B12 Trace Chemical Analysis of Potassium Permanganate Hypergolic Mixtures Analyzed With Inductively Coupled Plasma/Optical Emission Spectroscopy (ICP/OES)

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After attending this presentation, attendees will understand the types of chemical variation among commercial sources of potassium permanganate that can be used to create incendiary mixtures. Attendees will also be introduced to the utility of trace element differences and their potential to determine the source of arson or explosive residues recovered as evidence.

This presentation will impact the forensic science community by presenting a new chemical signature system based on elemental profiles that may be used for the attribution of arson/explosive residues.

Hypergolic mixtures are self-igniting reactions that have been used for various types of criminal mischief as well as higher-profile terrorism-related incidents. They are a particular concern for law enforcement and the forensic science community as the ingredients are easily accessible and the reactions are simple to execute. Many current forensic techniques for analyzing hypergolic residues can identify the primary components, but provide little other information pertaining to their source. Few strategies exist for differentiating mixtures that have the same bulk chemical composition but are derived from different source ingredients (i.e., brands, commercial sources of the same product).

Therefore, the goal of this research was to characterize variations in trace element concentrations in the post-reaction residues of hypergolic reactions made with potassium permanganate and test whether different commercial sources of permanganate yielded distinct elemental profiles. Four different commercial sources of potassium permanganate were examined as well as three different mixing ratios of potassium permanganate with automotive brake fluid or glycerin as the fuel: 1:1; 2:1; and, 3:1 (grams:milliliter). Four replicate reactions were produced for each source-mixing ratio combination. The residues were then extracted using 2% trace metal-free nitric acid and analyzed using Inductively Coupled Plasma/Optical Emission Spectroscopy (ICP/OES) to determine the concentration of 24 different elements. The quantitation range was between 5ppb and 100ppm. Discriminant Function Analysis (DFA) was used to analyze the resulting chemical profile for each mixture sample and identify a subset of variables that optimized multivariate differentiation of each sample group. These included Na, Mg, Zn, Pb, Ca, Al, and Ba.

Results show that ICP/OES profiles of the two post-reaction residues from the analytical-grade permanganate sources could be differentiated by the concentrations of magnesium and calcium (~10 ± 0.1 ppb vs. ~6 ± 0.1 ppb and ~100 ± 2 ppb vs. ~50 ± 1 ppb, respectively). DFA of the trace metal profiles also exhibited clear separation between the two analytical-grade sources. Standardized function coefficients indicate that the elements that had the highest contribution to the differences were magnesium and calcium and, to a lesser extent, aluminum and sodium. The abundance of many elements decreased as the permanganate ratio increased. For example, the concentration of magnesium varied between ~14ppb ± 0.1ppb, ~8.6ppb ± 0.1ppb, and ~5.8ppb ± 0.1ppb for 1:1, 2:1, and 3:1 mixture samples, respectively. Furthermore, each mixing ratio group was resolved with two discriminant functions. This indicates that trace elemental profiles may be influenced by the source of oxidant as well as other individualizing aspects of the reaction, such as the mixing ratio. This research suggests that various brands of potassium permanganate can be differentiated by their trace elemental variations and that elemental profiles may be useful for characterizing the source of hypergolic mixture residues recovered during an investigation.

Hypergolic Mixtures, ICP/OES, Trace Metals