chemicals involved. I now understand how certain elements interact to give varying glaze results. I also feel like I have gained the skills needed to be able to make my own glazes in the future. My research will be used to expand the glaze catalogue at Ouachita Baptist University, increasing the glaze options available for other students. This research will also be published online in hopes that other ceramicists can use these glazes. In the future, I would love to continue expanding the range of colors that Floating Blue can produce by testing other oxides and layering glazes. In my time in ceramics over the past two years, I've learned so much and have gained a strong adoration for this art form. I know that ceramics will be something I continue for the rest of my life. I'm thankful to have been able to combine chemistry and ceramics in the form of glaze testing, because it has only made me more curious and interested in the two fields.

Results of all glazes created

Glaze Catalog

Test A: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2

Test B: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	2.25
Copper	0.25

Test C: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	2.
Copper	0.5

Test D: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	1.75
Copper	0.75

Test E: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	1.5
Copper	1

Test F: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	1.25
Copper	1.25

Test G: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	1
Copper	1.5

Test H: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	0.75
Copper	1.75

Test I: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	0.5
Copper	2

Test J: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Cobalt	0.25
Copper	2.25

Test K: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	2.5

Test M: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Cobalt	2.5
Copper	1

Test A1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	6
Cobalt	0

Test B1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	5
Cobalt	0.5

Test C1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	4
Cobalt	1

Test D1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	3
Cobalt	1.5

Test E1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	2
Cobalt	2

Test F1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	1
Cobalt	2.5

Test G1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	0.5
Cobalt	3

Test H1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	4
Cobalt	2

Test I1: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	5
Cobalt	2
Copper	1

Test A2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	4
Tin	0

Test B2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	3.5
Tin	0.5

Test C2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	3
Tin	1

Test D2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	2.5
Tin	1.5

Test E2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	2
Tin	2

Test F2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	1.5
Tin	2.5

Test G2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	1
Tin	3

Test H2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	0.5
Tin	3.5

Test I2: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	0
Tin	4

Test A3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	4
Strontium	2

Test B3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	3.5
Strontium	3

Test C3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	3.
Strontium	4

Test D3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	2.5
Strontium	5

Test E3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	2
Strontium	6

Test F3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	1.5
Strontium	7

Test G3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	1
Strontium	8

Test H3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Copper	0.5
Strontium	9

Test I3: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Strontium	10

Test O: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Tin	2
Cobalt	2

Test P: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

Rutile	4
Red Iron Oxide	2
Manganese	4
Copper	2

Test Q: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6

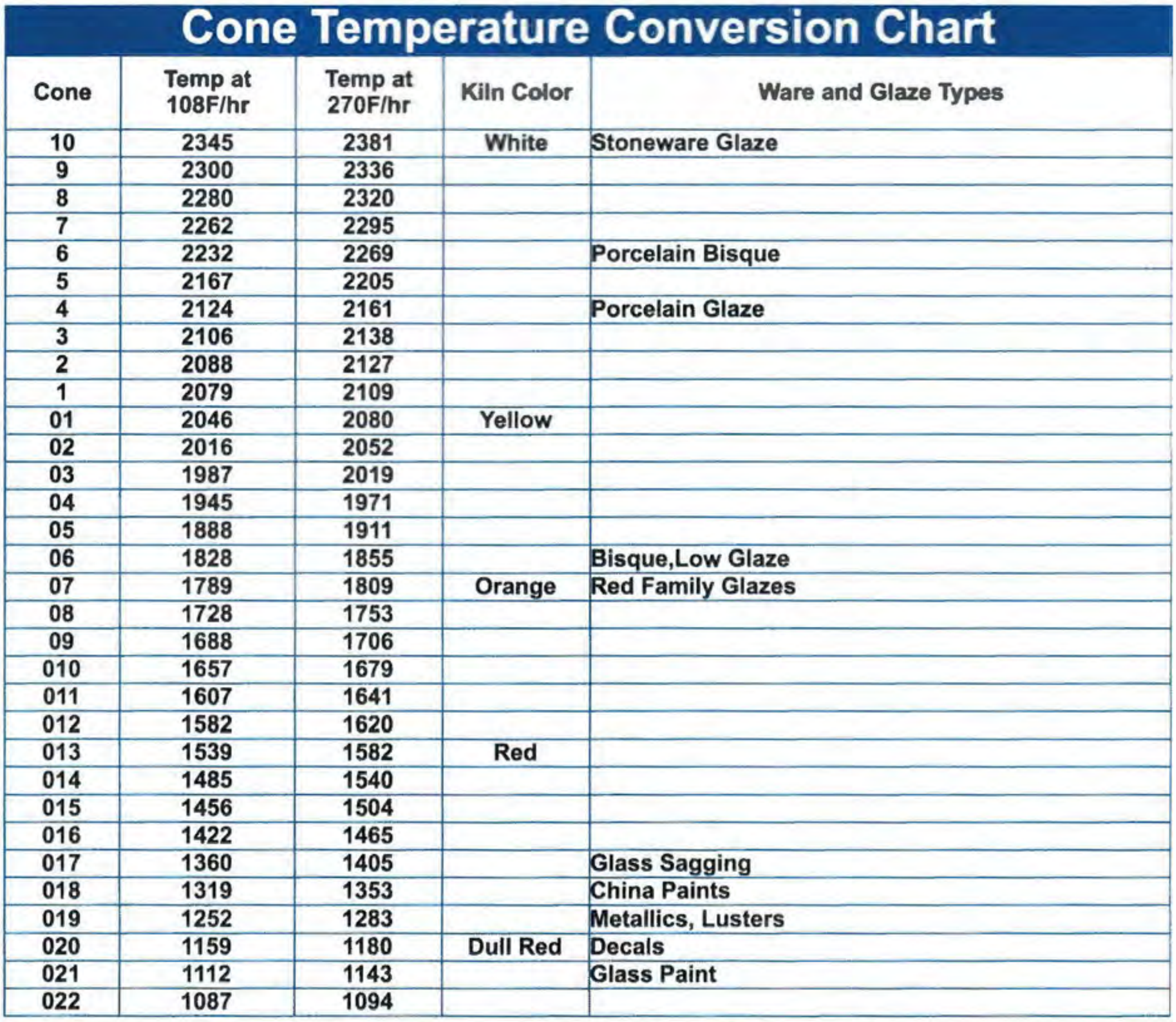
Rutile	4
Red Iron Oxide	2
Cobalt	2.5
Strontium	3
Copper	1

Test R: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Strontium	6
Manganese	3

Test S: Δ5 Oxidation

Nepheline Syenite	48%
Gerstley Borate	26
Flint	20
EPK	6
Rutile	4
Red Iron Oxide	2
Strontium	5
Cobalt	2



Cone Temperature Conversion Chart

Cone	Temp at 108F/hr	Temp at 270F/hr	Kiln Color	Ware and Glaze Types
10	2345	2381	White	Stoneware Glaze
9	2300	2336		
8	2280	2320		
7	2262	2295		
6	2232	2269		Porcelain Bisque
5	2167	2205		
4	2124	2161		Porcelain Glaze
3	2106	2138		
2	2088	2127		
1	2079	2109		
01	2046	2080	Yellow	
02	2016	2052		
03	1987	2019		
04	1945	1971		
05	1888	1911		
06	1828	1855		Bisque,Low Glaze
07	1789	1809	Orange	Red Family Glazes
08	1728	1753		
09	1688	1706		
010	1657	1679		
011	1607	1641		
012	1582	1620		
013	1539	1582	Red	
014	1485	1540		
015	1456	1504		
016	1422	1465		
017	1360	1405		Glass Sagging
018	1319	1353		China Paints
019	1252	1283		Metallics, Lusters
020	1159	1180	Dull Red	Decals
021	1112	1143		Glass Paint
022	1087	1094		

Cone Conversion to degrees Fahrenheit (Clay King, 2016)

References

AMACO. (n.d.). PC-53 Ancient Jasper. Retrieved May 01, 2016, from https://www.amaco.com/products/glaze-pc-53-ancient-jasper

Bloomfield, L., & Bloomfield, H. (2012). *Colour in glazes.* London: A&C Black.

Bloomfield, H. (n.d.). Chemistry for Potters. Retrieved May 01, 2016, from http://ceramicartsdaily.org/ceramics-monthly/article/technofile-chemistry-for-potters/

Clay King. (2016). Cone Temperature Conversion Chart. Retrieved May 04, 2016, from http://www.clay-king.com/kilns/pyrometric_cone_temperature_chart.html

Copper Carbonate. (n.d.). Retrieved April 06, 2016, from http://www.theceramicshop.com/store/product/945/Copper-Carbonate/

Cordes, U. (2008). Online Glaze Calculator. Retrieved May 01, 2016, from http://www.online-glaze-calculator.com/Calculator/fr2.php

Finkelnburg, D. (2014, September 15). A Case of the Blues: All You Ever Wanted to Know About Cobalt But Were Afraid to Ask. Retrieved April 02, 2016, from http://ceramicartsdaily.org/ceramic-glaze-recipes/high-fire-glaze-recipes/a-case-of-the-blues-all-you-ever-wanted-to-know-about-cobalt-but-were-afraid-to-ask/

Fromme, R. (1994). Basic Flux Oxides in Glazes: Tutorial IV (CeramicsWeb). Retrieved April 11, 2016, from https://sites.google.com/site/meeneecat/educational-materials/basic-flux-oxides-in-glazes-ceramicsweb

Gerstley Borate. (n.d.). Retrieved April 13, 2016, from http://www.theceramicshop.com/store/product/334/Gerstley-Borate/

Glaze Basics. (n.d.). Retrieved April 06, 2016, from http://www-01.glendale.edu/ceramics/glazebasics.html

Glossary of Glaze Colorants. (2009). Retrieved April 14, 2016, from https://prometheanpottery.wordpress.com/glaze-glossary-and-resource/glossary-of-glaze-colorants/

Hansen, T. A. (n.d.). Ceramic Materials. Retrieved April 10, 2016, from https://digitalfire.com/4sight/material/nepheline_syenite_1069.html

Hansen, T. B. (n.d.). Floating Blue. Retrieved April 06, 2016, from http://digitalfire.com/gerstleyborate/recipes/floatingblue.html

Nepheline Syenite. (n.d.). Retrieved April 11, 2016, from http://www.theceramicshop.com/store/product/339/Nepheline-Syenite,-270-mesh/

Parsons, P., & Dixon, G. (2013). *The periodic table: A field guide to the elements.* London: Quercus Editions.

Peterson, B. (2014, November 25). 3 Important Factors That Affect Glaze Color. Retrieved April 06, 2016, from http://pottery.about.com/od/diyglazes/tp/ceracolor.htm

Peterson, B. (2014, November 25). Oxidation and Reduction Atmospheres. Retrieved May 01, 2016, from http://pottery.about.com/od/kilnatmospheres/tp/oxinreduc.htm

Roeder, C. (1996, April 23). Clayart - thread 'cone 6 glaze test results-floating blue' Retrieved April 06, 2016, from http://www.potters.org/subject02170.htm

Rorison, T. (2015, October). Glaze, Blue, Rutile, Floating Blue. Retrieved May 01, 2016, from http://glazy.org/recipes/3226

Semler, D. (2009, November 17). Leaving Bariumville: Replacing Barium Carbonate in Cone 10 Glazes | Ceramic Arts Daily. Retrieved April 13, 2016, from http://ceramicartsdaily.org/ceramic-glaze-recipes/glaze-chemistry-ceramic-glaze-recipes-2/leaving-bariumville-replacing-barium-carbonate-in-cone-10-glazes/

Willis, R. (n.d.). Rutile. Retrieved April 17, 2016, from https://digitalfire.com/4sight/material/rutile_1204.html