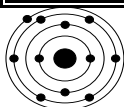


Ceramic Materials Guide

Guide to this table:

Material Raw formula Molecular wt.	Fired Formula	Equivalent Wt.	Fired Element Contribution	Function	Comments
Raw materials in forms that exist in nature	The compound formed from the raw materials after firing	The weight to determine ONE molecule of the desired element in the fired form	A list of elements this material contributes to the fired glaze.	How those elements function in ceramics glazes	Information about the material, its uses, effects.



Sodium



Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
alumina oxide Al ₂ O ₃	102	Al ₂ O ₃	102	Al	Viscosity	Hydrate form often used for wadding for vapor glazing. Also supplied in calcined form. Refractory. Used in wax resist to wax pot galleries, etc. and keep highly-fluxed clays from sticking to each other in firing.
alumina hydrate Al ₂ (OH) ₆	156	Al ₂ O ₃	156	Al	Viscosity	
Albany slip clay 0.059 Na ₂ O 0.156 K ₂ O 0.309 MgO 0.476 CaO 0.659 Al ₂ O ₃ 4.42 SiO ₂ 0.023 TiO ₂ 0.15 Fe ₂ O ₃ 2.399 H ₂ O	459.3	Same but w/o the 2.399 H ₂ O		Fe Ca, Mg, & KNa O Al Si	Colorant Flux Viscosity Glassfrmr	A slip glaze clay at high fire temperatures. No longer mined. Try using Blackbird or Barnard (slightly more fluxed), or Alberta Slip, see Oct. '88 CM article on substitutions: dolomite 9, soda ash 1, Redart 90.
antimony oxide Sb ₂ O ₃	292	Sb ₂ O ₃	292	Sb	Colorant	Colorant. Weak white, yellow w/lead. Used to make Naples yellow. Highly toxic by inhalation.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
barium BaCO ₃ carbonate	197	BaO	197	Ba	Flux	Alkaline earth flux, active primarily at high temps. Carbonate toxic if ingested or inhaled. No evidence of absorption thru unbroken skin. See Ceramics TECHNICAL no. 3, 1996 p. 66, J. DeBoos. May leach in high Ba or unstable glazes. Not suggested for food wares. Makes satin matts except w/boron. BaSO ₄ is almost completely insoluble and not a significant toxin. Secondary flux. ½% in earthenware clay bodies to prevent scumming. High Ba + Cu = matt blues in oxidation or reduction.
BaSO ₄ sulfate	233.4	BaO	233.4	Ba	Flux	
bentonite Al ₂ O ₃ •4SiO ₂ •H ₂ O	360.4	Al ₂ O ₃ • 4SiO ₂	360.4	Al Si	Viscosity Glassfmr	Volcanic, clay-like. Add up to 2% to help counter settling in glaze w/o changing fired result, or as a plasticizer in clay bodies. Bloats in water: add to dry ingred. first & mix, then add water.
bone ash Ca ₃ (PO ₄) ₂	310	CaO	103	Ca + trace s of Mg, Al, Fe	Flux	Calcium phosphate. P burns out in firing, promotes red-brown Fe colors. May give milky, mottled glaze color & encourages breaking from high spots. Secondary flux. Body flux in bone china. W/tin, less tin needed to opacify. May cause crawling & blistering due to boiling during firing. Can make lowfire foam glazes at about 20%.
borax (soluble) Na ₂ O•2B ₂ O ₃ •10H ₂ O	382	Na ₂ O•2B 2O ₃	382	B, Na	V, Flux Flux.	Soluble. Gives bright alkaline color. Sometimes used w/salt in vapor glazing for lower-firing, glassy glaze.
boric acid (soluble) B ₂ O ₃ •3H ₂ O	124	B ₂ O ₃	124	B	F, V	Soluble source of boron. Toxic raw.
cadmium carbonate CdCO ₃ sulfide CdS	172.4 144	CdO		Cd	Colorant	Not useful for the studio potter in raw form. Oranges and reds in low-fire stains with a limited firing range, burns out to grey above 05. Toxic raw, toxic fumes in firing. New "inclusion" stains encapsulate Cd in Zr to stabilize (will go to cone 10) and reduce solubility. Do not ball mill inclusion stains.
Cadycal						Calcium borate mineral produced by Fort Cady Minerals Corp of Newberry Springs, CA. Twice as much boron as Gerstley. GB glazes depend on its thixotropic properties for suspension, hardness and flow properties, but Cadycal will not impart these.
calcium carbonate CaCO ₃	100	CaO	100	Ca	Flux	Whiting, chalk, lime, limestone. Main source of Ca (alkaline earth flux) for glazes. Helps produce hard glazes. Excess matts.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
china clay $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$	258	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	258	Al Si	Viscosity Glassfmr	see clay
chromium oxide Cr_2O_3 raw form green	152	Cr_2O_3	152	Cr	Colorant	Most common color = opaque, dense green. Cr + Zn = brown. Small amts. Cr + high tin = pink. Cr + Pb = orange, red, or yellow. Cr + alkaline flux = yellower green. Refractory, but volatile over about 1800° F, so it may fume high (5%+) tin glazes to pinking. May cause skin and respiratory irritation. See sources of Cr: iron chromate, lead chromate. Colorant in well-know Otto's Texture sculpture glaze.
clay $\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2 \cdot 2\text{H}_2\text{O}$ ideal formula	258	$\text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2$	258	Al Si	Viscosity Glassfmr	China clay, kaolin are purest forms. Other clays may also contribute iron and trace minerals. May be added to glazes to raise the melting point, reduce flow, and eventually matt. Some clay in glaze aids application of raw glaze. Ball clay used to make harder raw surface for better handling before firing. For a raw glaze that cracks in drying, add part of the clay as calcined clay. Toxic if inhaled: inhalation of dry clay can cause silicosis (from free silica in clay) or kaolinosis of the lungs.
CMC gum see CM May'98 p92 by Pinnell.		Organic; burns out		Burn s out	Condition- er for raw glaze applica- tion.	Sodium carboxymethylcellulose. Organic gum used as a binder, surface hardener, and plasticizer. Aids brushability, counters settling in glazes. Decomposes in solution unless a preservative is added, e.g. formaldehyde, Canguard, Vancide (available from some ceramic suppliers). Excess CMC can cause crawling. Available in powder or liquid form (syrup). Slake ½ cup dry CMC to 5 ½ cups boiling water overnight, then mix in a blender. Will be thick. Thin to a heavy syrup.
cobalt carbonate CoCO_3 (lavender raw)	119	CoO	119	Co	Colorant	Strong colorant. Melts at low-fire temperatures. Expensive. Carbonate form (lavender raw) slightly weaker, disperses better than oxide form (black raw). Cobalt sulfate is a soluble form, toxic. Gives strong blue colors, transparent if dilute. Ultramarine w/alkaline fluxes. Purple w/ Mg. Green w/Ti. Screen glazes containing Co well to avoid spotting. Concentrated use of Co spits in firing, leaving blue halos on kiln shelves and adjacent wares.
oxide Co_3O_4 (black raw)	241	CoO	80	Co	Colorant	
sulfate (soluble) $\text{CoSO}_4 \cdot 7\text{H}_2\text{O}$ (lavender crystals raw)	281	CoO	281	Co	Colorant	
colemanite $2\text{CaO} \cdot 3\text{B}_2\text{O}_3 \cdot 5\text{H}_2\text{O}$	412	$\text{CaO} \cdot 1.5 \text{B}_2\text{O}_3$	206	Ca B	Flux Viscosity/ Flux	Calcium borate. Occurs in CA and NV. See gerstley borate. No longer available. Substitute Gerstley borate.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Contr.	Function	Comments
copper carbonate CuCO_3 (gray-green to turquoise raw)	124	CuO	124	Cu	Colorant	Toxic. Melts at low-fire temperatures, so may also flux in higher amts at hi temps. Volatile above cone 8. Carbonate (green raw) weaker but disperses better than oxide form (black raw). Red copper oxide does not mix w/water. Copper sulfate (a.k.a. blue vitriol) is soluble & toxic, equivalent to 28% of CuO . Red in reduction. Green to green-blue oxidized. $\text{Cu} + \text{alkaline flux} = \text{turquoise}$, $\text{Cu} + \text{Pb} = \text{transp. grass green}$. High amounts give gun-metal greys. Copper red info: Studio Potter magazine v.8 no.1 . Clay Times v.4 # 6 Nov/Dec. '98 Pt 1 and Jan./Feb. '99 v.5 no. 1 pt. 2 article on firing Cu reds by Pete Pinnell.
oxide black CuO	80	CuO	80	Cu	Colorant	
oxide red Cu_2O	143	CuO	70.6	Cu	Colorant	
sulfate $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$	223.3	CuO	223.3	Cu	Colorant	
cornwall stone .304 CaO • .340 Na_2O • .356 K_2O • 1.075 Al_2O_3 • 8.10 SiO_2	667	same	667	Ca, KNa O Si Al	Flux Glassfrm Viscosity	Similar to feldspar, but w/ higher proportion of silica than spar. Variable. May contain fluorine. Variable material. Melting range 2100° F to 2450° F, depending on the sample. For greater accuracy, obtain an analysis of the specimen being used. According to Hamer, de-fluorinated cornish stone is known as D.F. stone. Also according to Hamer, Cornwall stone has less surface tension than feldspar in the melted state and is sometime used in place of spar to prevent crawling.
crystoballite				Si	Glassfrm	Form of silica. Formed from free silica above about 1938°. Inversion of about 3% smaller at 439° F.
crocus martis FeSO_4	311.6	Fe_2O_3	623.2	Fe	Colorant	Natural form of iron, purplish raw. $2\text{FeSO}_4 \rightarrow \text{Fe}_2\text{O}_3 + \text{SO}_3(\text{gas}) + \text{SO}_2(\text{gas})$ Alone, dissociates at 2192°F. May give darker browns than red iron and black w/cobalt in glazes. Gives purplish-brown colors in sigillata: 1 cup liquid white sig base + 1 tsp. crocus martis.
cryolite $\text{Na}_3 \cdot \text{AlF}_6$	210	$3\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3$	420	Na Al (F)	Flux Viscosity	Sodium aluminum fluoride. Secondary flux, alkaline color response. May cause boiling of glaze and pinholes from F gas released in firing. Used in the production of opal glass, forms low-melting eutectics, potentially supplying alumina in low-melting form.
dolomite $\text{CaCO}_3 \cdot \text{MgCO}_3$	184	$\text{CaO} \cdot \text{MgO}$	184	Ca, Mg	Flux	Calcium magnesium carbonate. Hi temp flux. Ca and Mg properties: soft, buttery matts, pastels colors, gives purple colors w/Co due to Mg.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
Epsom salts magnesium sulfate MgSO ₄ •7H ₂ O				Mg		Epsom salts. Soluble. Used in small amounts (e.g. 1 tbs per 10,000 grams of wet glaze) as a flocculent to help keep glazes from settling. See Hamer for discussion of flocculation. Not generally used as a glaze source of Mg in glazes due to amount of S and action as flocculent.
feldspar KNaO• Al ₂ O ₃ • 6 SiO ₂ Idealized formula	556 K 524 Na	same	556 K 524 Na	K, Na or Li Si Al	Flux Glassfmr Viscosity	Common mineral in crystalline rocks. Flux: alumina: silica ratio approx. 1:1:6. Custer is a K spar, Kona F-4 a Na spar, Spodumene a Li spar. Used to flux clays and glaze at high temps. Most commercial feldspars have traces of Fe and Mg.
flint SiO ₂	60	SiO ₂	60	Si	Glassfmr	Silica, quartz. Major glass-former. Undergoes quartz inversion of 2% at 1000° F. Over 1938° F free silica may form cristoballite, which undergoes 3% inversion at 439° F.
fluorspar CaF ₂	78	CaO	78	Ca	Flux	Calcium fluoride. Fluorine burns off in firing, may cause boiling and pin-holing over 5%. Fluid melts at low temps. May cause unusual blues w/Co and Cu. According to Ceramic Industry: "During firing fluorspar in contact w/silica and clay is thought to dissociate into gaseous SiF ₄ . The volatile fluoride may in time promote destruction of kiln refractories."
frit various formulas. See mfg info				varie s	F. G. V	Man-made fluxes that melt between 1400-1700°F. Ferro, Pemco, O'Hommel companies make a variety of frits for low-fire temperatures. See published lists or mfg. specification for contents and substitutions. Ferro 3300 and 3400 and Pemco Pb series contain Pb (lead).
galena PbS	239.3			Pb	Flux	Lead sulfide. Toxic.
gerstley borate Na ₂ O .177• CaO.823• B ₂ O ₃ .886 • SiO ₂ .658	213.3	same	213.3	Ca, Na B Si	Flux V, Flux Glassfmr	Substitute for colemanite. Named after a Calif. man who operated a colemanite mine. Boron is both flux and viscosity agent. Thixotropic. Mining ceased in 1999. See DigitalFire web page for info on substitutions: http://digitalfire.com/education/material/gerstley.htm
ilmenite FeO•TiO ₂		same		Fe Ti	Colorant Opacifier	Opaque black mineral raw. In granular form, causes speckles. Effects similar to rutile, but more Fe. Contains less than 85% titanium. Refractory. Melting point 2489 degrees F.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Contr.	Function	Comments
Iron oxide black FeO (ferrous)				Fe	Colorant	Melts at low-fire temperatures. Red iron is finer in particle size than black. Iron is usually tan to brown to red-brown in oxidation, but can also be amber in lead glazes, or glazes w/ Ba or Sr. Yellow to olive in high alkaline glazes. In reduction 1-6% w/calcium phosphate gives blues, ½ -3% with some calcium gives celadons, 10-15% Temmoku. See other forms of iron: crocus martis, ochre, umber.
oxide red Fe ₂ O ₃ (ferric)				Fe	Colorant	
chromate FeCrO ₄	172	FeCrO ₄	172	Fe, Cr	Colorants	
kaolin Al ₂ O ₃ •2SiO ₂ •2H ₂ O	258	Al ₂ O ₃ •2SiO ₂	258	Al Si	V Glassfmr	See clay. For generic uses of kaolin, EPK is often used.
lead carbonate 2PbCO ₃ •Pb(OH) ₂	775	PbO	258	Pb	Flux	Metallic flux. Soft glazes, easily abraded or attacked by acids. Toxic, accumulative poison, esp. by ingestion or inhalation. May leach from fired glaze in the presence of acid foods. White, red, and yellow lead, galena, litharge and lead chromate are sources. Lead frits are safer to handle in studio than raw lead. Final safety of a glaze depends on glaze chemistry. Active at low temp - cone 6. Blisters if reduced. Volatilizes in firing, boils off by cone 6. Pb + Cu = transparent grass green. Pb + Fe = amber. Pb + Cr = yellow, red, orange. Pb + Cd = red.
Monosilicate 3PbO•2SiO ₂	789	same	263	Pb Si	Flux Glassfmr	
oxide litharge	223	PbO	223	Pb	Flux	
oxide red Pb ₃ O ₄	684	PbO	228	Pb	Flux	
lepidolite .55Li ₂ O•.39K ₂ O•.06Na ₂ O•Al ₂ O ₃ •3.74SiO ₂	383	same	383	Li, Na Si Al	Flux Glassfmr. Viscosity	
lithium carbonate Li ₂ CO ₃	74	Li ₂ O	74	Li	Flux	Active low - high temperatures. Alkaline flux. Low coefficient of expansion. Soft glaze, may produce matt crystals. May cause shivering in excess. Lithium carbonate will deflocculate glazes and cause them to settle in the bucket.
Macaloid Li ₂ O•MgO•SiO ₂				Li, Mg Si	Flux Glassfmr	Synthetic version of bentonite. More expensive. Doesn't bloat in water so can be directly mixed into liquids. Used as a glaze additive.
magnesium carbonate MgCO ₃	84	MgO	84	Mg	Flux	Source of Mg, alkaline earth flux. High temp flux. Buttery matts, pastels colors. + Co = purple.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
magnesium sulfate MgSO ₄ •7H ₂ O				Mg	Flux	Epsom salts. Soluble. Used in small amounts (e.g. 1 tbs per 10,000 grams of wet glaze) as a flocculent to help keep glazes from settling. See Hamer for discussion of flocculation. Not generally used as a glaze source of Mg in glazes due to amount of S and action as flocculent.
manganese dioxide MnO ₂	87	MnO	87	Mn	Colorant	Toxic. Carbonate is weaker but disperses better than oxide or dioxide form. Browns. Toward purple w/alkaline flux, lead. Used fritted w/alumina to make pink stain (Mason 6020, which is refractory and goes to cone 10). Can be metallic in high amounts with copper, e.g. Reynolds Gold Metallic glaze.
carbonate MnCO ₃	115	MnO	115	Mn	Colorant	
nepheline syenite .75Na ₂ O•.25K ₂ O• 1.11Al ₂ O ₃ • 4.65SiO ₂	477	same	477	KNa Si Al	Flux Glassfmr. Viscosity	Similar to feldspar but more KNa to Si(spar has flux:alumina:silica ratio of 1:1:6; neph sy is 1:1:4 ratio), so it melts lower than spar. Traces of Ca and Mg. Popular for mid-range materials. Somewhat soluble, deflocculates clays and glazes. Try substituting 5-6 parts spar + one part talc for the neph sy in mid-range bodies to avoid the deflocculating effect. Substituting neph sy for spar would be a place to begin testing lowering a hi-temp glaze to mid-range.
nickel oxide (green) NiO	75	NiO	75	Ni	Colorant	Toxic. Carbonate and oxide (black or green raw) forms. Used to produce subdued green, grey, brown, or blue. and to modify other colors (e.g. mute cobalt blues). In high Mg glazes, acid green may develop. In high Ba glazes, pink to purple.
oxide (black)Ni ₂ O ₃	166	NiO	83	Ni	Colorant	
ochre various formulas				Fe	Colorant	A natural source of iron (about 50%), mixed with clay and sand. May also contain manganese. Weaker than using iron. Come in Yellow, reds, or browns.
pearl ash K ₂ CO ₃	138	K ₂ O	138	K	Flux	Potassium carbonate. Soluble source of potassium. Deflocculates clay slips. Slightly caustic.
petalite Li ₂ O• Al ₂ O ₃ • 8SiO ₂	612	same	612	Li Al Si	Flux Viscosity Silica	Lithium-aluminum silicate. M.p. 2552°F. Considered a lithium-fluxed feldspar. Low thermal expansion when heated above 1832°F. Used as an auxiliary body flux to reduce thermal expansion and increase shock resistance. Source of lithium for glazes. Similar to spodumene, which contains less silica, and lepidolite, which provides less silica and lithium + KNaO.
plastic vitrox .045CaO•.058MgO• .054Na ₂ O•.842K ₂ O• 1.693 Al ₂ O ₃ • 14.634SiO ₂	1139	same	1139	Ca KNa Si Al	Flux Glassfmr. Viscosity	Resembles feldspar, but has more silica to flux and alumina than spar. Idealized formula is 1RO•1.69 Al ₂ O ₃ •14.64 SiO ₂ mol wt 1139

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
potassium dichromate (bright orange raw) K ₂ Cr ₂ O ₇	294	K ₂ O•Cr ₂ O ₃	294	Cr K	Colorant Flux	Very toxic. Soluble. Olive greens generally, behaves like chrome w/ fluxes. Used in glaze to produce Cr-Sn pinks. In glazes w/o Sn or Zn, gives olive drab colors.
potassium carbonate K ₂ CO ₃	138	K ₂ O	138	K	Flux	Pearl ash. Soluble source of potassium. Deflocculates clay slips. Slightly caustic.
praseodymium oxide PrO ₂	172.9	PrO ₂	172.9	Pr	Colorant	Toxic. Colorant used to make brilliant yellow stains. Stable @ high temps in oxidation or reduction.
pyrophyllite Al ₂ O ₃ • 4SiO ₂ • H ₂ O	360	Al ₂ O ₃ • 4SiO ₂	360	Si Al	Glassfmr. Viscosity	Decreases thermal expansion.
quartz				Si	Glassfmr.	see flint
rutile TiO ₂		TiO ₂		Fe Ti	Colorant Opacifier	Broken opaque color, crystals from Ti. Iron, other impurities (Cr, V) present. Suppliers sometimes carry light and dark varieties of rutile. Dark contains more iron. Contains up to 15% impurities. At least 85% titanium dioxide. Less iron than ilmenite. Considered an impure form of titanium.
salt NaCl				Na	Flux	Soluble. See sodium chloride.
silica SiO ₂				Si	Glassfmr.	Flint, quartz. Glass-former.
silicon carbide SiC	40.07			Si	Glassfmr.	Also known as carborundum. Causes local reduction if fine (200 mesh)(.5%), crater glazes if coarse (2-5%?).
sodium silicate Na ₂ O•SiO ₂						Water glass. Strong deflocculant. Usually sold in liquid form. Water glass is used as a glue, to preserve eggs w/o refrigeration, and as a fireproof. M.p. of various forms: 1112° - 1922°F. According to Hamer, sodium silicate combined w/carbon dioxide in the air = sodium carbonate and silicic acid that no longer deflocculates. Store in an air-tight container.
soda ash sodium carbonate Na ₂ CO ₃	106	Na ₂ O	106	Na	Flux	Soluble sources of sodium. Alkaline flux, high coefficient of expansion causes crazing in high amounts, brilliant color response. Sodium makes a mechanically soft glaze as a major flux. Deflocculates.
sodium chloride salt NaCl	58.5	Na ₂ O	58.5	Na	Flux	Na + Co ultramarine. Na + Cu = transp. turquoise Na + Cr + chartreuse. Na + Mn = plum. Used as rock salt in salt-glazing where Na combines w/the silica in clay to form a hard, durable glaze.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
spodumene $\text{Li}_2\text{O}\cdot\text{Al}_2\text{O}_3\cdot 4\text{SiO}_2$	372	same	3725	Li Si Al	Flux Glassfmr Viscosity	Lithium feldspar. Reduces thermal expansion. Good for ovenware clay bodies. In glazes too much may cause shivering due to low expansion of Li.
strontium carbonate SrCO_3	148	SrO	148	Sr	Flux	Alkaline earth flux. Test 0 .75 SrCO_3 to replace 1 barium carb in glazes for less toxic ingredient.
talc $3\text{MgO}\cdot 4\text{SiO}_2\cdot \text{H}_2\text{O}$	378	$\text{MgO}\cdot 1.3\text{SiO}_2$	126	Mg Si	Flux Glassfmr.	Magnesium silicate. Secondary flux. Often a body flux at low temps, due to eutectic amounts of ingredients. Reduces crazing. Smooth, buttery glaze surfaces, Mg color responses. Chronic inhalation causes lung scarring. Some talcs may be contaminated by asbestos or asbestos-like minerals. Check with your supplier.
tin oxide SnO_2	151	SnO_2	151	Sn	Opacifier	Stannic oxide. Opacifier. High tin (over about 5%) + small amts. Cr = pink. + Fe = orange to red. High tin may cause crawling. Buttery surface. 1 tin = 1.5 zirconium opacifier in strength. Opacifier in historic majolica glazes.
titanium dioxide TiO_2	80	TiO_2	80	Ti	Opacifier	Opacifier. Often produces crystalline matts. + Co = green. W/Cu reds = toward purples. 2% added to glaze can give microcrystalline formations & interesting colors. 1 TiO_2 + 1 Gerstley borate (by vol) used as a "patina" over fired terra sigillata is ivory to light yellow.
umber various formulas				Fe, Mn	Colorant	Contains iron + manganese. Raw umber is unheated. Burnt umber is calcined.
uranium oxide U_3O_8	842			U	Colorant	Toxic. Yellow, red, orange colors with lead. Yellow w/alkaline flux. Rarely used. Unavailable for casual use.
vanadium pentoxide V_2O_5	181.8	V_2O_5	181.8	V	Colorant	Weak yellow colorant, stronger source of yellow color when made into a stain with tin or zirconia. Inhalation and ingestion hazard.
whiting CaCO_3	100	CaO	100	Ca	Flux	Calcium carbonate, chalk, lime, limestone. Main source of Ca (alkaline earth flux) for glazes. Helps produce hard glazes. Excess matts.
wollastonite $\text{CaO}\cdot\text{SiO}_2$	116	same	116	Ca Si	Flux Glassfmr.	A calcium silicate. May be used to replace whiting and flint. Helps reduce pin-holing from whiting.

Material Raw formula	Mol. Wt.	Fired Formula	Eq. Wt.	Fire d Cont r.	Function	Comments
zinc oxide ZnO	81	ZnO	81	Zn	Flux	Metallic flux, mid- high temps. In large amts. (Over 25%) may cause crawling, pin holes, dry surfaces, opacity. Calcining the Zn may help prevent shrinkage during early heating that promotes crawling. Potential for sculpture glaze use. Zn + Cr= brown. Zn good for Co blues. Completely volatilized in cone 10 reduction, so it does not contribute as a flux to the fired glaze. See ClayArt archives for discussion.
zirconium oxide ZrO ₂	123	ZrO	123	Zr	Opacifier	Opacifies. Produces harder glaze than Sn or Ti. Less strong than tin (general rule: 1 Sn = 1.5 Zr opacifier). Trade names: Ultrox (all temps., stronger than Zircopax. 6% = white), Superpax, Zircopax (all temps., 5-10% = white), Opax (best at lower temps.).

It is recommended that ceramic artists familiarize themselves with potential hazards in materials. The above information does not fully cover this.

Resources for art material hazard information::

McCann, Michael. *Artist Beware*, 2nd ed. Lyons & Burford Publ., NY, 1992. ISBN 1-55821-175-6

Rossol, Monona. *The Artist's Complete Health and Safety Guide*. Allworth Press, NY, 1990. ISBN 0-927629-10-0

WWW:

Center for Safety in the Arts: <http://www.artswire.org:70/1/csa>

CeramicsWeb: Richard Burkett's San Diego State Univ. **World Wide Web site** of ceramics information, ClayArt archives, GlazeBase glaze data base, materials database and more. Many links to items of interest to Ceramics people: <http://art.sdsu.edu/ceramicsweb/>

ClayArt Archives Archived, searchable site of discussions from ClayArt. Many technical resources.

<http://lsv.uky.edu/archives/clayart.html>

Resources for ceramics materials information:

Ceramics Industry magazine, January Materials Issue. See web site: <http://www.ceramicindustry.com/>

Ceramic Materials listings from Digital Fire: <http://digitalfire.ab.ca/ceramat/material/a.html>

Green, David, *A Handbook of Pottery Glazes* Advanced technical reference.

Hamer, Frank, *A Potters Dictionary of Materials and Techniques* Excellent general source for specific information on materials, processes, and more. Highly recommended.

Hopper, Robin, *Ceramic Spectrum* A non-calculation approach to glaze development.

Lawrence, *W.G. Ceramic Science for the Potter* (out of print) Advanced technical reference.

McKee, Charles, *Ceramics Handbook*. Paperback. Inexpensive handbook.

Rhodes, Daniel, *Clay and Glazes For the Potter* In -depth explanations. Good resource but sometimes biased toward high-fire reduction.

Ceramic Glaze Calculation programs: see article by Rick Malmgren in Ceramics Mo. Jun/Jul/Aug '98 v.46 no. 6 for a range of programs and analysis of them.

CeramicsWeb

Richard Burkett's San Diego State Univ. **World Wide Web site** of ceramics information, ClayArt archives, GlazeBase glaze data base, materials data base and more. Many links to items of interest to Ceramics people. <http://art.sdsu.edu/ceramicsweb/>

GlazChem

<http://www.dinoclay.com/software/glzchem.html>

Bob Wilt's glaze calculation program Windows users. Shareware. Free download to try. \$25.00 registration fee. "GlazeChem is a ceramic glaze database, analysis, and calculation program. GlazeChem will help you to keep your glaze recipes and test results organized, will show you their chemical and cost analyses, and will assist in making substitutions, changing recipe sizes, performing batch calculations, fixing glaze fit problems, and adjusting glazes to new firing ranges. GlazeChem has extensive online help and a tutorial." E-mail Bob Wilt: rjw@studiopotter.org

Hyperglaze IIx

Richard Burkett
6354 Lorca Dr.
San Diego, CA 92115

<http://hyperglaze.com>

Excellent glaze calc and data program that runs on ALL computers: Windows, Macintosh, Linux.

Ordered directly from the author for \$100., include name, address, email and phone #, and type of computer. E-mail :

hyperglaze@sbcglobal.com

IMC web site

<http://digitalfire.com>

Diverse technical resource page from Tony Hansen, author of Insight glaze calculation program et. al. Page with interesting articles on glazes.