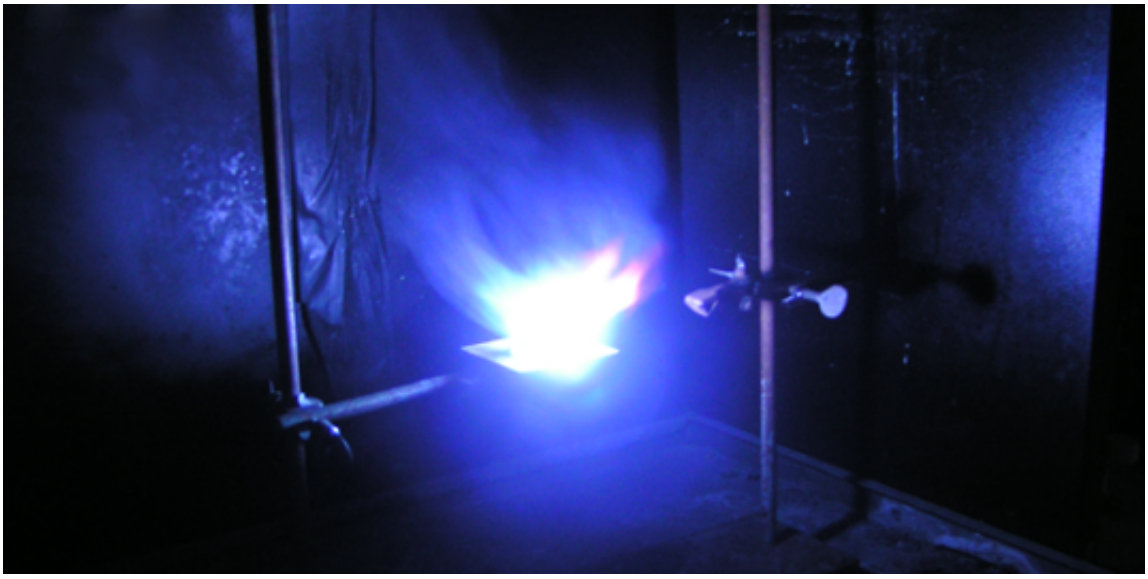
A more benign blue for pyrotechnics

September 14 2015



Copper bromide produces blue flames.

Ludwig Maximilian University of Munich chemists have developed a novel pyrotechnic formulation that produces a blue flame of unprecedented purity and radiance upon combustion, and is free of the toxic chlorine-containing compounds found in conventional fireworks.

Its dazzling glare is breathtaking but, to produce an intense blue flame, conventional fireworks and signal flares rely on the use of highly toxic chemicals. "Blue light is very difficult to generate pyrotechnically, and the traditional formulation uses a combination of copper salts and perchlorates for this purpose. At high combustion temperatures, the

mixture reacts to form copper chloride (CuCl), which is a blue emitter. But perchlorates are toxic, specifically impairing the function of the thyroid gland, while combustion of chlorine-containing organic compounds gives rise to other toxic polychlorinated hydrocarbons," says Thomas M. Klapötke, who holds the Chair of Inorganic Chemistry and High-Energy Materials at LMU. In cooperation with groups based in Lithuania and Finland, Klapötke and his colleagues have now developed an environmentally more benign alternative blue-light emitter. In terms of the intensity and chromatic purity of the flame produced, the new mixture is as least as good as the formulation currently in use. The results of the study appear online in the journal "Chemistry – A European Journal".

Earlier work carried out by Klapötke and his team had shown that copper iodide (CuI) also emit blue light upon combustion – in other words, blue emitters that are devoid of chlorine are available for use in fireworks and flares. "Several members of NATO are interested in acquiring high-quality blue signal flares. However, using iodine-containing copper compounds, we have been unable to produce flames with the high luminous intensities required for this purpose," says Klapötke. "The reason for this is that iodine is 3.5 times heavier than chlorine. So in order to produce a flame with the intensity attainable with copper chloride, one needs to burn 3.5 times as much copper iodide per unit time."

CuBr for a more intensive flame

By replacing the traditional chlorine with bromine (which is only twice as heavy) instead of iodine, the researchers have now found a way around this problem. "Using CuBr species, we have been able to produce blue light of high quality whose luminous intensity and spectral purity meet the criteria required for use in signal flares," says Dr. Magdalena Rusan, a member of Klapötke's group and first author of the new study.

Tests of the new formulation have shown that copper chlorides and copper bromides have very similar emission spectra. This observation suggests that, as has long been suspected, an excited state of the Cu+ ion serves as the source of the blue color.

In addition to copper bromate ($Cu(BrO_3)_2$) as the oxidizer and source of CuBr species, the researchers chose to use hexamine as the fuel and ammoniumbromate as the coolant. "The ingredients of all of our novel and less toxic pyrotechnic formulations are commercially available and are actually cheaper than the first alternatives we came up with. This not only makes them safer but also easier to use," says Klapötke. "With this latest mixture, it would now also be possible to make blue fireworks 'greener', i.e. less environmentally objectionable, because the flame produces no toxic chlorine-containing substances. We are now planning to develop and test prototypes of blue signal flares based on the new formulation. But it will take between five and ten years before such flares are ready for routine use."

More information: "Copper(I) Bromide: An Alternative Emitter for Blue-Colored Flame Pyrotechnics." *Chem. Eur. J.*.
doi: 10.1002/chem.201502752

Provided by Ludwig Maximilian University of Munich