

# Pyrotechnic colorant

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The red lithium flame leads to lithium's use in flares and [pyrotechnics](#)



[Copper](#) compounds glow green or blue-green in a flame.



[Calcium](#) compounds glow orange in a flame.



Sodium compounds glow yellow in a flame.

A **pyrotechnic colorant** is a chemical compound which causes a flame to burn with a particular color. These are used to create the colors in pyrotechnic compositions like fireworks and colored fires. The color-producing species are usually created from other chemicals during the reaction. Metal salts are commonly used; elemental metals are used rarely (e.g. copper for blue flames).

The color of the flame is dependent on the metal cation; the anion of the salt has very little direct influence. The anions however influence the flame temperature, both by increasing it (e.g. nitrates, chlorates) and decreasing it (e.g. carbonates, oxalates), indirectly influencing the flame brightness and brilliancy. For temperature-decreasing additives, the limit of colorant may be about 10–20 wt.% of the composition.<sup>[1]</sup>

Some common examples are:

Color	Compound name	Chemical formula	Notes
Red	<u>Strontium nitrate</u>	$\text{Sr}(\text{NO}_3)_2$	Common. Used with chlorine donors. Excellent red, especially with metal fuels. Used in many compositions including <u>road flares</u> .
Red	<u>Strontium carbonate</u>	$\text{SrCO}_3$	Common. Produces good red. Slows burning of compositions, decomposes yielding carbon dioxide. Fire retardant in <u>gunpowders</u> . Inexpensive, non-hygroscopic, neutralizes acids. Superior over strontium oxalate in absence of magnesium.
Red	<u>Strontium oxalate</u>	$\text{SrC}_2\text{O}_4$	Decomposes yielding carbon dioxide and carbon monoxide. In presence of magnesium fuel, carbon monoxide reduces particles of magnesium oxide, yielding gaseous magnesium and eliminating the black body radiation of the MgO particles, resulting in clearer

			color.
Red	<a href="#">Strontium sulfate</a>	SrSO <sub>4</sub>	Common. High-temperature oxidizer. Used in strobe mixtures and some metal-based red compositions.
Red	<a href="#">Strontium chloride</a>	SrCl <sub>2</sub>	Common. Produces bright red flame.
Orange	<a href="#">Calcium carbonate</a>	CaCO <sub>3</sub>	Produces orange flame. Yields carbon dioxide on decomposition. Often used in toy fireworks as a substitute for strontium.
Orange	<a href="#">Calcium chloride</a>	CaCl <sub>2</sub>	
Orange	<a href="#">Calcium sulfate</a>	CaSO <sub>4</sub>	High-temperature oxidizer. Excellent orange source in strobe compositions.
Orange	Hydrated <a href="#">calcium sulfate</a>	CaSO <sub>4</sub> (H <sub>2</sub> O) <sub>x</sub> *	
Gold/Yellow	<a href="#">Charcoal powder</a>	C	
Gold/Yellow	<a href="#">Iron powder with oxygen based carbon</a> OC12	Fe+C	
Yellow	<a href="#">Sodium bicarbonate</a>	NaHCO <sub>3</sub>	Compatible with potassium chlorate. Less burning rate decrease than sodium carbonate. Incompatible with magnesium and aluminium, reacts evolving hydrogen gas.
Yellow	<a href="#">Sodium carbonate</a>	Na <sub>2</sub> CO <sub>3</sub>	Hygroscopic. Significantly decreases burning rate, decomposes evolving carbon dioxide. Strongly alkaline. Very effective colorant, can be used in small amounts. Corrodes magnesium and aluminium, incompatible with them.

Yellow	<a href="#">Sodium chloride</a>	NaCl	Loses hygroscopicity on heating. Corrodes metals.
Yellow	<a href="#">Sodium oxalate</a>	Na <sub>2</sub> C <sub>2</sub> O <sub>4</sub>	Non-hygroscopic. Slightly reacts with magnesium, no reaction with aluminium.
Yellow	<a href="#">Sodium nitrate</a>	NaNO <sub>3</sub>	Also acts as oxidizer. Bright flame, used for illumination.
Yellow	<a href="#">Cryolite</a>	Na <sub>3</sub> AlF <sub>6</sub>	One of the few sodium salts that is nonhygroscopic and insoluble in water.
Green	<a href="#">Barium chloride</a>	BaCl <sub>2</sub>	
Green	<a href="#">Barium chlorate</a>	Ba(ClO <sub>3</sub> ) <sub>2</sub>	Classic exhibition green with shellac fuel. Sensitive to shock and friction. Oxidizer.
Green	<a href="#">Barium carbonate</a>	BaCO <sub>3</sub>	Pretty color when ammonium perchlorate is used as oxidizer.
Green	<a href="#">Barium nitrate</a>	Ba(NO <sub>3</sub> ) <sub>2</sub>	Not too strong effect. With chlorine donors yields green color, without chlorine burns white. In green compositions usually used with perchlorates.
Green	<a href="#">Barium oxalate</a>	BaC <sub>2</sub> O <sub>4</sub>	
Blue	<a href="#">Copper(I) chloride</a>	CuCl	Richest blue flame. Almost insoluble in water.
Blue	<a href="#">Copper(I) oxide</a>	Cu <sub>2</sub> O	Lowest cost blue colorant.
Blue	<a href="#">Copper(II) oxide</a>	CuO	Used with chlorine donors. Excellent in composite <a href="#">stars</a> .

Blue	<a href="#">Copper carbonate</a>	$\text{CuCO}_3$	Best when used with <a href="#">ammonium perchlorate</a> .
Blue	Basic copper carbonate	$\text{CuCO}_3 \cdot \text{Cu(OH)}_2$ , $2 \text{CuCO}_3 \cdot \text{Cu(OH)}_2$	Occurs naturally as <a href="#">malachite</a> and <a href="#">azurite</a> . Good with ammonium perchlorate and for high-temperature flames with presence of hydrogen chloride. Not easily airborne, less poisonous than Paris Green.
Blue	<a href="#">Copper oxychloride</a>	$3\text{CuO} \cdot \text{CuCl}_2$	Good blue colorant with suitable chlorine donor.
Blue	<a href="#">Paris Green</a>	$\text{Cu(CH}_3\text{COO)}_2 \cdot 3\text{Cu(AsO}_2)_2$	Copper acetoarsenite, <a href="#">Emerald Green</a> . Toxic. With <a href="#">potassium perchlorate</a> produces the best blue colors. Non-hygroscopic. Fine powder readily becomes airborne; toxic inhalation hazard. Used in majority of Japanese blue compositions as it gives very pretty color.
Blue	<a href="#">Copper arsenite</a>	$\text{CuHAsO}_3$	Almost non-hygroscopic. Almost as good colorant as copper acetoarsenite. Toxic. Can be used with chlorate oxidizers.
Blue	<a href="#">Copper sulfate</a>	$\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$	Can be used with nitrates and perchlorates. Acidic, incompatible with chlorates. With red phosphorus in presence of moisture liberates heat, may spontaneously ignite. Less expensive than copper acetoarsenite. Anhydrous copper sulfate is hygroscopic, can be used as a desiccant. With ammonium perchlorate produces almost as pretty blue color as achievable with copper acetoarsenite.
Blue	<a href="#">Copper metal</a>	$\text{Cu}$	Rarely used, other compounds are easier to work with. Yields pretty blue color in ammonium perchlorate based compositions; but reacts with ammonium perchlorate and liberates ammonia in presence of moisture. The

			composition must be kept dry.
Purple	Combination of red and blue compounds	Sr+Cu	
Purple	<a href="#">Rubidium</a> compounds	Rb	rarely used
Silver/White	<a href="#">Aluminium</a> powder	Al	
Silver/White	<a href="#">Magnesium</a> powder	Mg	
Silver/White	<a href="#">Titanium</a> powder	Ti	
Silver/White	<a href="#">Antimony (III) sulfide</a>	Sb <sub>2</sub> S <sub>3</sub>	
Infrared	<a href="#">Caesium nitrate</a>	CsNO <sub>3</sub>	two powerful <a href="#">spectral lines</a> at 852.113 nm and 894.347 nm
Infrared	<a href="#">Rubidium nitrate</a>	RbNO <sub>3</sub>	

The \* indicates that the compound will burn orange where x=0,2,3,5.

## Radiating species

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Despite the wide numbers of metal ion donors, they serve to form only a few atomic and molecular species that are useful as light emitters.<sup>[2]</sup>

In many cases, chlorine donors have to be added in order to achieve sufficiently deep colors, as the desired emitting molecules have to be generated.

Some color emitters are of atomic nature (e.g. lithium, sodium). Presence of chlorine, and the reaction to monochlorides, may actually impair their color purity or intensity.

At high temperatures, the atoms will ionize. The emission spectra of ions are different than of neutral atoms; the ions may emit in undesired spectral ranges. E.g. Ba<sup>+</sup> emits in blue wavelengths. Ionization

can be suppressed by addition of an easier-to-ionize metal with weak visible emission of its own, e.g. potassium; the potassium atoms then act as electron donors, neutralizing the barium ions.<sup>[3]</sup>

The color blue is notoriously difficult to produce in fireworks, as the [copper](#) compounds need to be heated at a specific temperature for the optimal shade of blue to be produced. Thus, a deep, rich blue is usually viewed as the mark of an experienced fireworks maker.

Care should be taken to avoid formation of solid particles in the flame zone, whether metal oxides or carbon; [incandescent](#) solid particles emit [black body radiation](#) that causes "washing out" of the colors. Addition of aluminium raises the flame temperature but also leads to formation of solid incandescent particles of aluminium oxide and molten aluminium. Magnesium has less such effect and is therefore more suitable for colored flames; it is more volatile than aluminium and more likely to be present as vapors than as particulates. Formation of solid particles of magnesium oxide can further be inhibited by presence of carbon monoxide, either by negative oxygen balance of the composition in presence of organic fuels, or by addition of the colorant in the form of an oxalate, which decomposes to carbon dioxide and carbon monoxide; the carbon monoxide reacts with the magnesium oxide particles to gaseous magnesium and gaseous carbon dioxide.

Colour	Emitter	Wavelengths	Notes
Yellow	<a href="#">Sodium(D-line)</a>	589 nm	very strong, overpowers other colors, avoid contamination
Orange	<a href="#">CaCl(molecular bands)</a>	most intense: 591–599 nm and 603–608 nm, and others	
Red	<a href="#">SrCl</a> (molecular bands)	a: 617–623 nm b: 627–635 nm c: 640–646 nm	The SrCl species tends to be oxidized to less desirable SrO; strontium-containing compositions are therefore usually formulated to be oxygen-deficient. <sup>[3]</sup>
Red	<a href="#">SrOH(?)</a> (molecular bands)	600–613 nm	
Red	Li (atomic spectral lines)		
Green	<a href="#">BaCl</a> (molecular bands)	a: 511–515 nm b: 524–528 nm d: 530–533 nm	Lines of BaOH and BaO are also present, emitting in yellow and yellowish-green (487, 512, 740, 828, and 867 nm for BaOH, 549, 564, 604 and 649 for BaO). The BaOH lines are much stronger than the BaO lines. In absence of chlorine, the BaCl lines are not present and only the BaOH

			<p>and BaO lines are visible.</p> <p>The BaCl species tends to be oxidized to less desirable BaO; barium-containing compositions are therefore usually formulated to be oxygen-deficient.</p> <p>Presence of Ba<sup>+</sup> is undesired, as it emits in a blue region at 455.4 nm. Potassium may be added to suppress barium ionization, as it ionizes easier and acts as an electron donor for the barium ions.<sup>[3]</sup></p>
Blue	<a href="#">CuCl</a> (molecular bands)	several intense bands between 403–456 nm, less intense at 460–530 nm	<p>Low dissociation energy of copper compounds causes presence of free copper atoms in the flame, weakly emitting in green (lines between 325–522 nm). In presence of chlorine, CuCl is formed, emitting strongly in blue. At higher temperatures CuCl dissociates and lines of atomic copper are present in the spectrum; CuO and CuOH are also formed, emitting molecular bands at green-yellow (535–555 nm) for CuOH and at orange-red (580–655 nm) for CuOH. Adequate control of temperature is therefore required for blue-burning compositions.</p>
Infrared	<a href="#">Carbon</a> particles	<a href="#">black body radiation</a>	<p>For good broadband infrared output, compositions producing lots of heat and carbon particles are required. The burning temperature should be lower than of visible-illuminating compounds. The intensity of the emitted radiation depends on the burn rate. Temperature can be increased by addition of <a href="#">magnesium</a>.</p> <p>A <a href="#">magnesium/Teflon/Viton</a> composition is common for <a href="#">missile decoy flares</a>.<sup>[4]</sup></p>
Infrared	<a href="#">CO<sub>2</sub></a> (molecular bands)	mostly 4300 nm	Produced by carbon-containing fuels.
Infrared	<a href="#">Cs</a> (atomic spectral lines)	two powerful <a href="#">spectral lines</a> at 852.113 nm and 894.347 nm	Used in infrared illumination compositions. Metal is avoided in the compositions to prevent formation of bright, visible-radiating particles. <sup>[5]</sup>
Infrared	<a href="#">Rb</a> (atomic spectral lines)	spectral lines in near-infrared	Used in infrared illumination compositions, less commonly than cesium.

## References

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