Heating or Cooling: Temperature Effects on the Synthesis of Atomically Precise Gold Nanoclusters

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Abstract

Developing an efficient, well-controlled synthesis strategy for gold nanoclusters (Au NCs) is crucial for delivering their expected applications in many fields; and such development requires fundamental understandings on the synthetic chemistry. The synthesis of Au NCs typically consists of a pair of reversible reactions: a fast reduction-growth reaction and a slow size-focusing reaction. Here we demonstrate that the above two reactions can be welt-balanced while accelerated in a heated synthesis protocol, thus providing an efficient and scalable synthesis method to obtain thermodynamically favorable Au-25(SR)(18) NCs (SR denotes thiolate ligand), with high yield (>95% on gold atom basis) and fast kinetics. By investigating the Au NC formation behavior at different temperature, we identified the endothermic nature of the reductive formation of Au-25(SR)(18) NCs from Au(I)-thiolate complex precursors: More interestingly, if overheated, after the formation of Au-25(SR)(18), there exists an irreversible first-order reaction, which could transform Au-25(SR)(18) into Au NCs of mixed sizes. As a result, 40 degrees C is identified as the optimal temperature to synthesize Au-25(SR)(18) in aqueous solution, as the half-life of the transformation reaction (67.8 h) is much longer than the time needed to obtain high yield Au-25(SR)(18). The detailed understandings on the temperature effects of Au NC synthesis would facilitate the development of efficient synthesis strategies for atomically precise Au NCs with predesigned size, composition and structure.

Keywords

KeyWords Plus: GRAM-SCALE SYNTHESIS; METAL NANOCLUSTERS; AU-25 NANOCLUSTERS; AU(I)-THIOLATE COMPLEXES; CHARGE-STATE; NANOPARTICLES; CLUSTERS; STABILITY; MONODISPERSE; SIZE

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Cited References: 61

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1. **Recent Progress in Cancer Thermal Therapy Using Gold Nanoparticles** — Times Cited: 269
   By: Abadeer, Nardine S.; Murphy, Catherine J.
   JOURNAL OF PHYSICAL CHEMISTRY C Volume: 120 Issue: 9 Pages: 4691-4716 Published: MAR 10 2016

2. **On the structure of thiolate-protected Au-25** — Times Cited: 527
   By: Akola, Jaakko; Walter, Michael; Whetten, Robert L.; et al.
   JOURNAL OF THE AMERICAN CHEMICAL SOCIETY Volume: 130 Issue: 12 Pages: 3756-+ Published: MAR 26 2008

3. **Interplay of Charge State, Lability, and Magnetism in the Molecule-like Au-25(SR)(18) Cluster** — Times Cited: 111
   By: Antonello, Sabrina; Perera, Neranjan V.; Ruzzi, Marco; et al.
   JOURNAL OF THE AMERICAN CHEMICAL SOCIETY Volume: 135 Issue: 41 Pages: 15585-15594 Published: OCT 16 2013

4. **SYNTHESIS OF THIOL-DERIVATIZED GOLD NANOPARTICLES IN A 2-PHASE LIQUID-LIQUID SYSTEM** — Times Cited: 5,597
   By: BRUST, M; WALKER, M; BETHELL, D; et al.
   JOURNAL OF THE CHEMICAL SOCIETY-CHEMICAL COMMUNICATIONS Issue: 7 Pages: 801-802 Published: APR 7 1994

5. **Synthesis of thiolate-protected Au nanoparticles revisited: U-shape trend between the size of nanoparticles and thiol-to-Au ratio** — Times Cited: 12
   By: Chen, Tiankai; Luo, Zhentao; Yao, Qiaofeng; et al.
   CHEMICAL COMMUNICATIONS Volume: 52 Issue: 61 Pages: 9522-9525 Published: 2016

6. **Carbon Monoxide: A Mild and Efficient Reducing Agent towards Atomically Precise Gold Nanoclusters** — Times Cited: 9
   By: Chen, Tiankai; Xie, Jianping
   CHEMICAL RECORD Volume: 16 Issue: 4 Pages: 1761-1771 Published: AUG 2016

7. **Single Crystal XRD Structure and Theoretical Analysis of the Chiral Au30S(S-t-Bu)(18) Cluster** — Times Cited: 160
   By: Crasto, David; Malola, Sami; Brosofsky, Grace; et al.
   JOURNAL OF THE AMERICAN CHEMICAL SOCIETY Volume: 136 Issue: 13 Pages: 5000-5005 Published: APR 2 2014

8. **Structure Determination of [Au-18(SR)(14)]** — Times Cited: 104
   By: Das, Anindita; Liu, Chong; Byun, Hee Young; et al.
   ANGEWANDTE CHEMIE-INTERNATIONAL EDITION Volume: 54 Issue: 10 Pages: 3140-3144 Published: MAR 2 2015

9. **Mass Spectrometric Identification of Au-68(SR)(34) Molecular Gold Nanoclusters with 34-Electron Shell Closing** — Times Cited: 151
   By: Dass, Amala
   JOURNAL OF THE AMERICAN CHEMICAL SOCIETY Volume: 131 Issue: 33 Pages: 11666-+ Published: AUG 26 2009

10. **The golden age: gold nanoparticles for biomedicine** — Times Cited: 1,559
    By: Dreaden, Erik C.; Alkilany, Alaaldin M.; Huang, Xiaohua; et al.
    CHEMICAL SOCIETY REVIEWS Volume: 41 Issue: 7 Pages: 2740-2779 Published: 2012

11. **Recent advances in the synthesis and catalytic applications of ligand-protected, atomically precise metal nanoclusters** — Times Cited: 114
    By: Fang, Jun; Zhang, Bin; Yao, Qiaofeng; et al.