

BULLSEYE PROJECTS GLASS LAB

.....

HOW GLASS IS MADE: FIELD GUIDE **HAND-CRAFTED GLASS MADE AT BULLSEYE GLASS CO.**

Imagine a world without glass. No light bulbs, no eyeglasses, no microscopes, no windows, and perhaps most unimaginable of them all, NO INTERNET!

Glass is a big part of all of our lives. It is pretty amazing stuff; it can be transparent, strong, beautiful, and breakable.

This field guide is an educational resource designed to accompany Bullseye Projects' Glass Kit, an apothecary style tool kit that provides a behind the scenes look at the making of a mysterious and magical material—glass.

Our hope is that it will be used by educators, docents, and others to help augment and facilitate a materials discussion about glass.

In it, you will find: (Corresponding to the Glass Kits four sections)

- > MIXING BATCH: The major ingredients of Soda-Lime Glass
- > MELTING BATCH INTO GLASS: Heat and time transform batch into glass
- > MAKING COLORED GLASS: Elements added to make transparent and opaque colored glass
- > COLORED GLASS: Elements and the colors they make

.....

WHAT IS GLASS?

Glass is made up of minerals that come from the earth's crust. These minerals are like ingredients in a recipe. When combined they create BATCH. The most common type of glass is Soda-lime glass: "soda" for the sodium carbonate and "lime" for the calcium carbonate. Windows, bottles, glass containers are all examples of soda-lime glass.

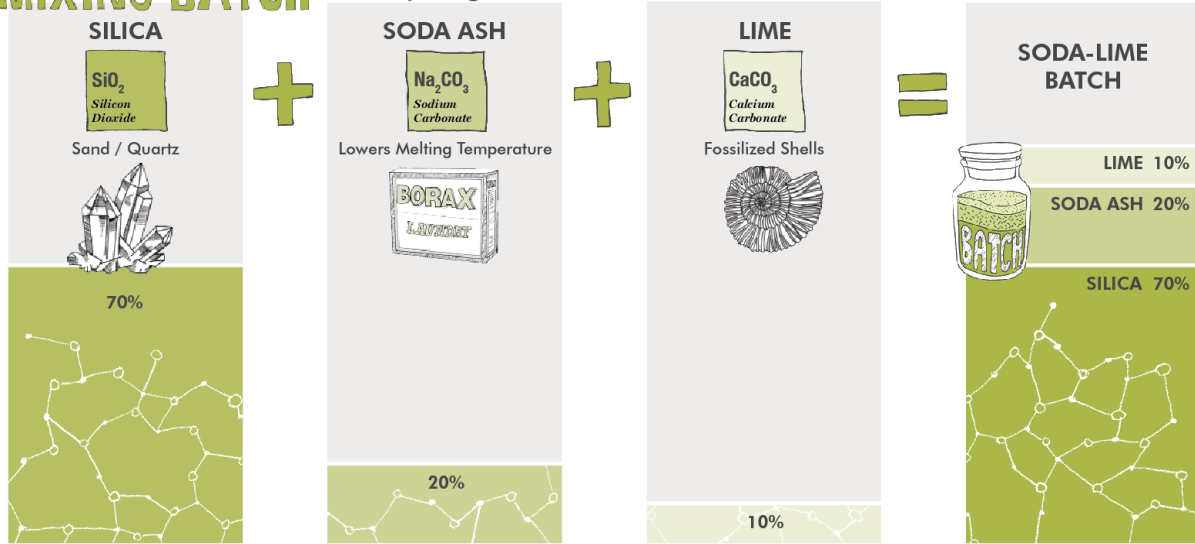
SO HOW IS SODA-LIME GLASS MADE?

There many ways to make glass. The main ingredient is silica, sand. Soda-lime glass is made by melting raw materials silica dioxide (sand), soda ash (also known as washing soda), and lime (calcium carbonate from fossilized shells and limestone to name a few) in a glass furnace.

A furnace is a device used for high-temperature heating. A furnace is just like an oven. However, an oven at home gets up to about 500°F and a glass furnace goes up to 2,867°F. Most soda-lime glass is melted at 2,450°F

MIXING BATCH

The major ingredients of Soda-Lime Glass



Silica (sand) SiO_2 – about 70% by weight

The composition of sand around the world varies. The main constituent of sand is silica, or silicon dioxide, usually from the mineral quartz.

In order to change the sand into glass it needs to melt. But silica on its own, has a very high melting point, it is close to $3,300^\circ\text{F}+$, hotter than volcanic lava! A temperature impossible to achieve without very sophisticated furnaces.

[fun fact: most silica has small amounts of iron in it which turns glass green]

Sodium Ash Na_2CO_3 – about 20% by weight



This is the soda in soda-lime glass. It is also called soda carbonate and washing soda, known for its use as a water softener. When soda ash is added it lowers the melting point of silica from $3,300^\circ\text{F}+$ to about 2300°F . Still very, very hot but much easier to achieve in simple clay brick furnaces.

This "soda glass" is mildly water-soluble, so some lime is added to the melt mixture to make the glass insoluble.

[fun fact: Borax is a common household item, also used in laundry detergents]

Lime CaCO_3 – about 10% by weight

This is the lime in soda-lime glass. Lime is formed by three elements: calcium, carbon, and oxygen. It's what chalk is made of; it can also be found in marble, fossilized shells, snails, and limestone. The lime helps the sodium and the silica all stay together. Adding lime to the mixture helps the glass be more stable, and prevent the glass from weathering and falling apart.

[Fun Fact: Calcium carbonate or chalk is a commonly used medicinally as an antacid]

MAKING COLORED GLASS Elements added to make Transparent and Opaque Colored Glass



By carefully following a recipe, the operator at Bullseye mixes the ingredients in large barrels using “The Octopus” very much in the same way that you would add ingredients when baking. “The Octopus” is a series of giant containers with funnels and long arms, used to combine ingredients.

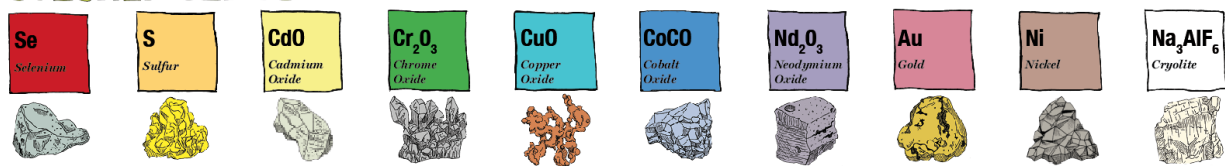
Our example in shows Copper / Cu being used to make a turquoise colored glass.

A compound is made by combining copper with oxygen to create copper oxide. Copper oxide is then added to the the batch. Fluorine is added to the batch to change the colored glass from being transparent/see through to opaque/not see through.

Can you remember what the three main ingredients are used to make Batch?

A: Silica, Soda ash, and lime.

COLORED GLASS Elements and the colors they make

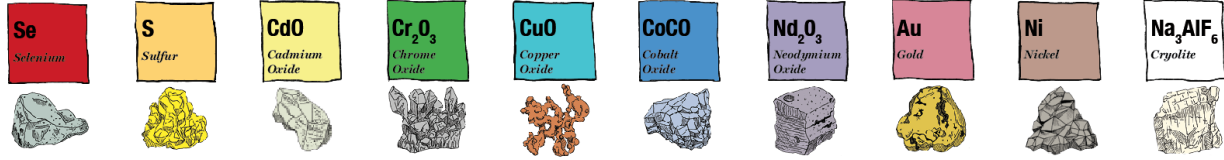


Bullseye uses many elements to create different colors of glass. Some colors can be made from the raw element, such as sulfur or selenium, however, many of the elements Bullseye uses are metallic compounds like metal oxides or metal carbonates.

Metal oxides are compounds formed by a metal and oxygen. This allows for more color options that create a broad spectrum of hues; especially when oxides are combined with other oxides in a batch. The most common metal oxide is iron oxide—rust.

A compound is a substance formed from chemically bonding two or more elements together in a specific ratio.

COLORED GLASS Elements and the colors they make



MINERALS FOR MAKING COLORED GLASS

Listed below are some of the elements and compounds Bullseye uses:

Selenium / Se

A nonmetal added to the batch to make reds.

Sulfur / S

A nonmetal added to the batch in combination with cadmium to make yellow/orange.

Cadmium Oxide / CdO (Cadmium + Oxygen)

A transition metal added to the batch in combination with sulfur to make yellow.

Green Chrome Oxide / Cr₂O₃ (Chrome + Oxygen)

A transition metal added to the batch to make green.

Black Copper Oxide / CuO (Copper + Oxygen)

A transition metal added to the batch to make light blue.

Cobalt Carbonate / CoCO₃ (Cobalt + Carbon + Oxygen)

A transition metal added to the batch to make blue.

Neodymium Oxide / Nd₂O₃ (Neodymium + Oxygen)

A transition metal added to the batch to make purple. *It a shifty little metal as it responds to different light wavelengths Try looking at the purple sample under fluorescent light and incandescent light. What happens?

Gold / Au

A transition metal added to the batch to make pink and red.

Nickel / Ni

A transition metal added to the batch to make brown.

Cryolite / Na₃AlF₆ (Sodium + Aluminum + Fluoride)

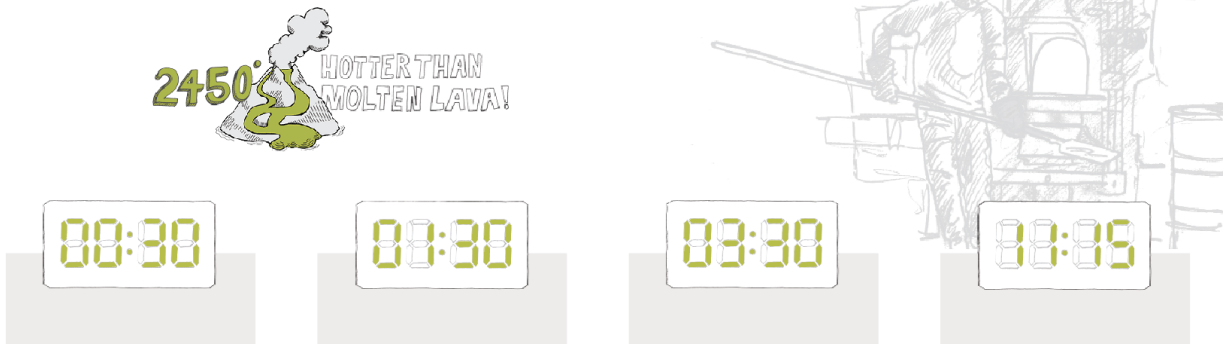
Na: Alkali Metal, Al: Other Metal, F: Nonmetal

Cryolite does not exist in nature as a singular element, like sulfur or gold. It is a mineral that is made up of sodium, aluminum, and fluorine. Cryolite is used to make opalescent (milk) glass.

.....

MELTING BATCH INTO GLASS

Heat and Time transform batch into glass



How does a mixture of minerals that looks like sand turn into smooth clear glass?

Once all the ingredients are well mixed, the batch is fed into the furnace. This is called, charging the furnace. It takes a total of 16 hours, 8 hours to add materials and 8 hours of melting and refining. Each interval of time, displayed in the kit is at 2450°F, Hotter than molten lava!

Glass items are formed in many different ways; rolled into windows, blown into glass. At Bullseye, when ready, the glass solution is ladled or cast by hand. Sheet glass is made by pouring the liquid glass on the table. It is then folded and manipulated to even the temperature and pop bubbles before it is squeezed through rollers that make it into a thin sheet 2mm, 3mm, or 6mm thick.

The glass is then annealed in a lehr at a slow and controlled rate to prevent stresses in the glass. This is called annealing. A lehr is a long oven with different heating zones through which the glass moves on a conveyer belt so gradual cooling can occur. If glass is cooled too quickly it will crack; have you ever seen ice cubes crack when you add them to room temperature water?

If temperature of the glass changes too quickly or unevenly, thermal shock occurs. Thermal shock is when the molecules in the glass expand and contract at different rates causing stress. The stress is what breaks the glass.

After annealing the glass, it's tested for fusibility and color compatibility.

A polarimeter is used to analyze the glass. This is a laboratory tool used to identify if there is stress between any colored glass and the standard clear glass not seen by our eyes. If there is very little or no stress than the colored glass is 'compatible'. If there is stress the colors aren't compatible and may break when fused in a kiln.

Once tested to meet Bullseye's standards of quality, the glass is ready to be packaged and shipped all over the world.

[A fun fact: the temperature of a candle flame is 2600°F]

.....