no-grind crystals

by Ryan Coppage, PhD

Crystalline pottery has long been a cone-10 pursuit—often in oxidation, just for ease. Unfortunately, due to the runny glazes, this process includes using catch-basin dishes and risers, then breaking the pot off of the top of the riser, hoping that it breaks cleanly, and then grinding/polishing the bottom. There is a lot of time and waste involved. What if those time-sinks weren't necessary?

Define the Terms

Glaze Calculation (Oversimplified): Keeping a tally of elemental compositions of glazes and using them interchangeably to those in the same column of the periodic table of elements, as they behave similarly for silica:alumina ratios and melt temperatures.

Heatwork: The terminology for heat applied over time, which is commonly misconstrued as top temperature in a firing. For example, if a kiln ramps up quickly and reaches a top temperature, there is significantly less heatwork applied to the pottery inside than if it ramped up slowly and reached the same top temperature. The glazes would be less fluid/fluxed with the faster heat ramp and less net heatwork.

R_2O: The easiest way to understand this molecular formula with a variable element denoted by "R" is that oxygen (the O in the formula) carries a charge of -2. As such, each "R" would have to be a +1 charge to be balanced. Everything in the first column of the period table, the alkali metals (lithium, sodium, potassium, etc.) would therefore behave similarly in a glaze as an R_2O. R_2O is almost always Li_2O, Na_2O, or K_2O.

Molecular Weight: When referring to R_2O, this is equal to the atomic weight of oxygen (16 g/mol) plus your R element, according to the periodic table of elements (i.e., Li is 7 g/mol, Na is 23 g/mol, and K is 39 g/mol).

Mol/Mole: An equivalence unit used in chemistry for describing matter, that equates to 6.022×10^{23} entities of anything: atoms, molecules, electrons, photons, etc. These are used to show proportions or ratios in chemical equations for anticipating theoretical yield of products.

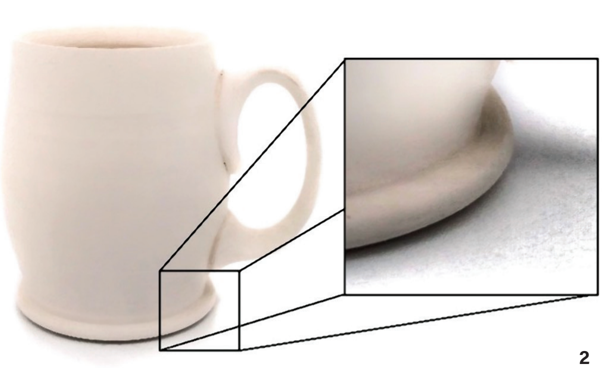
Weight Room/Weight Space: To maintain ratios of minerals in most glazes, a certain weight must be set aside for them. When substituting minerals that behave similarly, often down the periodic table but in the same column, these are heavier (if obtaining the same number of moles in ratio). In the No Grind Crystalline Glaze, finding space for 6–7% lithium oxide content requires too much Fusion Frit F-644, which pushes other needed materials out of the glaze.

Adapting Glazes

John Britt once said that you can adapt most any cone-10 glaze to cone 6 with lithium carbonate. As the contentious individual that I am, I argued, but for the overwhelming majority of circumstances, he is right. The exceptions to this include the oxidation states of metals that change (for color purposes) between cone-10 reduction and cone-6 oxidation (and cone-10 reduction to cone-6 reduction, although this is more cost prohibitive and labor intensive), though cone-10 to cone-6 oxidation is a much easier conversion. The problem with the conversion from cone 10 to 6 is that most tricks for glaze adaptation come down to finding substitutes via glaze calculations and glaze melt.

1 A mid-range crystalline mug, thrown with Standard 213 clay and fired to approximately cone 6 in oxidation.

It is common to just add lithium carbonate as a flux, find your glaze sweet spot, then replace it with other R_2O fluxes and rework the glaze with as little lithium as possible. The shortcoming of this approach is that lithium is already the lowest possible R_2O molecular-weight element. Even by substituting in Fusion Frit F-644 (a high-sodium-content frit) to meet the same R_2O parameters on glazy.org (a free glaze calculation program that models Stull charts with your proposed recipes), the glaze modeling fails because it throws off the R_2O:RO:SiO_2:Al_2O_3 ratios required for the glaze. There is not enough weight space for the amount of R_2O required, that is otherwise occupied by lithium. For example, lithium weighs 7 g/mol and sodium weighs 23 g/mol. That means that for every 30 grams of lithium oxide in a glaze recipe (starts as carbonate and turns into Li_2O after CO_2 burnoff, 1 equivalent (this is terminology used when discussing chemical reactions)), you need 62 grams of space in the recipe for Na_2O content (and you can't just add straight Na_2O)—literally more than double the weight space. This effectively pushes the other needed materials out of the glaze recipe, as there isn't weight room for the required content of R_2O without using lithium. With that said, figure 1 is a cone-6 crystalline glaze, adapted from a



2 Build subtle feet on mugs to act as catch basins for crystalline glazing.

3

3 From left to right: The same crystalline base glaze but with 8% rutile (for gold), 4.5% copper oxide (for green), 2% cobalt oxide (for blue) (also placed in an acid bath post firing), and 7.5% neodymium (for lavender).

cone-10 recipe with an added 6% lithium carbonate and adjusted firing schedule to minimize glaze running while still allowing for crystal formation.

I find that I need a small lip at the base of the pot to be fired—to catch the very minimal glaze run that does happen with my firing schedule, seen in figure 2. Many pots have these anyway, as feet; it just so happens that the crystalline glaze fills the feet in to look like a flared-out foot bottom.

Adapting a crystalline glaze to midrange is not incredibly easy, as almost any significant clay content in the original glaze causes over-nucleation of crystals—too many crystals form and they grow into one another, which is less visually appealing. With that in mind, I took all clay content out of a cone-10 crystalline base, added 0.1% CMC gum (as a deflocculant), and tested the glaze with 1% incremental additions of lithium carbonate. Upon finding a successful glaze that grows the right crystalline density at cone 6, you can start lowering the top temperature of your firing schedule, which reduces heatwork and how much the glaze runs (Sarah Nikitopoulos, who makes cone-6 crystalline-glazed work, suggests 10°F at a time). I was happy with my glaze movement and crystal formation when setting 2150°F (1177°C) as the top temperature for my glaze base, which is less than cone 6, but forces crystalline glaze recipes to behave somewhat. The No-Grind Crystalline Base glaze (right) works with various colorants in the following percentages: 8% rutile, 4.5% copper oxide, 2% cobalt oxide, 7% neodymium (see 3).

When glazing, without clay content in the glaze, the CMC gum does most of the legwork for the glaze setting up. This glaze dries very slowly, often dripping down the pot instead of instantly sticking to the bisque-fired surface. I recommend dipping the glaze and letting the pot sit upside down on a baking/silicone sheet. Let it dry between dips and dip 2–3 times, dependent on the colorant and thickness of your glaze. Much of this is "by feel" to get the glaze to behave properly. The very subtle feet also allow for these vessels to be refired 2–3 times for a crystalline pattern that is most desirable. With the firing schedule below, standard round crystals with one external halo will develop. For ringed halos, up/down ramps can be added between the 1616°F (880°C) and 1820°F (993°C) (up to 1900°F (1038°C)) temperatures.

Temperature Ramp	Top Temperature	Hold
300°F/hr	700°F (371°C)	0.0
400°F/hr	2000°F (1093°C)	0.0
150°F/hr	2150°F (1177°C)	15 minutes
9999°F/hr (natural cooling)	1820°F (993°C)	2 hours 20 minutes
9999°F/hr (natural cooling)	1616°F (880°C)	45 minutes
150°F/hr	1400°F (760°C)	45 minutes

NO-GRIND CRYSTALLINE BASE
Cone 6 Oxidation

Lithium Carbonate		5.26 %
Zinc Oxide		26.32
Ferro Frit 3110		48.42
Silica		20.00
		100.00 %
Add:	Titanium Dioxide	4.21 %
	CMC Gum	1.05 %
Optional Additives:		
	Rutile	8.42 %
	Copper Oxide	4.74 %
	Cobalt Oxide	2.11 %
	Neodymium Oxide	7.89 %

It's best to mix all the ingredients together dry, then add water; otherwise, all the CMC gum will clump together. Note: If adding rutile for gold crystals, drop the titanium dioxide content to 2%. Add 1% lithium carbonate increments if it over-crystallizes.

What It All Means

While the saying is "necessity is the mother of invention," my own laziness is the spark that drove me to test whether crystalline midrange pottery that requires very minimal work would be possible. I would argue that people like Matt Horne still accomplish unbelievable crystals and do so at cone-10 temperatures and with catch basins, grinding, and polishing. My investigation is geared toward helping artists who may have more limited studio time or need to fire at mid-range temperatures explore crystalline glazes.

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