OXIDE REFERENCE

Aluminum Oxide (Alumina) \( \text{Al}_2\text{O}_3 \)

Refractory / Stabilizer

Melting Point: 3722°F (2050°C)

Main Characteristics: Increases viscosity (stiffening), reduces fluidity and stabilizes the surface; without alumina the glaze will run off the pot (crystalline glazes); primary source of durability in glazes; controls the temperature of glaze melt

Color Response: Makes dull grayish colors; keep alumina low to get the best color response from alkali glazes (like copper reds)

CTE: Very low

Surface tension: Very high; too much alumina in a glaze can cause pinholes

Volatizes: No

Sources

Insoluble: Kaolin/clay, feldspar, frit, alumina hydrate, alumina oxide, etc.

Soluble:

Toxicity: No

Examples: Alumina mattes

Barium oxide \( \text{BaO} \)

Alkaline Earth Metal

Melting Point: 3493°F (1922°C); \( \text{BaCO}_3 \) starts to decompose at 1652°F (900°C) with reduction

Main Characteristics: Develops satin matte surfaces but with vivid colors; good flux at higher temperatures; forms eutectic with boron oxide which may cause running; barium carbonate is used in earthenware clay bodies to stop scumming
**Color Response:** Very bright; intensifies all colors; produces brilliant copper and cobalt colors; mottled, streaky satin surface

**CTE:** Moderate

**Surface tension:** Moderate

**Volatizes:** No

**Sources**

**Insoluble:** Barium Sulfate

**Soluble:** Barium carbonate (slightly soluble), frits (slightly soluble)

**Toxicity:** High (barium carbonate used in rat poison)

**Examples:** Barium blues

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**Boron Oxide** $\text{B}_2\text{O}_3$

**Glass former and flux** [Exception to the rule – Fits in several categories; powerful flux, looks like refractory ($\text{R}_2\text{O}_3$) but is a glass former.]

**Melting Point:** No melting point but a melting range from 572°F–1292°F (300°C–700°C)

**Major Characteristics:** Very useful and powerful flux at all temperatures; used in low-fire glazes including raku (cone 020 – 012)

**Color Response:** Similar to alkali fluxes; makes intense colors; milky, streaky blues with mottled and broken surfaces

**CTE:** has a very low CTE (less than 10%), which stops crazing but higher amounts may cause crazing

**Surface tension:** Low

**Volatizes:** No

**Sources**

**Insoluble:** Frits (slightly soluble)

**Soluble:** Borax, gerstley borate, colemanite, ulexite, Gillispie borate, Laguna borate, etc.

**Toxicity:** No
**Examples:** Blue flushing Milk Gloss 50/30/20 glaze (cone 6-8):
50 Gerstley Borate/or substitutes
30 Silica
20 Kaolin

**Calcium oxide** CaO

**Alkaline Earth**

**Melting Point:** 4658°F (2570°C); begins to melt 2012°F (1100°C)

**Main Characteristics:** Most dependable flux at all temperatures; lends hardness and durability and resistance to abrasion

**Color Response:** Low with most colorants; slight bleaching effect on iron

**CTE:** Intermediate

**Surface tension:** High

**Volatile:** No

**Sources**

**Insoluble:** Whiting is the major source (slightly soluble in water), dolomite, wollastonite, limestone, sea shells.

**Soluble:** Gerstley borate, Bone ash (natural and synthetic)

**Toxicity:** No

**Lithium oxide** Li₂O

**Alkaline Metal**

**Melting Point:** 1472°F (800°C)

**Main Characteristics:** Is the lightest, smallest and most powerful flux; similar to sodium and potassium; can be used in large amounts at low temperatures; at high temperatures, too much will cause shivering.

**Color Response:** Adding 1% brightens most colors considerably, increases gloss; adding 3% can drop one cone in temperature; blues with copper and pinks with cobalt oxide.
CTE: It has a low expansion contraction; if lithium is high in a glaze, you must watch out for shivering.

Surface tension: Low

Volatile: No

Sources

Insoluble: Lithium feldspars, spodumene and petalite, frits (slightly soluble)

Soluble: Lithium Carbonate, most common source, slightly soluble in water.

Toxicity: Yes

Examples: Shinos,
Karen Starshine (Cone 10 Glaze)

Custer Feldspar 51
Soda Ash 4
Gerstley Borate 6
Whiting 13
Strontium Carbonate 4
Lithium Carbonate 1
Silica 21
Total 100%

Add:
Titanium Dioxide 2
Copper Carbonate 5
Bentonite 3

Magnesium oxide MgO

Alkaline Earth Metal

Melting Point: 5072°F (2800°C); begins to flux 2138°F (1170°C) and gets stronger as temperature increases; MgCO₃ lets go of carbon dioxide at 662°F (350°C)

Main Characteristics: Produces beautiful matt surfaces (Sometimes called fatty mattes); produces lichen glazes because of high surface tension; produces tea-dust (pyroxene crystals) type glazes
Color Response: Modifies color toward pastel; it is a bad choice for bright colors; gives lavender with cobalt.

CTE: Low

Surface tension: High (lichen and beads glazes)

Volatizes: No

Sources

Insoluble: Talc, dolomite, magnesium carbonate (slightly soluble), some earthenware clays.

Soluble: Epson Salts (magnesium sulfate)

Toxicity: No

Examples: Crawl or lichen glazes, tea-dust temmokus, satin whites.

Phosphorous Oxide \( \text{P}_2\text{O}_5 \)

Glass former

Melting Point: 1076°F (350°C)

Major Characteristic: good melter at mid-range and high fire. Used in bone china.

Color Response: Creates variegated and mottled effects; bluish flush in chuns; used in tomato reds

CTE: Moderate

Surface tension

Volatizes: No

Sources

Insoluble

Soluble: Bone Ash (natural), Synthetic Bone Ash (TCP – tri-calcium phosphate), wood and plant ash, etc.

Toxicity: No

Potassium Oxide \( \text{K}_2\text{O} \) (Kalium Oxide)
Alkaline Metal

**Melting Point:** 1382°F (750°C)

**Main Characteristics:** Strong alkaline flux similar to sodium and lithium; slightly less active flux than sodium oxide, but does not volatilize like sodium oxide: the two almost always occur together (KNaO)

**Color Response:** Adds brilliance and intensity although not as much as lithium: celadon iron blue glazes work best with potassium, as do temmoku and rust glazes, but they can be made with soda feldspars

**CTE:** Second highest expansion/ contraction; large amounts can lead to crazing

**Surface tension:** Low

**Volatizes:** No

**Toxicity:** No

**Sources**

**Insoluble:** Potassium Feldspars-Custer Feldspar, Cornwall Stone, G-200, G-200 HP (high potassium), Sodium Feldspars (all contain some potassium), Frits (slightly soluble), etc.

**Soluble:** Potassium carbonate (pearl ash), contains 68% potassium oxide

**Examples:** Blue Celadon, Temmoku

**Silica SiO₂**

**Glass former**

**Melting Point:** 3110°F (1710°C)

**Major Characteristic:** the most abundant element on earth and the most important glass-forming oxide; with alumina, helps control the maturing temperature of a glaze; gives rigidity and durability, as well as tensile strength and acid resistance to glazes

**Color Response:** Insignificant

**CTE:** Low CTE as a amorphous glass (when melted) but high when in crystal form (or as cristobalite)

**Surface tension:** Moderate
Volatizes: No

Sources

Insoluble: silica, sand, feldspar, kaolin, frit, talc, wollastonite, etc.

Soluble:

Toxicity: No, in a glaze but as a dust/powder – Yes!

Examples: Silica matte

**Sodium oxide** Na₂O (Natrium Oxide)

Alkaline Metal

Melting Point: 1652°F (900°C); begins melting around 1472°F (800°C)

Main Characteristics: Strong flux; similar to other alkaline fluxes, potassium and lithium, but slightly stronger flux than potassium

Color Response: Adds brilliance and intensity; strong color response; blues from copper, purples from cobalt and manganese and yellow or blue from iron

CTE: It has the highest coefficient of expansion/contraction of all fluxes; can result in crazing in glazes that are low in alumina and silica

Surface tension: Low

Volatizes: above 2192°F (900°C)

Toxicity: No

Sources

Insoluble: Soda Feldspars, (somewhat soluble), Potassium Feldspars (all contain some sodium), frits (somewhat soluble)

Soluble: Nepheline Syenite, Soda Ash, Sodium Bicarbonate, Borax

Examples: Carbon Trap Shino, Sodium Blue, Egyptian Paste

**Strontium oxide** SrO
Alkaline Earth Metal

**Melting Point:** 4406°F (2430°C); starts fluxing at 1994°F (1090°C); lets go of carbon dioxide at 1967°F (1075°C); can cause pinholing

**Main Characteristics:** adds strength and durability to glazes; good auxiliary flux at all temperatures but at low temperatures, should be supplied by a frit; used for micro-crystalline mattes

**Color Response:** Produces bright matte surfaces similar to barium oxide but with no known toxicity; slightly more intense than calcium

**CTE:** Moderate

**Surface tension:** Moderate

**Volatile:** No

**Sources**

**Insoluble:** Frit (slightly soluble)

**Soluble:** Strontium carbonate (slightly soluble)

**Toxicity:** No known toxicity

**Examples:** Strontium glaze

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**Tin oxide SnO\textsubscript{2} (Stannic oxide; Stannous Dioxide)**

**Opacifier**

**Melting Point:** 2102°F (1150 °C) – Tin the metal melts at 450°F (232°C)

**Major Characteristic:** most common opacifier at 3 – 5%; twice as strong as zirconium opacifiers

**Color Response:** produces soft tin whites as opposed to refrigerator whites of zirconium; intensifies copper reds; chrome/tin pinks and burgundy at cone 6; can combine with other oxides produce unwanted effects, like copper pinks, chrome pinks, etc.; over-reduction at high temperatures causes it to lose its opacifying effect and gives speckled greys; at low temperatures gives tin lusters

**CTE:** Low
**Surface Tension**: Medium

**Volatile**: No

**Sources**

**Insoluble**: Tin oxide

**Soluble**

**Toxicity**: No

**Examples**: Majolica

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**Titanium dioxide** $\text{TiO}_2$

**Opacifier**

**Melting Point**: 3326°F (1830°C)

**Major Characteristics**: Give opacity and soft crystalline matt; seed crystals in macro-crystalline glazes

**Color Response**: Makes milky blue/white flush, variegated and opaque surfaces; modifies colors from Cr, Mn, Fe, Co, Ni, etc.; gives yellows with iron

**CTE**: Medium

**Surface Tension**: Medium

**Volatile**: No

**Sources**

**Insoluble**: Titanium dioxide, rutile (dark), granular ilmenite and light rutile.

**Soluble**

**Toxicity**: No

**Examples**: Crystalline, Nuka like

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**Zinc oxide** $\text{ZnO}$
Metal

**Melting Point:** 3587°F (1975°C) but Zinc the metal melts at 768°F (409°C); above 1742°F (950°C) zinc oxide can be reduced to Zinc the metal in reduction atmosphere and will volatilize as a gas.

**Main Characteristics:** Secondary/auxiliary flux, creates crystalline effects, lends strength, durability and some opacity to glazes; alternative to lead oxide.

**Color Response:** “Zinc makes ink” is the old time phrase potters often used but more appropriate is “zinc makes dramatic color response.” Either turns glazes brownish or brightens like in macro-crystalline glazes. Good with copper greens bad with chrome greens (turn them brown).

**CTE:** Medium to low

**Surface tension:** Medium

**Volatizes:** Yes

**Sources**

**Insoluble:** Zinc Oxide and Calcined Zinc Oxide

**Soluble**

**Toxicity:** Yes

**Examples:** Crystalline