# Making gold green: New non-toxic method for mining gold

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Northwestern University scientists have struck gold in the laboratory. They have discovered an inexpensive and environmentally benign method that uses simple cornstarch—instead of cyanide—to isolate gold from raw materials in a selective manner.

This green method extracts gold from crude sources and leaves behind other metals that are often found mixed together with the crude gold. The new process also can be used to extract gold from consumer electronic waste.

Current methods for gold recovery involve the use of highly poisonous cyanides, often leading to contamination of the environment. Nearly all gold-mining companies use this toxic gold leaching process to sequester the precious metal.

"The elimination of cyanide from the gold industry is of the utmost importance environmentally," said Sir Fraser Stoddart, the Board of Trustees Professor of Chemistry in the Weinberg College of Arts and Sciences. "We have replaced nasty reagents with a cheap, biologically friendly material derived from starch."

Sir Fraser's team discovered the process by accident, using simple test tube chemistry. A series of rigorous follow-up investigations provided evidence for the competitive strength of the new procedure.

The findings will be published May 14 in the online journal *Nature*

*Communications*.

Zhichang Liu, a postdoctoral fellow in Stoddart's lab and first author of the paper, took two test tubes containing aqueous solutions—one of the starch-derived alpha-cyclodextrin, the other of a dissolved gold (Au) salt (called aurate)—and mixed them together in a beaker at room temperature.

Liu was trying to make an extended, three-dimensional cubic structure, which could be used to store gases and small molecules. Unexpectedly, he obtained needles, which formed rapidly upon mixing the two solutions.

"Initially, I was disappointed when my experiment didn't produce cubes, but when I saw the needles, I got excited," Liu said. "I wanted to learn more about the composition of these needles."

"Nature decided otherwise," said Stoddart, a senior author of the paper. "The needles, composed of straw-like bundles of supramolecular wires, emerged from the mixed solutions in less than a minute."

After discovering the needles, Liu screened six different complexes—cyclodextrins composed of rings of six (alpha), seven (beta) and eight (gamma) glucose units, each combined with aqueous solutions of potassium tetrabromoaurate ($KAuBr_4$) or potassium tetrachloroaurate ($KAuCl_4$).

He found that it was alpha-cyclodextrin, a cyclic starch fragment composed of six glucose units, that isolates gold best of all.

"Alpha-cyclodextrin is the gold medal winner," Stoddart said. "Zhichang stumbled on a piece of magic for isolating gold from anything in a green way."

Alkali metal salt waste from this new method is relatively environmentally benign, Stoddart said, while waste from conventional methods includes toxic cyanide salts and gases. The Northwestern procedure is also more efficient than current commercial processes.

The supramolecular nanowires, each 1.3 nanometers in diameter, assemble spontaneously in a straw-like manner. In each wire, the gold ion is held together in the middle of four bromine atoms, while the potassium ion is surrounded by six water molecules; these ions are sandwiched in an alternating fashion by alpha-cyclodextrin rings. Around 4,000 wires are bundled parallel to each other and form individual needles that are visible under an electron microscope.

"There is a lot of chemistry packed into these nanowires," Stoddart said. "The elegance of the composition of single nanowires was revealed by atomic force microscopy, which throws light on the stacking of the individual donut-shaped alpha-cyclodextrin rings."

The atomic detail of the single supramolecular wires and their relative disposition within the needles was uncovered by single crystal X-ray crystallography.

The research—a prime example of serendipity at work, brought to fruition by contemporary fundamental science—is poised to find technological application. This basic science has been forged by the team into a practical labscale process for the isolation of gold from scrap alloys.

**More information:** The paper is titled "Selective isolation of gold facilitated by second-sphere coordination with α-cyclodextrin."

Provided by Northwestern University