Method to produce gold nanorod radiotracers for industrial applications.

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Fluids flowing with high temperatures are expected in industrial plants, mainly in the distillation process in oil installations. In these cases, special radiotracers are necessary to measure the residence time curves or the transient time using nanoradiotracers. Gold Nanorods (AuNRs) have drawn the most attention because they can be synthesized using a relatively simple process such as wet chemical methods. Its morphology can be controlled both by choice of experimental conditions and the type and concentration of surfactants or reducing agent. The objective of this work was to develop gold nanorods as a radiotracer. The preparation of AuNRs is divided into three steps: the first, the purification of gold shards; the second, the synthesis of gold nano seeds and the third, the synthesis of AuNRs.

Step 1 - Purification of gold shards
Initially, gold scrap must be cut and reduced to the size and increase the surface area; if there are any organic substances, the sample must be previously calcined. Then they are transferred to a 250 ml Becker to be dissolved by adding small volumes of aqua regia. The gold solution was dried and then redissolved in 250 ml of HCl (0.1 M). The tetrachloride aurate (III) ($HAuCl_4 \cdot 3H_2O$) ion is formed and stoke the solution in an amber glass flask.

Step 2 - Synthesis of gold nanoparticles
The method to produce AuNPs was described by Turkevich [3] and involves the reduction of gold ions (Au3+) to gold atoms (Au0) in the presence of citrate as a reducing agent. The $HAuCl_4 \cdot 3H_2O$ solution is heated (using reflux) to the boiling point with vigorous stirring, using a magnetic hotplate stirrer. At this point, 5.0 ml of citrate solution (1.0%) is added. The citrate addition causes Au^{3+} ions reduced to the neutral gold atoms, and the color changes from a yellow to a greyish-blue. The solution is stirred vigorously, and the color changes to a deep wine red. The gold solution is allowed to cool to room temperature. In this color, the AuNPs will be slightly uniform in size and have a mean diameter equal to 200 +/- 15 A. The AuNPs solution is transferred to an amber glass flask and stored in the refrigerator for future use.

Step 3 - Synthesis of Refined Gold Nanorods
The basic principle is to add a certain amount of gold nanoparticle seeds to the growth solution under the action of surfactants, the AuNRs grow. The morphology AuNRs can be controlled by varying the reduction conditions: type and concentration of reducing agent and temperature.

3.1 - The seed solution
Under stirring, to the step 2 solution, add 0.6 ml of an iced-colled aqueous solution of $NaBH_4$ (0.010 M), this results in the formation of a brownish-yellow solution.

3.2 - The stock solution
Mix in a 200 mL Becker 60.0 ml of aqueous $HAuCl_4$ (5.0×10^{-4} M) and 60.0 ml of CTAB solution (0.2 M). To this, add 1.0 ml of AgNO3 (4.0×10^{-3} M) and maintain the temperature at 25 °C. After gentle mixing, 350 µl of 0.10M ascorbic acid was added. The color of the stock solution changes from dark yellow to colorless.

3.3 - AuNRs synthesis
First, prepare two solutions: the A-solution, mixing 9.0 ml of the stock solution with 1.0 ml of the seed solution; the B-solution, mixing 9.0 ml of the stock solution with 1.0 ml of the A-solution. In an Erlenmeyer flask, mix 90.0ml of stoke solution with 10.0 ml of B-solution. The Erlenmeyer flask was gently stirred to homogenize the system. The color of this solution slowly changed to purple.

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