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 fifing	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.

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

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
Albany slip clay 0.059 Na_2O• 0.156 K_2O• 0.309 MgO• 0.476 CaO• 0.659 Al_2O_3• 4.42 SiO_2• 0.023 TiO_2• 0.15Fe_2O_3• 2.399 H_2O	459.3	Same but w/o the 2.399 H2O		Fe Ca, Mg, & KNaO 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.
alumina oxide Al_2O_3	102	Al_2O_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_2O_3	156	Al	Viscosity	
antimony oxide Sb_2O_3	292	Sb_2O_3	292	Sb	Colorant	Colorant. Weak white, yellow w/lead. Used to make Naples yellow. Highly toxic by inhalation.
barium carbonate $BaCO_3$	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. DISPOSE OF AS A HAZARDOUS WASTE.
sulfate $BaSO_4$	233.4	BaO	233.4	Ba	Flux	
bentonite Al_2O_3•$4SiO_2$•H_2O	360.4	Al_2O_3• $4SiO_2$	360.4	Al Si	Viscosity Glassfrmr	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. While bentonite does provide alumina and silica, it's used in small quantities in glazes and the contribution is inconsequential chemically.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
bismuth **trio**xide Bi_2O_3 **subnitrate** $4BiNO_3(OH)_2$ $BiO(OH)$	 465.96 609.90		 465.96 465.96	Bi	Flux	Can give mother-of-pearl luster in reduction. Low-melting flux that replaces lead in more contemporary China paints. Considered to be the least toxic heavy metal. Less toxic than lead, although there is some toxicity if ingested, it is said to be reversible if contact ceases. Bismuth subnitrate melts at 500 deg F, and in glazes can give iridescent surfaces.
bone ash $Ca_3(PO_4)_2$	310	CaO	103	Ca + traces 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%. Used in saturated iron red glazes.
borax (soluble) $Na_2O•2B_2O_3•10H_2O$	382	$Na_2O•2B_2O_3$	382	B, Na	V, Flux Flux.	Soluble. Gives bright alkaline color. Sometimes used w/salt in vapor glazing for lower-firing, glassy glaze. Toxic if ingested May irritate skin.
boric acid (soluble) $B_2O_3•3H_2O$	124	B_2O_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.
china clay $Al_2O_3•2SiO_2•2H_2O$	258	$Al_2O_3•2SiO_2$	258	Al Si	Viscosity Glassfrmr	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 1800º 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. DISPOSE OF AS A HAZARDOUS WASTE.
clay $Al_2O_3•2SiO_2•2H_2O$ ideal formula	258	$Al_2O_3•2SiO_2$	258	Al Si	Viscosity Glassfrmr	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.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
CMC gum see CM May'98 p92 by Pinnell.		Organic; burns out		Burns 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) $CoSO_4 \bullet 7H_2O$ (lavender crystals raw)	281	CoO	281	Co	Colorant	
colemanite $2CaO \bullet 3B_2O_3 \bullet 5H_2O$	412	CaO• 1.5 B_2O_3	206	Ca B	Flux Viscosity/Flux	Calcium borate. Occurs in CA and NV. See Gerstley borate. No longer available. Substitute Gerstley borate.
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 about 1877 deg F, and become more volatile at higher temperatures. At high-fire, it may fume adjacent ware. 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. Blackish at high amounts, where it may leach from the glaze. In raku post-firing reduction gives metallic copper penny surfaces which are thin and may re-oxidize over time. Used for metallic copper luster. Cu + alkaline flux = turquoise, Cu + Pb = 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 $CuSO_4 \bullet 5H_2O$	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, KNaO Si Al	Flux Glassfrmr Viscosity	Similar to feldspar, but w/ higher proportion of silica than spar. 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. De-fluorinated Cornish stone is known as D.F. stone. Hamer says Cornwall stone has less surface tension than feldspar in the melted state and is sometime used in place of spar to prevent crawling.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
cristoballite				Si	Glassfrmr	Form of silica. Formed from free silica above about 1938°. Inversion of about 3% smaller at 439º F.
crocus martis $FeSO_4$	311.6	Fe_2O_3	623.2	Fe	Colorant	Natural form of iron, purplish raw. $2FeSO_4 \bullet Fe_2O_3 + SO_3(gas) + SO_2$ (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 $Na_3 \bullet AlF_6$	210	$3Na_2O \bullet Al_2O_3$	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 $CaCO_3 \bullet MgCO_3$	184	$CaO \bullet$ 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.
Epsom salts magnesium sulfate $MgSO_4 \bullet 7H_2O$				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. More soluble in room temp water than warm water.
erbium oxide	382.5	Er_2O_3			colorant	This is a lanthanide rare earth oxide. Raw: pink powder. Produces pale, translucent pink. Erbium, atomic no.: 68, symbol as Er, weight at 167.26, has application in glass coloring, as an amplifier in fiber optics, and in lasers for medical and dental use. The Erbium ion has a very narrow absorption band coloring erbium salts pink. It is therefore used in eyeware and decorative glassware. It can neutralize discoloring impurities such as ferric ions and produce a neutral gray shade. It is used in a variety of glass products for this purpose. m.p. 2355 degrees C (4,271 deg F); density 8.64 g/cm3. David Pier has researched this colorant in glazes and says, “Erbium oxide’s density means it is absolutely essential that you use CMC gum. Erbium oxide gives its best pink color at concentrations of 8-10%, but it is difficult to get more than 8% to fully dissolve in the melt. It has given a more lavender color in the presence of iron traces in reduction.”
feldspar $KNaO \bullet Al_2O_3 \bullet 6SiO_2$ Idealized formula	556 K 524 Na	same	556 K 524 Na	K, Na or Li Si Al	Flux GlassfrmrViscosity	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. Custer is a popular K-fluxed spar, Kona F-4 a popular Na-fluxed spar.
Flint SiO_2	60	SiO_2	60	Si	Glassfrmr	Silica, quartz. Major glass-former. Undergoes quartz inversion of 2% at 1000º F. Over 1938º F free silica may form cristobalite, which undergoes 3% inversion at 439º F.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
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				varies	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_2O .177• CaO.823• B_2O_3 .886 • SiO_2 .658 + 3.049 Loss on Ignition	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/gerstleyborate/substitutes.html
ilmenite $FeO•TiO_2$		same		Fe Ti	Colorant Opacifier	Opaque black mineral raw. In granular form, causes speckles. Effects similar to rutile (90% TiO_2; 10% Fe_2O_3), but with more iron: 49% TiO_2; 51% FeO.
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. Iron chromate: source of iron and chrome. Taupe in slips.. McKee says use 4% iron chromate + 4% copper to make black.
oxide red Fe_2O_3 (ferric)				Fe	Colorant	
chromate $FeCrO_4$	172	$FeCrO_4$	172	Fe, Cr	Colorants	
kaolin $Al_2O_3•2SiO_2•2H_2O$	258	$Al_2O_3•$ $2SiO_2$	258	Al Si	V Glassfrmr	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. Pb + Mn = plum.
monosilicate $3PbO•2SiO_2$	789	same	263	Pb Si	Flux Glassfrm	
oxide litharge	223	PbO	223	Pb	Flux	
oxide red Pb_3O_4	684	PbO	228	Pb	Flux	
lepidolite $.55Li_2O•.39K_2O•$ $.06Na_2O•Al_2O_3•$ $3.74SiO_2$	383	same	383	Li, Na Si Al	Flux Glassfmr. Viscosity	Similar to feldspar. Li content may cause shivering in excess.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
lithium carbonate Li_2CO_3	74	Li_2O	74	Li	Flux	Alkaline flux. Active low - high temperatures. Low coefficient of expansion. May cause shivering in excess. Produces a mechanically soft glaze, matt crystalline surfaces. Will deflocculate glazes and cause them to settle in the bucket. Produces typical alkaline colors: + Cu = turquoise; + Mn = plum; + Cr = yellow-green; + Co = ultramarine blues.
Macaloid $Li_2O•MgO•SiO_2$				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.
magnesium sulfate $MgSO_4•7H_2O$				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 $.75Na_2O•.25K_2O•.$ $1.11Al_2O_3• 4.65SiO_2$	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_2O_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_2CO_3	138	K_2O	138	K	Flux	Potassium carbonate. Soluble source of potassium. Deflocculates clay slips. Slightly caustic.
petalite $Li_2O• Al_2O_3• 8SiO_2$	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.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
plastic vitrox .045CaO•.058MgO• .054Na_2O•.842K_2O• 1.693 Al_2O_3• 14.634SiO_2	1139	same	1139	Ca Mg KNa Al Si	Flux Flux Flux Viscosity Glassfmr.	Resembles feldspar, but has more silica to flux and alumina than spar. Idealized formula is 1RO•1.69 Al_2O_3•14.64 SiO_2 mol wt 1139
potassium carbonate	138	K_2O	138	K	Flux	A.K.A. pearl ash. Soluble source of K_2O. Deflocculates clay slips. Slightly caustic.
potassium dichromate (bright orange raw) $K_2Cr_2O_7$	294	K_2O•Cr_2O_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.
praseodymium oxide PrO_2	172.9	PrO_2	172.9	Pr	Colorant	Toxic. Colorant used to make brilliant yellow stains (pale yellow toward yellow-green). Stable @ high temps in oxidation or reduction.
pyrophyllite Al_2O_3• 4SiO_2• H_2O	360	Al_2O_3• 4SiO_2	360	Si Al	Glassfmr. Viscosity	Decreases thermal expansion. Good volume stability in high, repeated firings. Used in refractories. Non-plastic ingredient. Used as a filler in porcelain bodies, said to strengthen, but not proven in practice. Used in place of flint in a clay body, decreases crazing due to thermal shock or moisture 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.
salt NaCl				Na	Flux	Soluble. See sodium chloride.
silica SiO_2	60	SiO_2	60	Si	Glassfrmr	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_2O•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 fireproofer. M.p. of various forms: 1112° - 1922°F. According to Hamer, sodium silicate combined w/carbon dioxide in the air eventually no longer deflocculates. Store in an air-tight container.
soda ash sodium carbonate Na_2CO_3	106	Na_2O	106	Na	Flux	Soluble sources of sodium. Dissolves more readily in warm water. 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. 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.
sodium chloride salt NaCl	58.5	Na_2O	58.5	Na	Flux	
spodumene Li_2O•Al_2O_3•4SiO_2	372	same	372	Li Si Al	Flux Glassfrmr Viscosity	Lithium feldspar. Reduces thermal expansion. Good for ovenware clay bodies. In glazes too much may cause shivering due to low expansion of Li.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
strontium carbonate $SrCO_3$	148	SrO	148	Sr	Flux	Alkaline earth flux. Single oxide source material. Behaves similarly to barium – makes mattes, + Cu = robin's-egg blues. Promotes amber colors from iron. Test 0 .75 replaces 1 barium carb in glazes for less toxic ingredient.
talc $3MgO•4SiO_2•H_2O$	379.3	MgO• $1.3SiO_2$	126.4	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. Texas talc is reported to be less gassy than NY talc, and recommended for clay bodies used w/stiff glazes like majolica.
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. To avoid chrome-tin pinking in majolica, use <4% tin and supplement with zirconium opacifier. May have a refractory effect at low temps and high concentrations. Opacifying may be less at high-fire temperatures. Increases the elasticity of the glaze slightly, thus decreasing crazing.
titanium dioxide TiO_2	80	TiO_2	80	Ti	Opacifier	Opacifier. Often produces crystaline mattes. + 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 mattes.
wollastonite $CaO•SiO_2$	116	same	116	Ca Si	Flux Glassfmr.	A calcium silicate. May be used to replace whiting and flint.
zinc oxide ZnO	81	ZnO	81	Zn	Flux	Metallic flux, mid- high temps. In large amts. (0ver 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.

Material Raw formula	Mol.Wt.	Fired Formula	Eq. Wt.	Fired Contr.	Function	Comments
zirconium oxide ZrO_2	123	ZrO	123	Zr	Opacifier	Modern opacifier, often used in the form of zirconium silicate ($ZrSiO_4$), used between 3-15%. Low amounts do not opacify, but do decrease thermal expansion and deter crazing. Produces harder glaze than Sn or Ti. Less strong opacity than tin (general rule: 1 Sn = 1.5 Zr opacifier) because it's more soluble in glaze. Produces a more translucent white than tin, and a slightly shinier surface. Acts as both an inert particle suspended in the glaze and a re-crystallized opacifier. Refractory, often used in kiln wash. Low coefficient of expansion: counters crazing. Increases glaze viscosity, surface tension, and > 10% mechanical hardness. Best results in glazes high in Ca and low in boron.

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

Text resources for ceramics materials information:
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.* 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.

A.C.T.S	http://www.artscraftstheatersafety.org/ Art Craft Theater Safety – info about safety in the arts.
Ceramic Industry	Industrial ceramics publication. Online materials guide. http://www.ceramicindustry.com
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
ClayArt	Online discussion group for ceramics. Searchable archives have many helpful discussions about materials and process. http://www.acers.org/cic/clayart/
GlazChem	http://www.dinoclay.com/software/glzchem.html Bob Wilt's glaze calculation program Windows users. Shareware. Free download to try. $35.00 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.

Health Hazards for the Artist - PDF	http://www.cheminfonet.org/art/listing_of_resourses.pdf Art safety resources - Michael McCann
Hyperglaze 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. hyperglaze@sbcglobal.com
Digital Fire	http://digitalfire.com/ Diverse technical resource page from Tony Hansen, author of Insight glaze calculation program et. al. Education section papers are good for troubleshooting and materials info.