TECHNO FILE

all about iron

by John Britt

Iron is everywhere in many different forms, but that doesn't mean it has to be boring—or even brown.

Defining the Terms

Iron—The fourth most common element in the earth's crust and the most common element (in terms of mass) on the planet, comprising 35% of the earth's core.

Melting Point: 2795°F (1535°C)

Toxicity: Non-toxic

Forms of Iron

Iron oxide is the most common colorant in ceramics. It is so ubiquitous that it is very difficult to find a material without some iron—it's found in almost everything from feldspars to kaolin to ball clays, earthenware clays, and many colorants. In fact, many materials require expensive processing to reduce the amount of iron to acceptable levels.

Iron is a very active metal that combines easily with oxygen. That means it is very sensitive to oxidation and reduction atmospheres, producing a wide range of glaze colors and effects from off white, light blue, blue, blue-green, green, olive, amber, yellow, brown, russet, tea-dust, black, iron saturate, iron spangles, iron crystalline (goldstone/tiger's eye), oil spot, hare's fur, kaki (orange), leopard spotted kaki, tan, black seto, pigskin tenmoku, shino, gray (Hidashi), iridescent, silver, gold, etc. Iron also plays a major role in clay bodies, slips, terra sigillata, and flashing slips.

There are three major forms of iron used in ceramics: red iron oxide (Fe_2O_3), black iron oxide (FeO or Fe_3O_4), and yellow iron oxide (FeO (OH)). There are different mesh sizes and grades, and each contains varying degrees of impurities that can make a significant difference in the results you get.

The most interesting thing about iron is that it can act both as a refractory and a flux. As red iron oxide, Fe_2O_3, it is an amphoteric (refractory/stabilizer) similar in structure to alumina (Al_2O_3). But if it is reduced to black iron oxide (FeO) it acts as a flux similar in structure to calcium oxide (CaO). What this means is that a tenmoku glaze with 10% red iron oxide will be a stiff black glaze if fired in oxidation because the iron oxide acts as a refractory. But, if the same glaze is fired in reduction that 10% Fe_2O_3 will be reduced to FeO, changing it to a flux, which will make it a glossy brown/black glaze that may run.

Another interesting property of iron oxide is that if it is fired in oxidation it will remain Fe_2O_3 until it reaches approximately 2250°F (approximately cone 8) where it will then reduce thermally to Fe_3O_4 on its way to becoming FeO. The complex iron oxide molecule simply cannot maintain its state at those temperatures. This results in the release of an oxygen atom that will bubble to the surface of the hot glaze and pull a bit of iron with it. When it reaches the surface the oxygen releases the iron as it leaves the glaze, creating spots with greater concentrations of iron oxide. This is what creates an oil spot glaze. This reaction can easily be seen through the spy hole of a kiln or with draw tiles. There is an obvious and unmistakable bubbling. If heated further, these spots begin to melt and run down the pot, creating a distinctive "hare's fur" effect.

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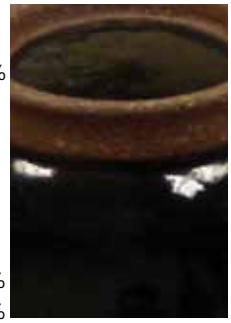
Iron Glazes

It would be impossible to show all iron glazes in this article but highlighting a few will give you a glimpse of the wide variety.

RON ROY BLACK
Cone 6

Talc	3	%
Whiting	6	
Ferro Frit 3134	26	
F-4 Feldspar	21	
EPK Kaolin	17	
Silica	27	
	100	%
Add: Cobalt Carbonate	1	%
Red Iron Oxide	9	%



FAKE ASH
Cone 6 reduction

Bone Ash	5.0	%
Dolomite	24.5	
Gerstley Borate	10.0	
Lithium Carbonate	2.0	
Strontium Carbonate	9.5	
Ball Clay	21.0	
Cedar Heights Red Art	28.0	
	100.0	%

CHINESE CRACKLE (KUAN)
Cone 10 reduction

Custer Feldspar	83	%
Whiting	9	
Silica	8	
	100	%
Add: Zircopax (optional)	10	%

Adding small amounts of red iron oxide to this feldspathic base and firing in reduction will result in the following:
Blue Celadon: 0.5%–1.0%
Blue–Green: 1–2%
Olive to Amber: 3–4%
Tenmoku: 5–9%
Iron Saturate: 10–20%

KETCHUP RED (JAYNE SHATZ)
Cone 6 oxidation

Gerstly Borate	31	%
Talc	14	
Custer Feldspar	20	
EPK Kaolin	5	
Silica	30	
	100	%
Add: Spanish Red Iron Oxide	15	%

Works best on dark colored stoneware. If used on a buff clay body, the red is less intense.

Sources of Iron

Form	Chemical Name	Characteristics	Most Common Use
Red Iron Oxide	Fe_2O_3 ferric iron, Hematite	Most common form of iron and is a finely ground material that disperses well in glaze slurries, contains 69.9% Fe in the chemical formula, sold as: • Natural Red Iron Oxide or Brown 521 (85% purity) • Spanish Red Iron Oxide* (83–88% purity) • Synthetic Red Iron Oxide* (High Purity Red Iron or Red 4284) (96–99% purity). Very fine 325 mesh. Sometimes sold as the brand name Crocus Martis or Iron Precipitate.	Used in glazes, washes, slips, engobes, terra sigillatas, and clay bodies, used to make celadons, tenmoku, kaki, iron saturates, etc. (more listed in the text on page 14) Normally used from 1–30% in glazes.
Black Iron Oxide	FeO ferrous oxide, wustite	Strongest form of iron, containing 72.3% Fe in the chemical FeO, sold as: • Natural Black Iron Oxide (85–95% purity) 100 mesh; is black in color and has a larger particle size. In glazes it's prone to speckling but is easily eliminated by ball milling. • Synthetic Black Iron Oxide* (99% purity) 325 mesh	Used in glazes, washes, slips, engobes, and terra sigillatas; used to make celadons, tenmoku, kaki, iron saturates, etc.
Yellow Iron Oxide	FeO (OH) ferric oxide hydrate, Geothite	Weakest form of iron, containing 62.9% Fe in the chemical formula, has a high LOI of 12%, sold as: • Synthetic Iron Oxide* (96% purity) 325 mesh • Yellow Ochre or Natural Yellow Iron Oxide (35% purity) contains impurities of calcium carbonate, silica, and sometimes manganese dioxide	Used in glazes, washes, slips, engobes, terra sigillatas, and clay bodies; used to make celadons, temmoku, kaki, iron saturates, etc.; sometimes yellow ochre is added to porcelain to make "dirty" porcelain (5–9%)
Umber, Burnt Umber		Calcined Umber which is a high-iron ochre material containing manganese	Used in glazes, washes, slips, engobes, terra sigillatas or claybodies to make a range of reddish-brown colors; darker than sienna and ochre (yellow iron)
Sienna, Burnt Sienna		Calcined Sienna, which is a high-iron ochre material with less manganese than umber	Used to make browns in glazes, washes, slips, engobes, terra sigillatas or clay bodies
Iron Chromate	Cr_2FeO_4	Contains chrome and iron oxide (ferric chromate); toxic—absorption, inhalation, and ingestion	Used to make dark colors in glazes, slips, engobes or clay bodies; can give gray, brown, and black; can give pink halos over tin white glazes
Ferric Chloride/ Iron Chloride	$FeCl_3$	Water soluble metal salt; toxic—corrosive/caustic, affects liver, inhalation and ingestion	Used in low-fire techniques, like pit firing, aluminum foil saggars, horse hair and raku techniques; also used in water coloring on porcelain techniques
Iron Sulfate (Copperas)	$FeSO_4$	Water soluble metal salt, soluble form of iron, (aka Crocus Martis)	Salt used in water coloring on porcelain, raku, and low-fire soda
Iron Phosphate	$FePO_4$		Rarely used but can be used to develop iron red colors; sometimes used instead of bone ash as a source of phosphate without the calcium in synthetic bone ash (TCP or tri-calcium phosphate)
Rutile (light, dark, and granular)	TiO_2	Most common natural ore of titanium, containing various impurities including iron (up to 15%)	Used in glazes, washes, slips, engobes, and terra sigillatas to give yellows, tans, greens, blues, and milky, streaky, mottled textures; also used to produce crystalline glaze effects
Illmenite (powdered and granular)	$FeTiO_3$	Naturally occurring ore containing iron and titanium, higher in iron than rutile (when 25% or more iron is present)	Commonly used to produce speckles in glazes or clay bodies
Iron Clays		e.g., Redart, Albany slip, Alberta Slip, Barnard Slip (aka Blackbird Slip), Michigan slip, Lizella, laterite, and other assorted earthenware clays	Used in glazes, slip glazes, slips, engobes, terra sigillatas, and claybodies to make a range of reddish-brown colors
Magnetic Iron Oxide	Fe_3O_4 Magnetite	Iron scale or iron spangles—coarse, hard particles that resist melting and chemical breakdown	Gives speckles in clay bodies and glazes

*Synthetic and Spanish Varieties

Synthetic Red Iron is produced by calcining black iron oxide particles in an oxidation atmosphere. They are then jet milled, which produces "micronized" red iron oxide particles that are approximately 325 mesh. This type of red iron is very heat stable (up to 1832°F (1000°C). This differs from black iron oxide, which changes color at 365°F (180°C) from black to brown to red as it oxidizes. The color of red iron oxide changes from light pinkish to red to dark purplish red as the particle size increases.

Spanish red iron oxide is bacterially ingested iron oxide that is micronized. The Tierga mines in Spain found that their iron sulfide was inadequate for steel making (which accounts for 95% of the iron market). After some time a worker noticed that the iron in a pool of rain water turned a brighter shade of red after it was heated. This turned out to be caused by a bacterium, that uses iron sulfide as an energy source. The bacterium changes the state of the iron, which is then put into evaporative ponds where it forms green crystals. These are then roasted to produce Spanish red iron oxide.