



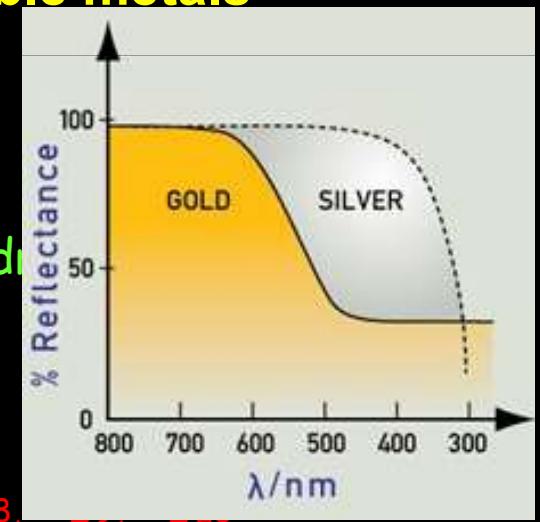
Established in 1959

## Size evolution of luminescent lactoferrin protected gold clusters Luminescent molecular clusters of noble metals

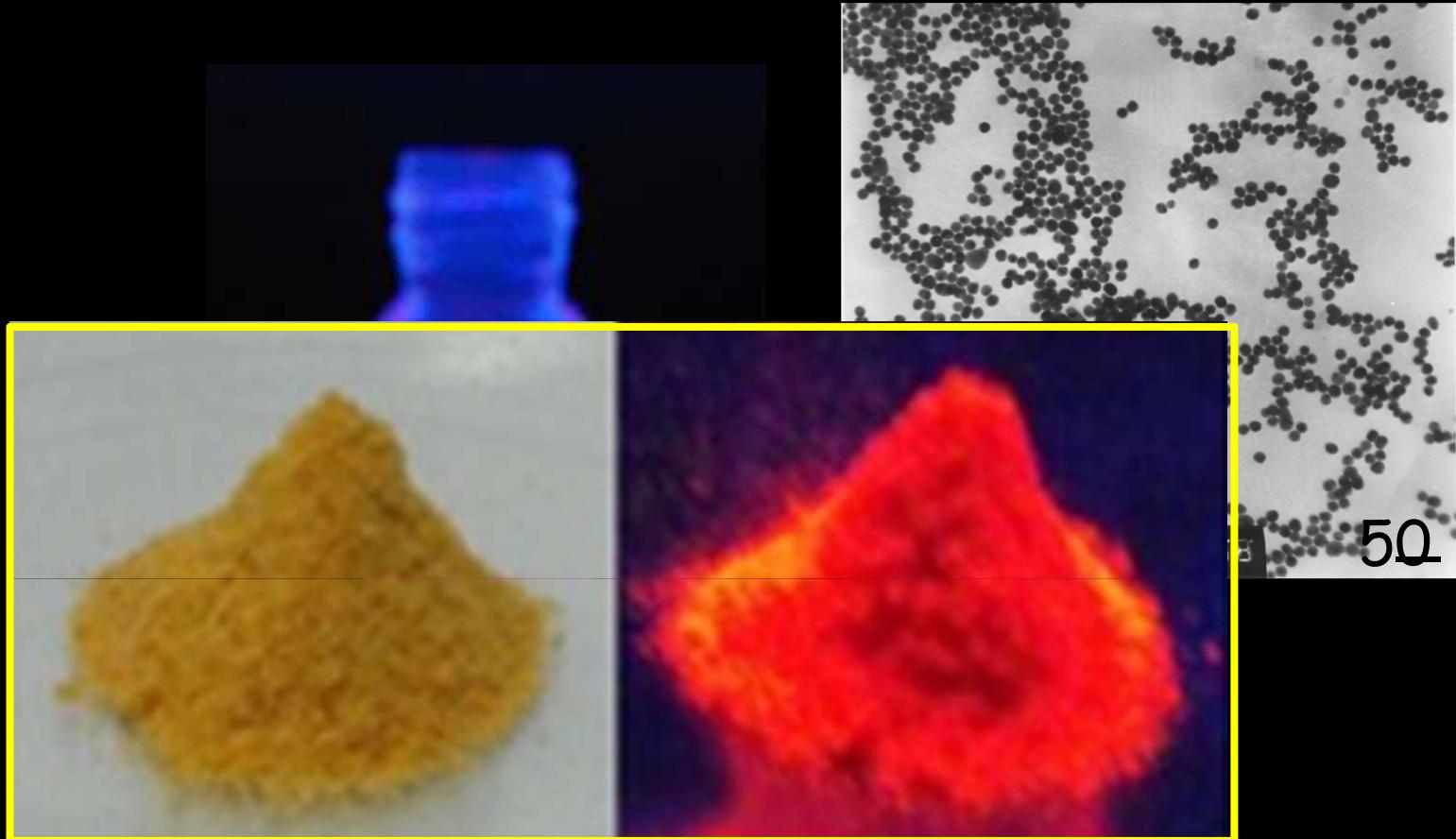


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$\text{Au}_{23}$ ,  $\text{Au}_{22}$ ,  $\text{Au}_8$ ,  $\text{Ag}_8$ ,  $\text{Au}_8\text{Ag}_8$

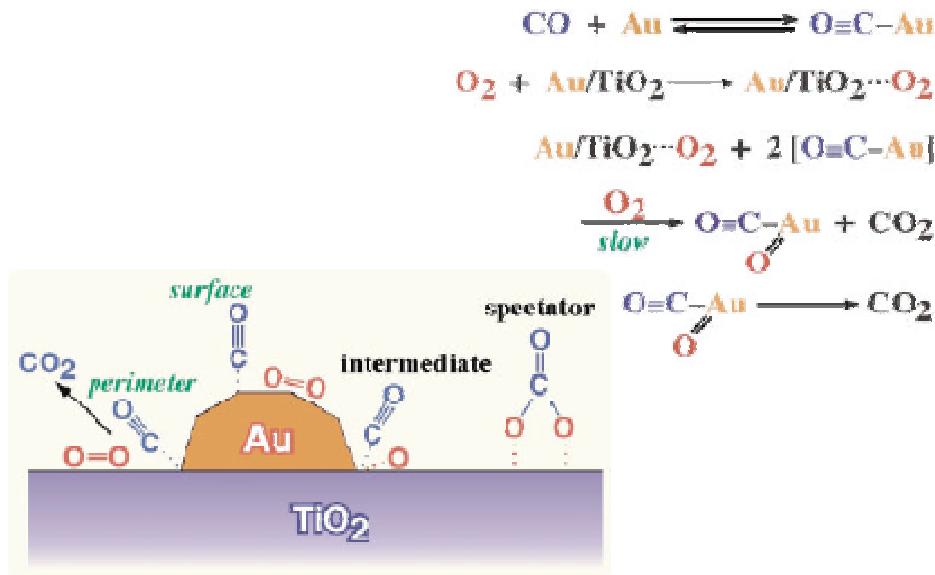


International Symposium on The Safe Use of Nanomaterials, Indian Institute of Toxicology Research, Lucknow, February 1-3, 2011



Faraday's gold preserved in Royal Institution. From the site,  
<http://www.rigb.org/rimain/heritage/faradaiyঃ.jsp>

## Supported gold clusters in catalysis



Schematic representation for CO oxidation pathways over Au/TiO<sub>2</sub>.

M. Haruta. When Gold Is Not Noble: Catalysis by Nanoparticles. *Chem. Rec.* **2003**, 3, 75.

## Magic clusters

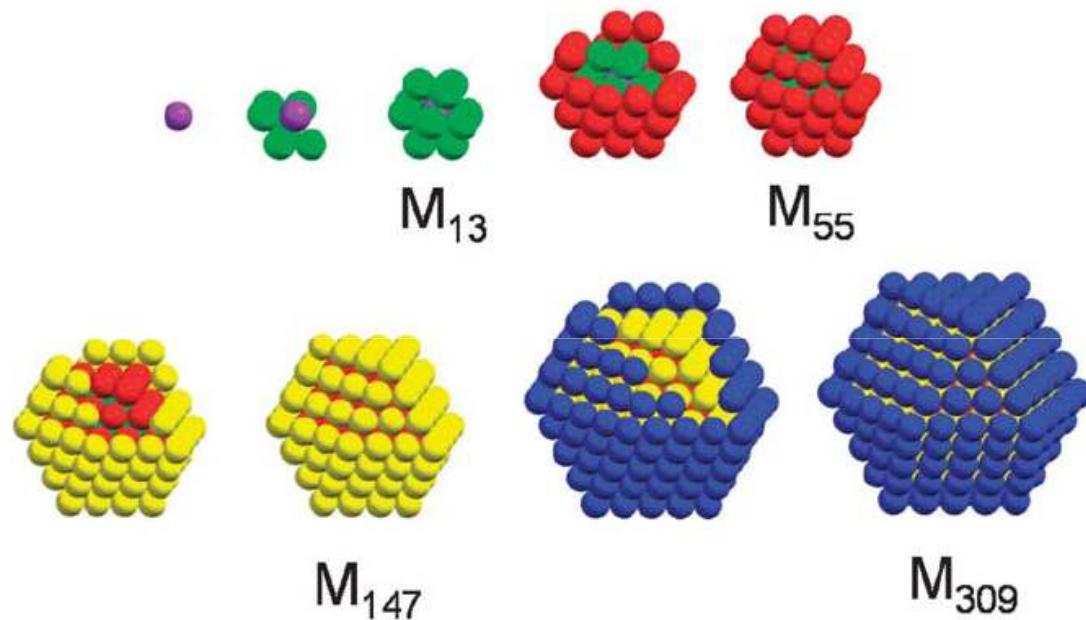
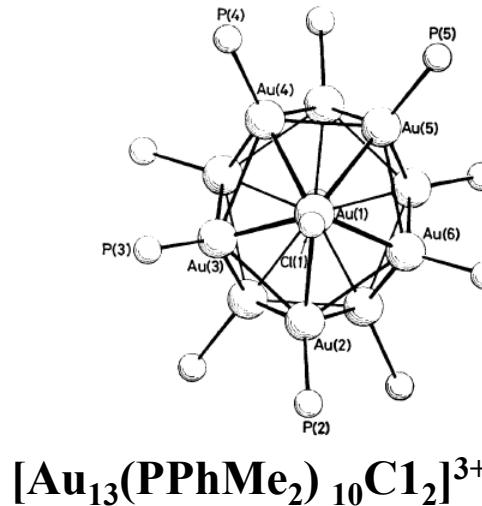


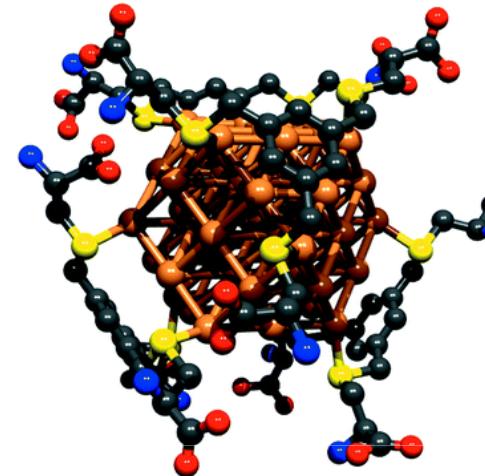
Fig. 1 Organization of full-shell clusters: a first single atom (purple) is surrounded by 12 others (green) to give a one-shell cluster  $M_{13}$ . 42 atoms (red) can be densely packed on the 12 green atoms ending with the  $M_{55}$  two-shell cluster, followed by 92 atoms (yellow) and 162 atoms (blue) to give  $M_{147}$  and  $M_{309}$ , respectively.

From Gunter Schmidt, *Chem. Soc. Rev.* 2008, 37, 1909-1930

## Gold clusters



$Au_{13}$

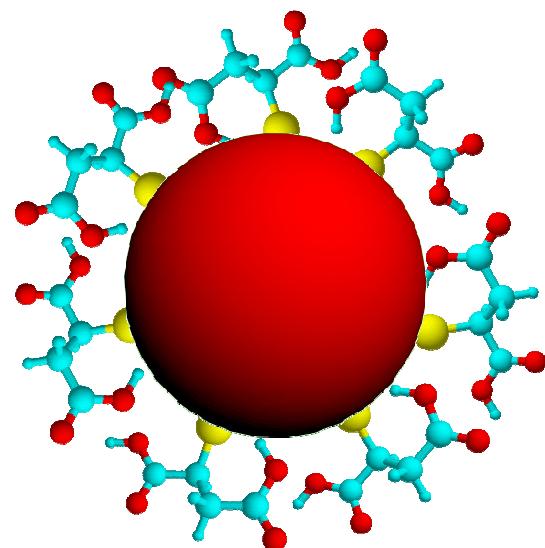


$Au_{55}$

- **$Au_{55} [P(C_6H_5)_3]_{12}Cl_6$  - a gold cluster of unusual size,** Schmid, G.; Pfeil, R.; Boese, R.; Brädermann, F.; Meyer, S.; Calis, G. H. M.; Van der Velden.; Jan W. A. *Chemische Berichte* **1981**, 114, 3634.
- **Synthesis and x-ray structural characterization of the centered icosahedral gold cluster compound  $[Au_{13} (PMe_2Ph)_{10}Cl_2](PF_6)_3$ ; the realization of a theoretical prediction,** Briant, C. E.; Theobald, B. R. C.; White, J. W.; Bell, L. K.; Mingos, D. M. P.; Welch, A. J. *Chem. Commun.* **1981**, 5, 201.
- **Synthesis of water-soluble undecagold cluster compounds of potential importance in electron microscopic and other studies in biological systems,** Bartlett, P. A.; Bauer, B.; Singer, S. *J. Am. Chem. Soc.* **1978**, 100, 5085.

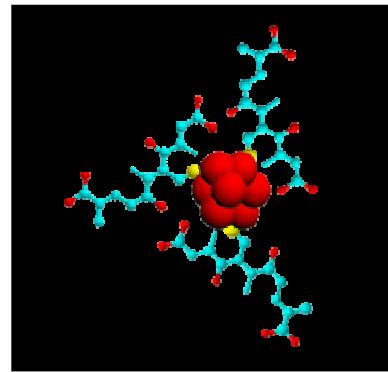
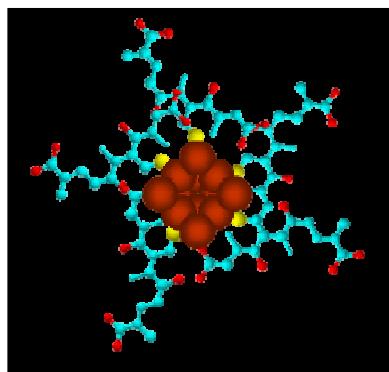
# **Monolayer Protected Metal Nanoparticles**

## **Monolayer Protected Clusters (MPCs)**



N. Sandhyarani and T. Pradeep, *Int. Rev. Phys. Chem.* **2003**

## Molecular Clusters

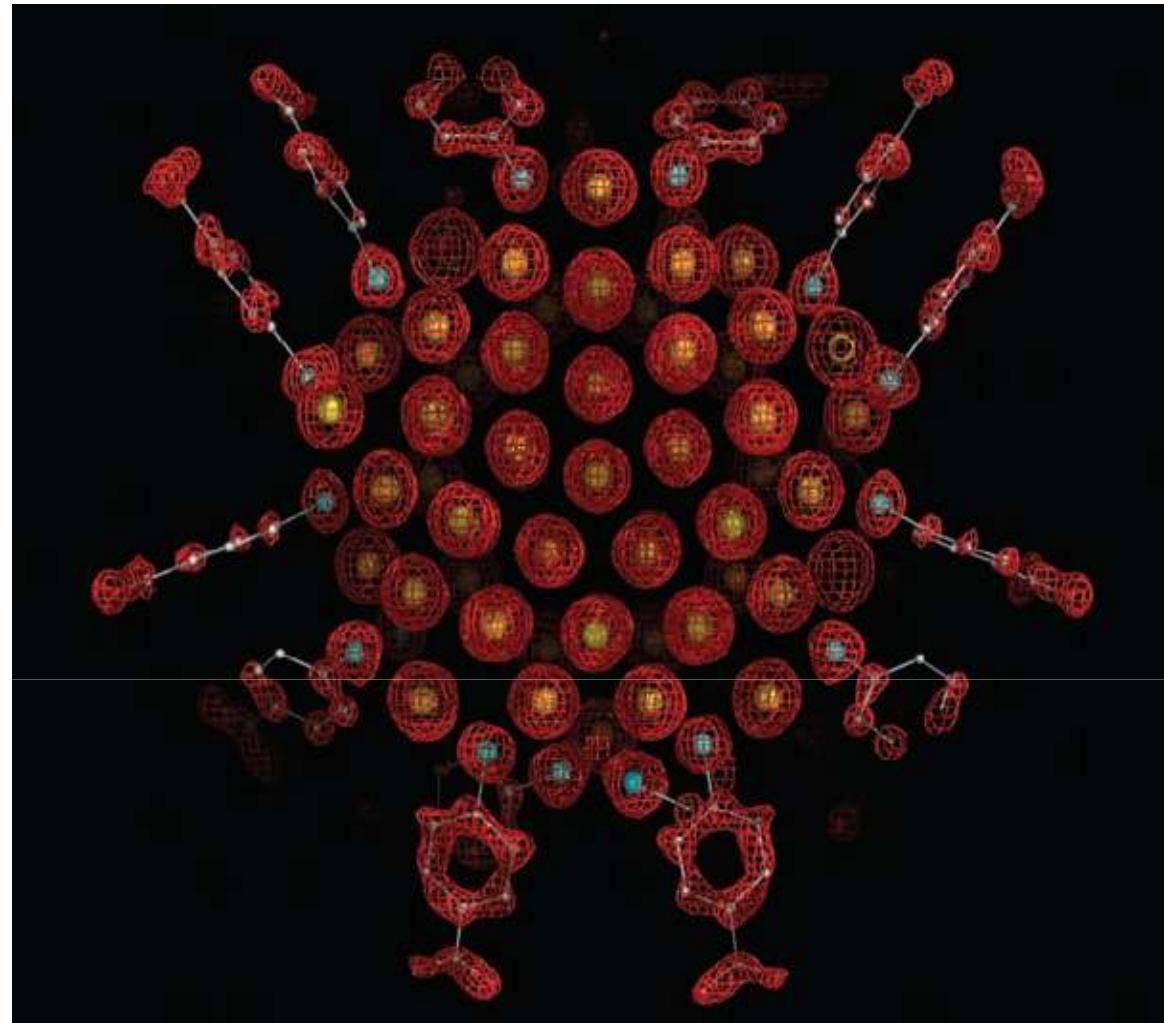


- **28 kDa Alkanethiolate-Protected Au Clusters Give Analogous Solution Electrochemistry and STM Coulomb Staircases**, Ingram, R. S.; Hostetler, M. J.; Murray, R. W.; Schaaff, T. G.; Khouri, J.; Whetten, R. L.; Bigioni, T. P.; Guthrie, D. K.; First, P. N. *J. Am. Chem. Soc.* **1997**, *119*, 9279.
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- **Optical Absorption Spectra of Nanocrystal Gold Molecules**, Alvarez, M. M.; Khouri, J. T.; Schaaff, T. G.; Shafiqullin, M. N.; Vezmar, I.; Whetten, R. L. *J. Phys. Chem. B* **1997**, *101*, 3706.

- **Isolation and Selected Properties of a 10.4 kDa Gold:Glutathione Cluster Compound**, Schaaff, T. G.; Knight, G.; Shafiqullin, M. N.; Borkman, R. F.; Whetten, R. L. *J. Phys. Chem. B* **1998**, *102*, 10643.
- **Controlled Etching of Au:SR Cluster Compounds**, Schaaff, T. G.; Whetten, R. L. *J. Phys. Chem. B* **1999**, *103*, 9394.
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- **Visible to Infrared Luminescence from a 28-Atom Gold Cluster**, Link, S.; Beeby, A.; FitzGerald, S.; El-Sayed, M. A.; Schaaff, T. G.; Whetten, R. L. *J. Phys. Chem. B* **2002**, *106*, 3410.
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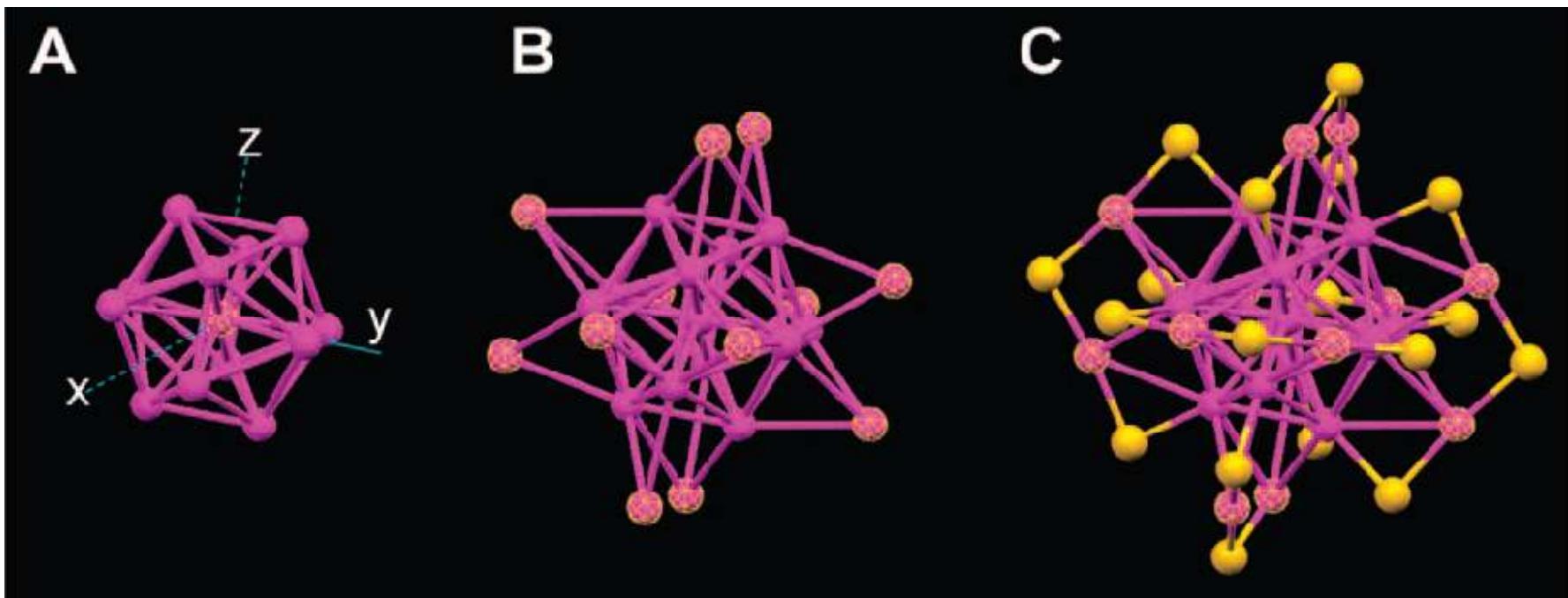
# $\text{Au}_{102}$

$\text{Au}_{102}(\text{p-MBA})_{44}$



Jadzinsky, P. D.; Calero, G.; Ackerson, C. J.; Bushnell, D. A.; Kornberg, R. D. Structure of a Thiol Monolayer-Protected Gold Nanoparticle at 1.1 Å Resolution *Science* **2007**, *318*, 430.

# Au<sub>25</sub>



Murray et al. JACS, 2008

**How to make them?**