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ceramic raw materials



understanding ceramic glaze ingredients and clay making materials

Ceramic Raw Materials

Understanding Ceramic Glaze Ingredients and Clay Making Materials

Today, we live in an age of super abundance of ceramic raw materials. Innumerable clays and glaze materials offer us a bewildering array of choices. Far from understanding these materials as familiar rocks, feldspars, and clays, each with unique personalities of their own, we know them only as white, gray, or brown powders neatly packaged in uniform bags. Consequently we beg, borrow, and steal glaze and clay body recipes that "work."

Ceramic raw materials come to us from every corner of the earth in a purified and refined state. We no longer live at the source of our ceramic materials as did the potters of ancient times. It now becomes a Herculean feat to know or understand in any meaningful way the flood of ceramic materials at our disposal. Fortunately, it is not necessary to have an intimate understanding of these hundreds of ceramic materials. Ancient potters created their masterpieces from three or four ceramic materials, and, if we similarly narrow our choices, we can also achieve extraordinary results. ***Ceramic Raw Materials: Understanding Ceramic Glaze Ingredients and Clay Making Materials*** offers access to that knowledge, including how to formulate a glaze using a glaze core, charts for clays and feldspars found in most clay and glaze recipes, a glossary of common ceramic raw materials, and the primary functions of those materials.

Understanding Glazes Through Raw Materials: Using Glaze Cores

By Mimi Obstler

There are so many materials available to ceramic artists that it can be somewhat overwhelming. But if you understand the concept and function behind glaze cores, the process becomes far more manageable.

Glossary of Common Ceramic Raw Materials

This quick reference to the most common North American raw materials will come in handy when formulating clay bodies as well as glazes.

Primary Functions of Common Ceramic Raw Materials

A companion to the glossary of common materials used in studio ceramics, this chart allows quick identification and understanding of the main uses of our materials.

Clay Materials We Use

Because clays and recipes can change over time, it is good to know specifically what your clay contains. If you need to substitute one material for another, you'll want to get as close as possible, so you're changing as little as you can.

Feldspars Used in Ceramic Glazes and Clay Making

These handy materials, used as the core of glazes as well as in most clay bodies, appear in lots of recipes. Some of the recipes may be so old half of the materials listed are no longer available or their names have been changed. If this happens to you, this guide will help you identify the best possible substitute.

Understanding Glazes Through Raw Materials: Using Glaze Cores

By Mimi Obstler

An analysis of certain beautiful Song Dynasty porcelain glazes revealed that a single feldspathic rock material (Petuntse) provided the core of the glaze. This single material contained nearly the right proportion of glassmaker, adhesive, and melter oxides. Only small amounts of wood ash and limestone materials were added to improve the color and melt of the glaze. I believe that this is still the most meaningful way to approach the stoneware glaze, or any glaze or clay body for that matter. The objective is to locate one single earth material that alone almost provides the desired surface, and then to add as few additional materials as possible. I call this primary material, which almost achieves the desired glaze surface, a "glaze core." The list of glaze cores is long and disparate and includes feldspars, mica, granitic rocks, some clays, volcanic ash, wood ash, boron minerals, and the artificial manufactured frits. The key characteristic of these materials is their combination of glassmaker, adhesive, and melter functions.

***Feldspars and Rocks*: Stoneware test pots by Barbara Beck, fired to cone 9–10 reduction. Glaze: Feldspar 90%, Whiting 10%, Red iron oxide, ½%. Pots, left to right: Potash feldspar, Cornwall Stone, Soda feldspar. Pot, rear, center: Nepheline Syenite. Rocks, left to right: Soda feldspar, Potash feldspar, Nepheline Syenite, Cornwall Stone.**

Feldspars and feldspathic rocks contain a complex structure of silica, alumina, and the melter oxides of sodium, potassium, and calcium. This structure makes them ideal glaze cores at stoneware temperatures.

Mix powdered feldspar with water, apply this mixture to a clay form, fire it to stoneware temperatures, and there will appear a glossy, white surface on the clay. Thus, feldspars and feldspathic rocks with their complex chemical structure of silica, alumina, and melter oxides of sodium, potassium, and calcium possess the unique ability to form an "almost" acceptable glaze surface at stoneware firing temperatures.

Origin

Throughout earth's history, violent upheavals have forced silica-rich magma up toward the earth's outer layers. Under these outer layers, the magma cooled slowly for thousands of years to form the large-grained crystalline rocks known as granite. When exposed on the earth's surface, granites are subjected to two types of weathering. Mechanical weathering (physical disintegration of granites by expansion of water, tree roots, groundwater, animal footsteps, etc.) causes the granites to be broken down into their various minerals—mainly feldspars, quartz, and micas. Chemical weathering (chemical reaction of the granites to the air, living beings, earth, and water on the earth's surface and atmosphere) causes some feldspar and mica minerals to further decompose into clay minerals.

Granites are the basis of most of our ceramic materials and make up 75% of the earth's crust. They are rocks, which by definition are mixtures of one or more minerals. Granites consist of over 50% potash and soda feldspar and up to 25% quartz. They also contain as much as 20% mica and lesser amounts of magnesium-iron minerals. Some granites, if crushed to a fine particle size, will make exciting glaze surfaces at high stoneware temperatures.

Rock: Calcite: Calcium Carbonate (Collection of Department of Earth and Environmental Sciences, Columbia University, New York).
Tests: Feldspar and Whiting (Calcium Carbonate) on stoneware fired to cone 9–10 reduction.
Left: Potash feldspar 100%.
Center: Potash feldspar 90%, Whiting 10%.
Right: Whiting (Calcium Carbonate) 100%.

Left: Granite. Slow-cooled, coarse-grained, igneous rock containing 25% quartz, 50% feldspar (mostly potash in this sample), some muscovite, biotite, and/or amphibole.
Right: Rhyolite. Fast-cooled, fine-grained igneous rock with the same chemical composition as granite.
(Collection of Department of Earth and Environmental Sciences, Columbia University, New York).

General Characteristics of Feldspars

Feldspar includes an assortment of minerals of varying composition. Despite this range, the feldspars commonly used by potters tend to follow a fairly recognizable pattern when fired to stoneware temperatures.

1. The most striking characteristic of a feldspar that is fired to stoneware temperatures is the formation of a glassy, white surface. The heat of the stoneware kiln fire, combined with the feldspar's soda and potash melter oxides (14%–15%) have transformed its considerable silica content (60%–70%) into glass. The white color is a happy consequence of the selection of atoms by size—the atoms of the coloring minerals such as iron and copper are too large to fit into the feldspathic structure. The result is a relatively pure white material to which colorants can always be added.

2. The melting action of the feldspars has a very long range: 2138°F (cone 4) to 2381°F (well beyond cone 10).

3. Melted feldspars possess a high surface tension because of their considerable alumina content (17%–25%); they crawl and flow unevenly. This is especially noticeable with a thick coat of feldspar.

4. The surface of melted feldspars contains an intricate network of fine cracks alternately described as "crazes" if considered a glaze defect and "crackle" if considered aesthetically desirable. Melting oxides, contained in the oxide structure of the feldspar, are responsible for the craze/crackle network. These melting oxides are for the most part sodium and potassium, which undergo a high rate of expansion when heat converts them from a solid into a liquid state.

5. Feldspars do not remain evenly suspended in the liquid glaze mixture. The feldspathic powder settles at the bottom of the glaze bucket, forming a dense, rock-like substance that defies even the most vigorous attempts at disbursement.

It must now be apparent that although feldspar provides the basic core of a stoneware glaze, it does present certain problems for the potter. We can solve these problems by adding small quantities of three or four minerals to the feldspathic glaze.

Additions of limestone or calcium minerals will increase the

Cone 5–6 oxidation. Porcelain claybody. Left: Satin-matt surface: Nepheline Syenite 80%, Wollastonite 20%. Back: Gloss surface: Jacky's Clear: Nepheline Syenite, 50; Colemanite, 10; Wollastonite, 10; Flint, 20; Zinc oxide, 5; Ball Clay, 5; Bentonite, 2. Front: Matt surface: Ron's White Matt #5: F-4 Feldspar, 55; Whiting, 15; EPK, 16; Zinc oxide, 14.

melt at stoneware temperatures and thus quicken the flow of the feldspathic glaze.

Additions of the glassmaker (silica) will eliminate the craze/crackle network, should this be desired. Silica, unlike the sodium and potassium melters, has a minimal rate of contraction upon cooling, and thus inhibits the high contraction rate of these melters.

Physical suspension of the feldspar in the liquid glaze may be improved by adding 10% or more of clay materials such as kaolin or ball clays. The addition of the clay materials will also toughen the raw glaze coat and help it withstand the handling that takes place when the kiln is stacked. Suspension will be further improved by the addition of 2%– 3% superplastic clay (bentonite) or even smaller amounts of soda ash or Epsom salts (magnesium sulfate).

Minerals, such as copper, iron, or cobalt, may be added in oxide or carbonate form to achieve color.

This combination of materials spawns a broad range of standard stoneware glazes. Although a specific stoneware glaze formula may show four or even five ingredients in its recipe, in most cases the core of the glaze is the feldspar. The rest of the materials are present in order to cure the problems contained in the feldspar.

At the cone 5/6 oxidation temperatures, 70% F-4 feldspar and 30% Wollastonite creates a creamy, satin-matt surface. See also the example piece with Nepheline Syenite 80%, Wollastonite 20% above.

The oxide structure of a feldspar explains why it constitutes the central ingredient core of a stoneware glaze. Most feldspars contain about 60%–70% silica (the glassmaker), 17%–25% alumina (the adhesive), and 10%–15% sodium, potassium, and/or calcium oxide (the melters).

This text was excerpted from Out of the Earth, Into the Fire: A Course in Ceramic Materials for the Studio Potter, by Mimi Obstler. Available at www.ceramicartsdaily.org/bookstore.

Glossary of Common Ceramic Raw Materials

barium carbonate $BaCO_3$—alkaline earth—active high temperature flux, but also promotes matt glaze surface. Unsafe for low-fire functional glazes. Often used as an additive in clay bodies in very small percentages to render sulfates insoluble, reducing scumming.

bentonite $Al_2O_3•5SiO_2•7H_2O$—formed from decomposition of airborne volcanic ash. Suspension agent used in quantities no more than 3% of dry materials weight.

bone ash (calcium phosphate) $Ca_3(PO_4)_2$—high temperature flux—opacifier in low temperature glazes—translucence in high temperature glazes.

borax (sodium tetraborate) $Na_2O•2B_2O_3•10H_2O$—a major low temperature alkaline flux, available in granular or powdered form. Gives smooth finish, bright colors. Water soluble, so often used in fritted form.

chrome oxide Cr_2O_3—standard vivid green colorant—often softened with a little iron or manganese. Very refractory. With tin produces pink.

cobalt carbonate $CoCO_3$—standard blue colorant for slips and glazes—5% will give dark blue in glaze or slip. Will cause crawling if used raw for underglaze brushwork.

copper carbonate $CuCO_3$—a major glaze colorant to produce greens in low temperature and high temperature, copper reds in high temperature reduction, and greens and metallic effects in raku.

dolomite $MgCO_3•CaCO_3$—high temperature alkaline earth flux, promotes hard, durable surfaces and recrystallization/matting in glazes.

feldspar High temperature alkaline fluxes—insoluble aluminum silicates of potassium, sodium, calcium, and/or lithium—inexpensive flux for glaze.

frit Fluxes that have been melted to a glass, cooled, and ground in order to stabilize soluble and/or toxic components during handling of unfired material.

ilmenite An iron ore with significant titanium—most often used in granular form to produce dark specks in clay or glaze. Higher iron concentration than in rutile.

iron oxide, red (ferric oxide) Fe_2O_3—refractory red in oxidation, converts to black iron (flux) in reduction and/or high-fire. Low quantities in clear glaze produces celadon green—high quantities produce temmoku black or saturated iron red—powerful flux.

kaolin; china clay $Al_2O_3•2SiO_2•2H_2O$—very refractory white primary clay. Source of alumina in glazes.

lithium carbonate Li_2CO_3—powerful all temperature alkaline flux, especially with soda or potash feldspars. Promotes hardness and recrystallization in low temperature glazes.

magnesium carbonate $MgCO_3$—alkaline earth—high temperature flux, promotes mattness and opacity in low temperature glazes, smooth, hard, buttery surface in high temperature glazes—promotes purples/pinks with cobalt. Used to promote controlled crawl glaze effects.

manganese dioxide MnO_2—flexible colorant—with alkaline fluxes gives purple and red colors—by itself gives soft yellow-brown—with cobalt gives black. Used with iron to color basalt bodies. Concentrations of more than 5% may promote blistering.

nepheline syenite $K_2O•3Na_2O•4Al_2O_3•9SiO_2$—a common feldspathic flux, high in both soda and potash. Less silica than soda feldspars, and therefore more powerful. Increases firing range of low-fire and mid-range glazes.

rutile Source of titanium dioxide, contains iron, other trace minerals—gives tan color, promotes crystallization giving mottled multi color effects in some high temperature glazes, or in overglaze stain.

silica (silicon dioxide, flint, quartz) SiO_2—main glass-former—vitrification, fluidity, transparency/opacity controlled by adding fluxes and/or refractories.

spodumene $Li_2O•Al_2O_3•4SiO_2$—lithium feldspar—powerful high temp alkaline flux, promotes copper blues, good for thermal-shock bodies and matching glazes.

strontium carbonate $SrCO_3$—alkaline earth, high temperature flux, similar to barium, slightly more powerful—gives semi-matt surfaces. Nontoxic in balanced glaze.

talc $3MgO•4SiO_2•H_2O$—high temperature alkaline earth flux in glaze, promotes smooth buttery surfaces, partial opacity—similar composition to clay.

tin oxide SnO_2—most powerful opacifier, but expensive—inert dispersoid in glaze melt—5–7% produces opaque white in a clear glaze.

titanium dioxide TiO_2—matting/opacifying agent. Promotes crystal growth, visual texture in glazes.

whiting (calcium carbonate, limestone) $CaCO_3$—alkaline earth, contributing calcium oxide to glaze—powerful all temperature flux—major high temperature flux for glazes—gives strong durable glass.

wollastonite (calcium silicate) $CaSiO_3$—In some cases, it is used in place of whiting.

zinc oxide ZnO—high temperature flux that promotes brilliant glossy surfaces. Can encourage opacity, with titanium in low-alumina glaze can encourage macrocrystalline growth.

zirconium silicate $ZrSiO_4$—zircon opacifier—low-cost substitute for tin oxide—use double the recipe weight of tin. Includes Zircopax, Opax, Superpax, Ultrox.

Excerpted from *Clay: A Studio Handbook* by Vince Pitelka.

Primary Function of Common Ceramic Raw Materials

Material	Glaze Function	Substitute	Comment
Barium Carbonate	Flux	Strontium carbonate	
Bentonite	Suspension agent	Ball Clay	Do not exceed 3%
Bone Ash	Opacifier		
Borax	Flux, glassmaker	Boron frits	
Chrome Oxide	Colorant		Green
Cobalt Carbonate	Colorant	Cobalt oxide	Blue
Copper Carbonate	Colorant	Copper oxide	Greens, copper reds
Cornwall Stone	Flux, opacifier		
Custer Feldspar	Glaze core	Potash feldspar (G-200)	
Dolomite	Flux, opacifier	Whiting	Many brands
EPK Kaolin	Alumina, opacity	Kaolin	
Ferro Frit 3110	Glaze core, flux	Pemco P-IV05, Fusion F-75	Crystalline glazes
Ferro Frit 3124	Glaze core, flux	F-19, P-311, Hommel 90	Boron frit
Ferro Frit 3134	Glaze core, flux	F-12, P-54, Hommel 14	Boron frit
Ferro Frit 3195	Glaze core, flux	Hommel 90, Fusion F-2	Complete glaze
Ferro Frit 3269	Flux, glaze core	Pemco P-25	
Ferro Frit 3278	Flux, glaze core	Fusion F-60, Pemco P-830	
G-200 Feldspar	Glaze core	Potash feldspar (Custer)	
Green Nickel Oxide	Colorant	Black nickel oxide	Blues, tan, browns, greens, grays
Kentucky OM4 Ball Clay	Alumina, opacity	Ball Clay	
Kona F-4 Feldspar	Glaze core	Soda feldspar	
Lithium Carbonate	Flux		
Magnesium Carbonate	Flux, opacifier		Promotes crawling
Manganese Dioxide	Colorant		Purple, red, yellow-brown
Nepheline Syenite	Glaze core		
Red Iron Oxide	Colorant		Celadon green to brown
Rutile	Colorant	Ilmenite	
Silica	Glass former, glaze fit	Flint	Use 325 mesh
Spodumene	Lithium glaze core		
Strontium Carbonate	Flux	Barium carbonate	
Talc	Flux, opacifier		Many brands
Tin Oxide	Opacifier	Zircopax	
Titanium Dioxide	Opacifier		
Whiting	Flux, opacifier	Wollastonite, Dolomite	Many brands
Wollastonite	Flux, opacifier	Whiting, dolomite	
Wood Ash	Glaze core, flux, colorant	Whiting	Results vary by type
Zinc Oxide	Flux, opacifier		
Zircopax	Opacifier	Superpax, Ultrox	

Notes:

1. Substituting glaze ingredients may alter color, texture, opacity, viscosity, and/or sheen, as well as create pinholing, crazing, black spotting, and/or pitting. In most cases, additional adjustments to other ingredients need to occur when substituting.
2. Test and record your results.
3. Materials vary from supplier to supplier and batch to batch.

Clay Materials We Use

There are probably as many kinds of clay as there are riverbanks, creekbeds, roadcuts, abandoned coal mines and backyard gullies, but most of the clays that many of us use on a regular basis are commercially mined.

Because not all materials are available through all suppliers, this chart is meant to provide data for the most common clays used in recipes you are likely to come across. You can use these data to compare the materials available through your supplier, or those you have on hand, with materials in the published recipes.

While the satisfaction, discovery and personal control that is possible through prospecting and processing your own clay are certainly valid reasons for the effort, most of us rely on the consistency and (relative) reliability of air-floated materials mined in large quantities. Even though the reasons for using commercially mined clays are most often based on a desire for a trouble-free product, the properties of clay as a natural material can make this goal somewhat elusive. The following chart contains the most recent information available.

However, because the chemical and physical makeup of naturally mined materials can change across a given deposit, this chart is meant to be used as a starting point for clay substitutions. In order to precisely recalculate a recipe using a substituted clay, you will need to obtain a current data sheet for all materials you purchase from your supplier.

Please note that the clays are presented in alphabetical order, and the formulae are presented with alumina (Al_2O_3) in unity (totalling 1). This makes it easier to immediately see the ratio of alumina to silica, and also more accurately compares the relative amounts of all other components in the clays.

Clay Name	Al:Si	M.Wt.	BaO	CaO	MgO	K2O	Na_2O	TiO	MnO	Al_2O_3	Fe_2O_3	P_2O5	SiO_2
54-S Ball Clay	1:3.28	314.3		.009	.027	.039	.006	.074		1	.023		3.28
6 Tile Clay	1:2.03	267.72		.019	.033		.002	.047		1	.005		2.03
A.P. Green Fireclay	1:2.85	327.92		.021	.029	.017	.027	.083		1	.041		2.85
Albany Slip Clay	1:4.44	462.93		.479	.304	.157	.06	.046	.004	1	.15		4.44
Alberta Slip	1:7.66	742.12		.785	.574	.230	.229			1	.219		7.66
Avery Kaolin	1:2.12	234.35				.026	.007	.002		1	.013		2.12
Barnard Clay	1:10.51	1343		.136	.227	.162	.123	.038		1	2.845		10.5
Bell Dark Ball Clay	1:3.58	368.23		.02	.018	.016	.006	.069		1	.023		3.58
Blackbird Clay	1:9.3	937.53		.045	.174	.204	.018	.079	.367	1	.860		9.33
C&C Ball Clay	1:3.51	327.16		.007	.018	.028	.012	.074		1	.023		3.51
Carbondale Red Clay	1:4.97	531.21	.005	.053	.085	.029	.051	.069	.002	1	.4	.003	4.97
Cedar Heights Bonding Clay	1:3.16	311.57		.012	.026	.063	.011	.069		1	.037		3.16
Cedar Heights Goldart	1:3.53	373.17		.015	.039	.074	.01	.082		1	.033		3.53
Cedar Heights Redart	1:7.11	626.27		.05	.26	.29	.04	.09		1	.29	.01	7.11
Edgar Plastic Kaolin	1:2.09	272.29		.006	.008	.012	.002	.01		1	.012	.002	2.09
Fremington Clay	1:5.04	507.14		.441	.5	.214	.036	.06		1	.19		5.04
Grolleg Kaolin	1:2.2	271.38		.005	.021	.009	.004	.001		1	.012		2.21
Hawthorn Bond Fireclay	1:2.51	268.80		.017	.023	.026	.005	.070		1	.033	.004	2.51

Continued

Clay Name	Al:Si	M.Wt.	BaO	CaO	MgO	K2O	Na_2O	TiO	MnO	Al_2O_3	Fe_2O_3	P2O5	SiO_2
Helmer Kaolin	1:2.22	283.33		.024	.018	.016	.004	.040		1	.023		2.22
Hymod A1	1:3.05	306.76		.012	.034	.101	.022	.043		1	.030		3.06
Hyplas 71	1:5.86	481.54		.009	.051	.103	.033	.109		1	.029		5.86
Jordan Fireclay	1:5.64	500.69		.014	.065	.033	.05	.075		1	.063		5.64
Kaopaque 20 Kaolin	1:1.56	253.14		.01	.002	.002	.001	.021		1	.005		1.96
Kentucky Special Clay	1:3	354.88		.023	.031	.035	.01	.066		1	.019		2.98
Kentucky Stone	1:5.51	492.75		.035	.037	.068	.016	.068		1	.043		5.51
KTS-2 Ball Clay	1:4.28	419.75		.022	.042	.058	.014	.074		1	.026		4.28
Lincoln 60 Fireclay	1:3.76	372.15			.006	.089	.022	.036		1	.05		3.76
Lizella Clay	1:4.8	488.93		.048	.098	.068	.048	.068		1	.154		4.82
New Foundry Hill Creme Clay	1:3.94	353.89		.014	.030	.030	.013	.070		1	.025		3.94
Ocmulgee Red Clay	1:4.2	401.5		.048	.034	.064	.027	.07		1	.187		4.2
OM #4 Ball Clay	1:3.36	365.59		.020	.036	.039	.018	.055		1	.025		3.36
PBX Fireclay	1:2.49	262.47		.017	.023			.05		1	.029		2.5
PBX Valentine Clay	1:2.5	278.74		.001	.019	.004	.002	.07		1	.125		2.49
Pine Lake Fireclay	1:3.64	338.13		.02	.009	.02	.018	.089		1	.035		3.64
Pioneer Kaolin	1:2.02	265.03		.009	.007	.003	.002	.047		1	.007		2.02
Plainsman Fireclay	1:3.49	332.19		.013	.009	.081	.059	.032		1	.034		3.49
Plastic Vitrox	1:8.64	686.51		.027	.034	.496	.032			1	.004		8.64
Ravenscrag Slip	1:8.28	686.42		.639	.339	.257	.058	.039		1	.04		8.28
Redstone	1:8.93	736.21		.028	.138	.202	.001	.06		1	.191		8.93
Remblend Kaolin	1:8.28	686.42		.639	.339	.257	.058	.039		1	.039		8.28
Sagger XX Ball Clay	1:3.3	349.68		.031	.026	.033	.017	.075		1	.015		3.30
Taylor	1:4.17	367.29		.003	.021	.022	.007	.092		1	.023		4.17
Tennessee #10 Ball Clay	1:2.67	309.89		.005	.015	.036	.01	.07		1	.015		2.67
Thomas Clay	1:3.8	443.58		.004	.019	.016	.005	.077		1	.025		3.81
TN#1-SGP Ball Clay	1:3.52	365.59		.013	.027	.047	.012	.069		1	.018		3.52
Troy Clay	1:2.51	261.54		.011	.015		.005	.046		1	.021		2.51
Velvacast Kaolin	1:2.01	265.76		.003	.011	.008	.004	.044		1	.004		2.01
Yellowbanks #401	1:3	294.24		.022	.079	0	.002	.034		1	.030		3

Feldspars Used in Ceramic Glazes and Clay Making

Feldspars are important ingredients in clay bodies and glazes. In both applications, their primary function is to supply fluxes to the formulations, but they also provide additional alumina (Al2O3) and silica (SiO2). Feldspars are naturally occurring minerals and are generally classified as either potash (potassium) or soda (sodium) feldspars based upon the predominant alkali metal element (the flux) that is present. The minerals commonly referred to as lithium feldspars are not true feldspars, but they are aluminosilicates like feldspars and contain the fluxing element lithium, and are used for the same purposes as the feldspars.

The following table presents typical chemical analyses (in weight percent) provided by the suppliers, for a number of common feldspar products and related materials. Most of the names are trade names, with the exceptions of lepidolite, petalite, and spodumene, which are true mineral names. Nepheline syenite is actually a rock composed of potash and soda feldspars plus the mineral nepheline (a sodium aluminum silicate). In the table, the trade names for the feldspars are grouped according to the actual type of feldspar that they contain. Distinguishing between the different types of feldspars based upon the fluxes that they provide is important because of the different characteristics that each of the fluxes contributes to a wide variety of properties such as melting point, thermal expansion, glaze color and hardness. For each analysis, the remaining percentage needed to bring the total of all the elements to 100% is the ignition loss (not shown in the table).

The analyses will allow you to compare the compositions of different raw materials when it is desirable to make substitutions in clay body and glaze recipes. The weight percent values will be useful in the conversion of glaze recipes from Seger molecular formulas to weight percent recipes when using these raw materials.

The theoretical formulas and molecular weights for the different types of minerals present in the products are as follows:

Potash feldspars	$K_2O \bullet Al_2O_3 \bullet 6SiO_2$	556.66
Soda feldspars	$Na_2O \bullet Al_2O_3 \bullet 6SiO_2$	524.45
Lepidolite	$(Li,Na,K)_2 \bullet (F,OH)_2 \bullet Al_2O_3 \bullet 3SiO_2$	(varies w/alkalis)
Petalite	$Li_2O \bullet Al_2O_3 \bullet 8SiO_2$	612.52
Spodumene	$Li_2O \bullet Al_2O_3 \bullet 4SiO_2$	372.18

However, all of these naturally occurring mineral products often contain additional minerals or elements as minor impurities, as can be seen in the table, and as a result, their calculated molecular weights will differ somewhat from the theoretical values. The final column in the table shows molecular weights calculated for each of the materials, based on the specific analysis shown (all the elements including the impurities). These specific molecular weights can be used, instead of the theoretical molecular weights given above, in the conversion of glaze recipes from weight percent to Seger molecular formulas. It should be kept in mind, however, that as the actual composition of the minerals varies with time and source, these calculated molecular weights will also change.

Feldspars We Use

The following table presents typical chemical analyses in weight percent, which will allow you to compare the compositions of different raw materials when it is desirable to make substitutions in clay body and glaze recipes.

Potash (Potassium) Feldspars

Name	SiO_2%	Al_2O_3%	K_2O%	Na_2O%	MgO%	CaO%	Li_2O%	TiO_2%	Fe_2O_3%	Calc. Mol. Wt.
Bell	68.2	17.9	10.1	3.1		0.4			0.1	607.69
Buckingham	66.3	18.4	11.8	2.7		0.4			0.1	566.44
Chesterfield	70.6	16.3	8.5	3.8		0.3			0.1	637.92
Clinchfield #202	68.3	17.6	10.9	2.6		0.2			0.1	616.44
Coles	69.0	16.9	10.8	2.7		0.5			0.1	597.00
Cornwall Stone	70.9	16.7	6.5	2.3		1.6		0.5	0.2	726.06
Custer	69.0	17.1	10.1	3.0		0.3			0.2	618.82
Del Monte	67.8	18.5	6.6	4.3		2.1			0.1	565.71
Eureka	69.8	17.1	9.4	3.5					0.01	638.85
Fukushima	65.4	19.2	9.8	4.6	0.2	0.3			0.1	526.34
G-200	66.5	18.6	10.8	3.0		0.8			0.1	560.19
Harshaw	65.4	19.6	12.1	2.2	0.3	0.4				558.82
Imperial	66.5	18.5	12.4	2.3		0.3				575.08
K-200	67.99	17.84	10.13	3.36		0.18			0.08	603.74
Keystone	64.8	19.9	12.2	2.5		0.2				575.92
Kingman	66.5	18.4	12.0	2.7		0.1			0.1	577.67
Kona A-3	71.6	16.3	7.8	3.7		0.4			0.1	667.52
Madoc	67.4	18.2	7.8	5.6		0.5			0.1	547.62
May	67.8	17.2	12.6	2.0		0.2			0.1	586.93
Oxford	70.6	17.3	8.1	3.3		0.4			0.1	686.70

Soda (Sodium) Feldspars

Name	SiO_2%	Al_2O_3%	K_2O%	Na_2O%	MgO%	CaO%	Li_2O%	TiO_2%	Fe_2O_3%	Calc. Mol. Wt.
C-6	67.5	19.0	5.4	6.8		0.9			0.1	543.93
Glaze Spar #54	67.1	21.2	1.5	9.1		1.1				548.41
Godfrey	71.7	16.5	4.6	5.3	0.9	1.0				570.18
Kona F-4	66.9	19.7	4.5	7.0		1.8				517.95
NC-4	68.5	18.9	4.1	6.9		1.4			0.1	557.18
Nepheline Syenite	56.5	24.2	9.1	8.1		0.1			0.1	404.80
Sil-O-Spar	77.6	13.5	2.9	4.9		1.1			0.1	781.96
Unispar 50	67.3	19.4	4.9	6.7		1.5			0.1	533.98

Lithium "Feldspars"

Name	SiO_2%	Al_2O_3%	K_2O%	Na_2O%	MgO%	CaO%	Li_2O%	TiO_2%	Fe_2O_3%	Calc. Mol. Wt.
Lepidolite	42.40	19.25	6.93	0.76			3.09		0.1	382.31
Lithospar	69.03	21.59	2.90	4.02		0.48	1.99			612.95
Petalite	77.13	17.50	0.26	0.25			4.32			655.86
Spodumene	64.50	26.00	0.10	0.30		0.10	7.60		0.1	376.28