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A Novel UV-Vis Spectroscopic Method to Detect Elemental Mercury Using Gold Nanoparticles

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Introduction:

Mercury is a persistent, bioaccumulative, toxic pollutant that poses significant environmental and human health effects including impaired childhood development, neurological damage, and kidney and liver failure. Elemental mercury, given its high vapor pressure and low water solubility has an atmospheric residence time of 1-2 years and is the most abundant form of mercury (c. 95%) in the atmosphere. In this paper, we demonstrate a novel technique to detect gas phase elemental mercury at sub-ppm concentrations using colloidal gold particles that display a characteristic surface plasmon resonance absorption peak in the visible spectrum. Spectroscopic analysis and transmission electron microscopy (TEM) are used to quantify the concentration of mercury present and to calibrate the detection system.

Method:

Mercury vapor from a temperature controlled bead of elemental mercury was entrained in nitrogen gas and exposed to 5 nm gold particles by bubbling the mercurous carrier stream through three silica cuvettes connected in series. Each cuvette contained 3.2 mL of colloidal solution or 1.6×10^{14} gold particles suspended in distilled water. The concentration of mercury was varied from approximately 0.25-80 ppm (on a mass basis). A Perkin Elmer Lambda 2 UV-Vis spectrometer was used to track the position of the surface plasmon resonance peak during and after exposure, and a Philips Tecnai 12 TEM was employed to investigate changes in the morphology and composition of the gold particles after exposure.

Results:

The UV-Vis spectrographs indicate a significant blue-shift, or shift toward smaller wavelengths, and increase in absorbance of the surface plasmon resonance peak upon exposure to elemental mercury. The extent of the blue-shift is both temperature and time dependent and provides a measure for the concentration of mercury flowing through the system. The blue-shift after exposure to 1.6 ppm elemental mercury flowing at 140 cm^3/min for 15 minutes was approximately 10 nm. TEM images revealed that the overall size of the particles remained relatively unchanged. The number of mercury atoms adsorbed by single gold particles under such conditions was determined to be less than 1% of the total number of surface atoms. Long after the exposure, the surface

plasmon peak was observed to relax toward its original position suggesting, perhaps, solid state diffusion of the mercury atoms into the gold particles and self-regeneration of detection medium to a point. This effect is currently being investigated.

Discussion and Conclusions:

A novel technique to detect elemental mercury at sub-ppm concentrations is presented. Results to date are promising and a device based on this technique is potentially inexpensive and sensitive enough to find use in many areas including coal fired combustion plants, metals processing facilities, hospitals, research laboratories, schools, and homes.