UCF/DSI-CR-1 Simulant Spec Sheet

The CR asteroid simulant is based on the average composition of several CR carbonaceous chondrite meteorites. This is a high-fidelity simulant, targeting the modal mineral composition specified by D.T. Britt. This simulant has intentional differences from the composition reported in the literature to improve the safety of the simulant and to provide adequate strength and morphology.

1. Safety Considerations

The components of this simulant are selected to be safe; hazardous materials have been avoided. Most of the source minerals are commonly found in soils and/or households. Others such as elemental nickel-iron and sodium metasilicate (binder) are not found naturally on the Earth's crust. Note that these minerals in powder form all can be a nuisance dust hazard, and dust masks should be worn when handling these powders. Also, they should not be eaten.

1.1 Serpentine

This family of minerals includes variants that can form asbestos fibers. This simulant uses the serpentine mineral Antigorite, which does not form asbestos.

1.2 Kerogen

Carbonaceous chondrite meteorites generally have several percent of carbon present as complex polycyclic aromatic hydrocarbons (PAHs), compounds generally considered to be carcinogenic. We have substituted sub-bituminous coal, which is considered safe while having the correct ratio of C to H.

1.3 Sulfides

Asteroids typically contain iron sulfides such as troilite (FeS) or pyrrhotite (~$Fe_{0.8}S$). These are hazardous during the manufacturing process since fine powders can be explosive in air. We substitute pyrite (FeS_2) as a safety consideration for ourselves.

1.4 Iron-Nickel

Asteroids typically contain elemental iron alloyed with nickel. Fine nickel powders are considered hazardous, although nickel plating and alloys (such as stainless steel) are ubiquitous. The nickel in our simulants (like the iron) is a course powder, not easily lofted into the air and subsequently inhaled. It may still cause dermatitis in sensitive individuals (as does some jewelry or nickel-plated watches).

2. Morphologies

The CR simulants are available in several forms:

2.1 Regolith

This form has been properly mixed, dried/lithified, and shattered into a power-law size distribution to match a possible asteroid regolith.

2.2 Slabs / Cobble

Wet mix has been pressed into molds and carefully dried/lithified to produce slabs or cobble.

2.3 Ready-to-prepare Dry Mix

This form consists of dry mixed powder. When ready to use:

2.3.1 Add water to the dry powder.

Each 3.5 gallon bucket contains 22 kg of dry mix. However, these instructions are appropriate for 2 kg batches. Measure 2.03 kg of dry powder into a metal or plastic bowl. Add 340 ml of distilled water and mix thoroughly; this results in a very thick, crumbly mixture. To reduce porosity, the mix should be vibrated and/or subjected to vacuum.

2.3.2 This results in 2.37 kg of wet mix.

This should be shaped into the desired form, or pressed into a mold. We line our molds (typically ordinary clay pots or pot bases) with parchment paper to prevent the mixture from adhering to it. We also use a hand-sifter to deposit a very fine layer of additional dry mix on the parchment paper to prevent the wet mixture from binding to it. Once the wet mix has been firmly pressed into the mold, it is lithified by baking (in a 1000 watt microwave oven) for 40 minutes at 80% power, then 15 minutes at 70% power, followed by cooling. Other masses (or ovens) will require microwave timing adjustments which may not be linearly extrapolated due to surface effects. Note that the surface will appear quickly rock-like while the interior is still crumbly until the entire sequence is completed.

The dried mixture should mass 2.0 kg, having lost the added water plus the water of hydration in the sodium metasilicate pentahydrate. Our process temperatures are 120°C to 150°C (as measured by an IR thermometer targeting the surface), high enough to precipitate sodium silicate polymers but low enough to not drive off the water and other volatiles bound into the antigorite or coal.

2.4 Bagged Un-Mixed Source Minerals

Each bucket contains the proper source materials to produce 22 kg of CR simulants, in individual labelled bags. The purpose is to allow a researcher the ability to change the composition either using a different ratio of source minerals or by replacing some with alternates, such as replacing antigorite with chrysotile (asbestos) serpentine, or using hazardous kerogens instead of coal.

The process is to carefully mix all source materials, taking care to avoid or disrupt clumps (we use cement mixers and tumble the dry powders with steel balls for 30 minutes, which results in a uniform powder). Then follow the steps in 2.3 above to prepare a wet mix.

2.5 Notes

Using the wrong proportion of water, or not carefully following the lithification instructions, may result in a simulant mixture which does not – and will not – completely set. The lithification is due to the polymerization of sodium silicate, and if that process is disrupted, the polymer units may be too short to achieve a good cementation, and will no longer dissolve in water. The final product is not affected by water. Using too much water – or using vacuum or vibration to reduce porosity – may result in a wet surface which will likely result in a surface skin, which may separate or may be tightly bound. The ability to create a dense surface layer is why sodium metasilicate (water glass) is sometimes used as a cement sealer.

3. Elemental Composition

Element	Weight %
Fe - Iron	22.23%
Si - Silicon	16.22%
Mg - Magnesium	17.58%
S – Sulfur	2.09%
C - Carbon	1.53%
H - Hydrogen	0.26%
Elements < 1%	~1.7%
O Oxygen	balance

4. Mineralogical Composition

Here is the list of minerals in this simulant. Note these are generally mine sources, and have impurities such that they do not match the pure mineral exactly.

Mineral	Weight %	Notes
Antigorite	9.0%	A serpentine mineral, $(Mg,Fe{++})_3Si_2O_5(OH)_4$
Pyroxene	31.0%	$Mg_{0.75}Fe_{0.25}SiO_3$
Magnetite	14.0%	Iron Oxide – Fe_3O_4
Iron-Nickel	5.0%	An iron/nickel mixture consisting of 93% Fe, 7% Ni
Olivine	33.0%	Magnesium Iron Silicate – $(Mg_{0.9}Fe_{0.1})_2SiO_4$
Pyrite	4.0%	Iron Sulfide (FeS_2), substituted for troilite (FeS)
Sodium Silicate	2.0%	Note that 3.5% of sodium silicate pentahydrate is added, but the water is driven out by the lithification process
Coal	2.0%	Sub-bituminous coal is a kerogen substitute