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Thalappil Pradeep

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Co-founder

InnoNano Rese
InnoDI Water Technologies Pvt. Ltd.
VayuJAL Technologies Pvt. Ltd.
Aqueasy Innovations Pvt. Ltd.
Hydromaterials Pvt. Ltd.
EyeNetAqua Solutions Pvt. Ltd.
DeepSpectrum

Associate Editor
ACS Sustainable Resource Management

Professor-in-charge

ICCW
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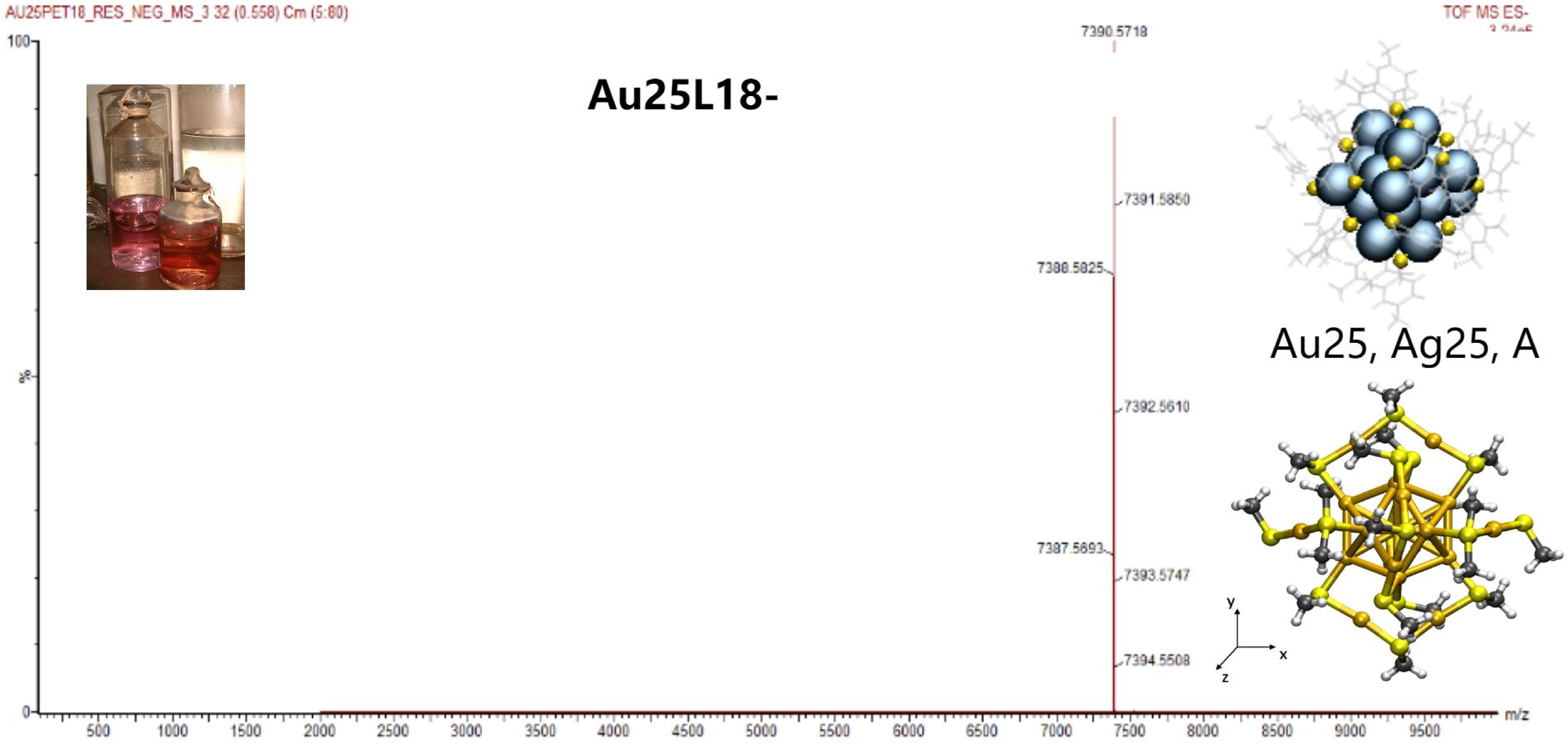
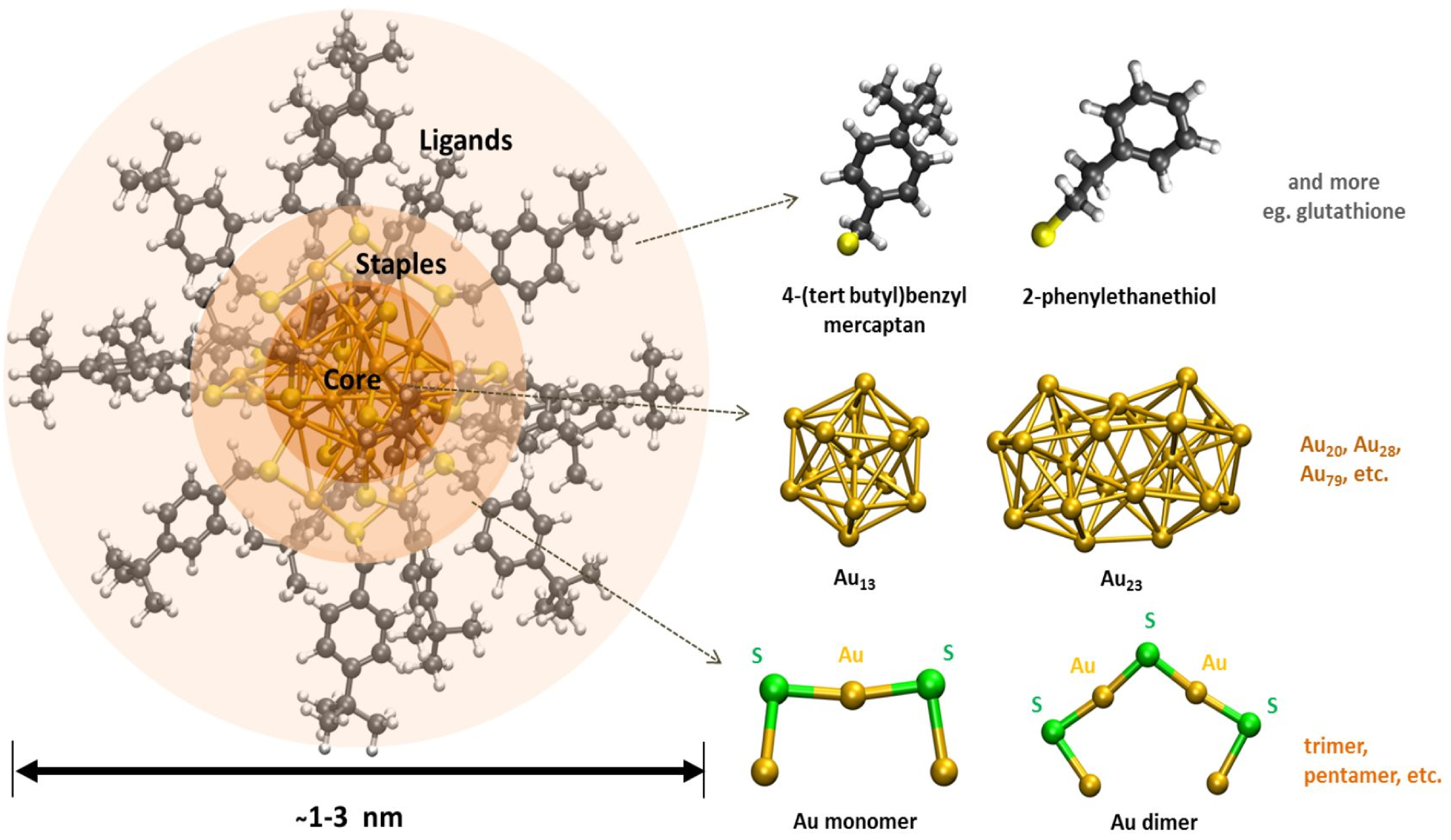
Pradeep RESEARCH GROUP

THEMATIC UNIT OF EXCELLENCE

Atomically precise metal clusters as material s



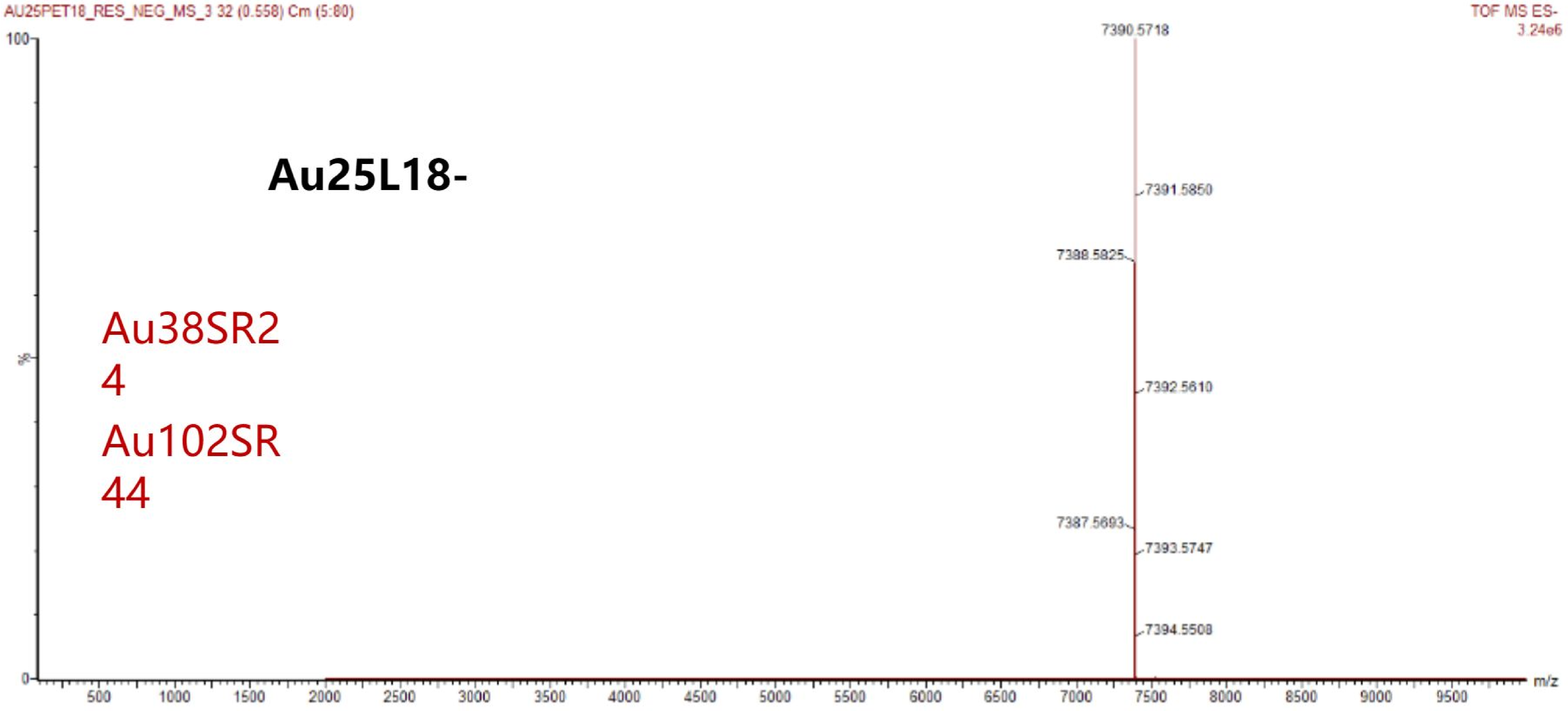
T. Pradeep et. al. *Acc. Chem. Res.* 2018; 201 9



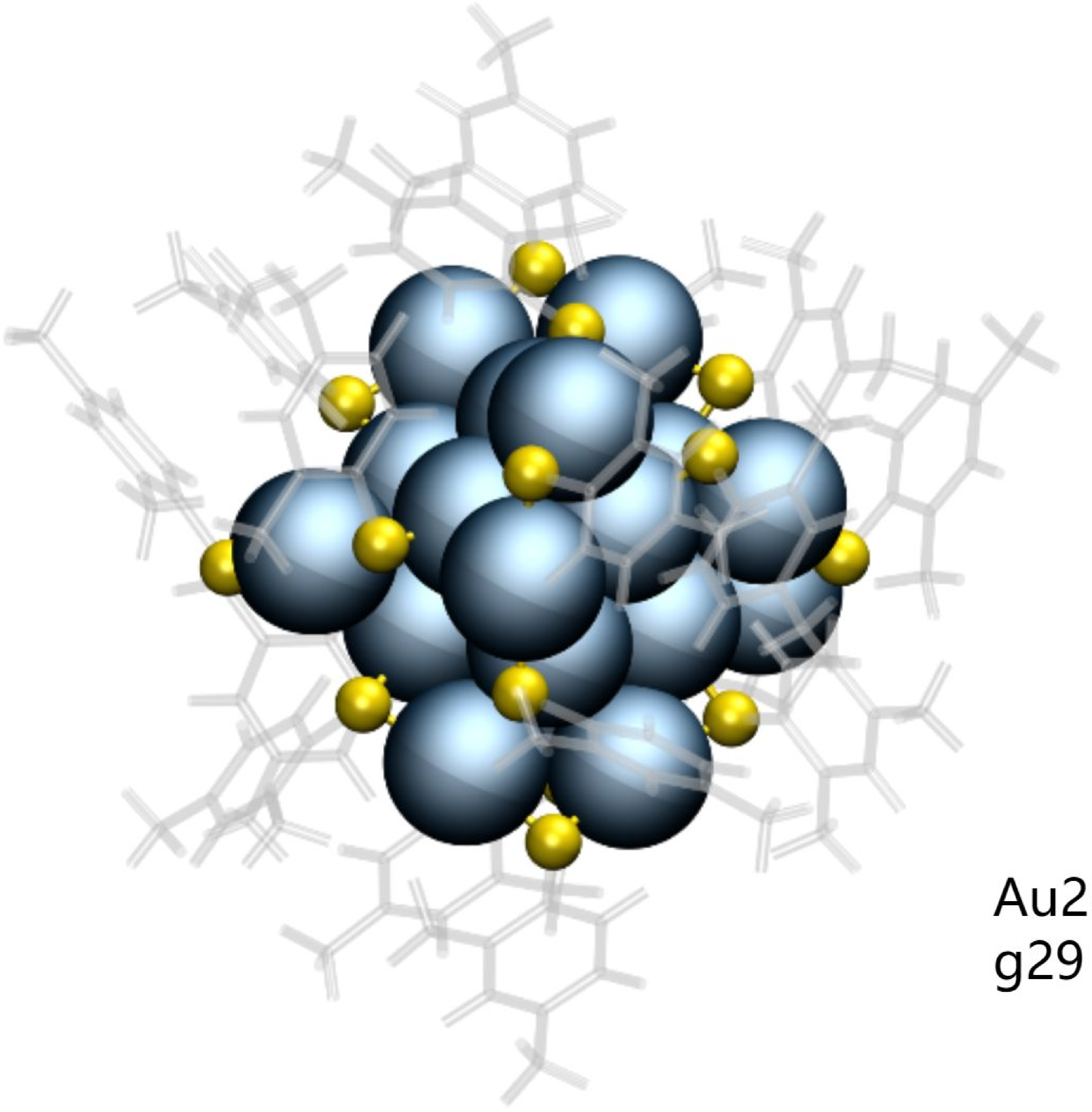
Ligands
Staples
Core
~1-3 nm
4-(tert butyl)benzyl mercaptan
2-phenylethanethiol
and more
eg. glutathione
Au_{13}
Au_{23}
Au_{20}, Au_{28}, Au_{79}, etc.
S
Au
S
Au monomer
S
Au
Au
S
S
Au dimer
trimer, pentamer, etc.

Based on the work of: R. W. Murray, Robert L. Whetten, Uzi Landman, Tatuya Tsukuda, Yuichi Negishi, Konishi, Hannu Hakkinen, Rongchao Jin, Nanfeng Zheng, Terry Bigioni, Osman Bakr, Kornberg, Jianping Xie, C. M. Aikens, Thomas Buergi, Stefan Wajda, Amala Dass, Christopher Ackerson, Kenneth L. Knappenberger, Rodolphe Antoine, Noelia Barrabes, Joanna Olesiak-Banska, Rajesh Sardar, George C. Schatz, Robert W. J. Scott, Kevin Stamplecoskie, Marcus Tofanelli, Jie Zheng, Gangli Wang, Julia Laskin, De-en Jiang, Robin Ras, Olli Ikkala, María Francisca Matus, Nonappa, Manfred Kappes, Stefanie Dehen, Stacy Copp, Andre Clayborne, Anindita Das, Ignacio Garzon, Lasse Jensen, Chris Johnson, Chen-Wei Liu, Dongil Lee, Di Sun, Quan-Ming Wang, Manzhou Zhu, Taeghawan Hyeon, Jian He, Yan Zhu, Meng Zhou, Wenwu Xu, Man-Bo Li, Shuang Quan Zang, Yongbo Song, Huan Yan, Zhikun Wu, Chuanhao Yao, Jinbin Liu, Hai-Long Jiang, Gao Li, Shaowei Chen, Sukhendu Mandal, Indranath Chakraborty, E. S. Shibu, Ananya Baksi, Amitav Patra, Pradipta Purkayastha, Saptarshi Mukherjee, Rajendra Singh Dayal, Tarak Karmakar, Biswarup Pathak, Nirmal Goswami,….. A.

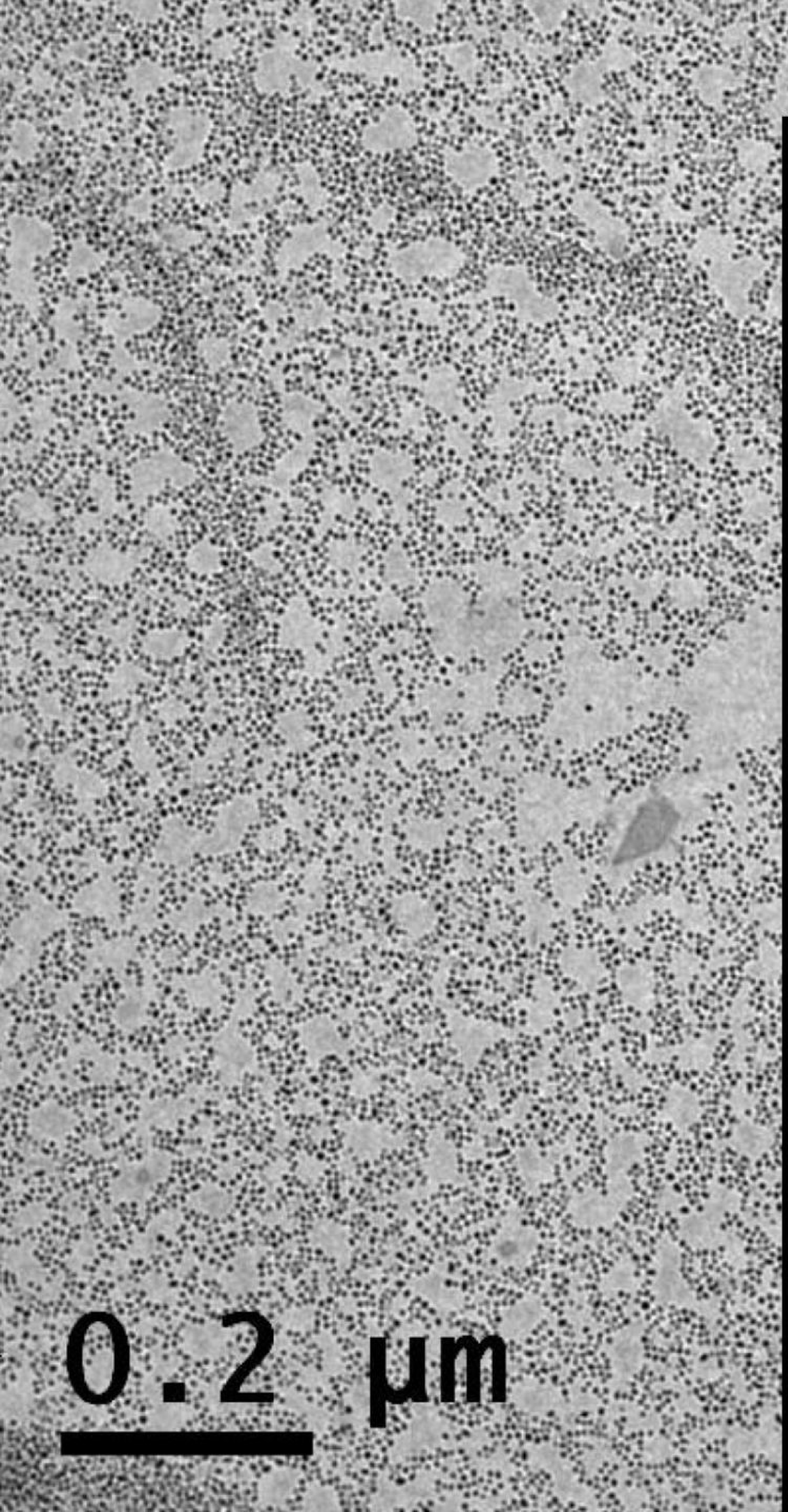
Molecular formula, Molecular weight

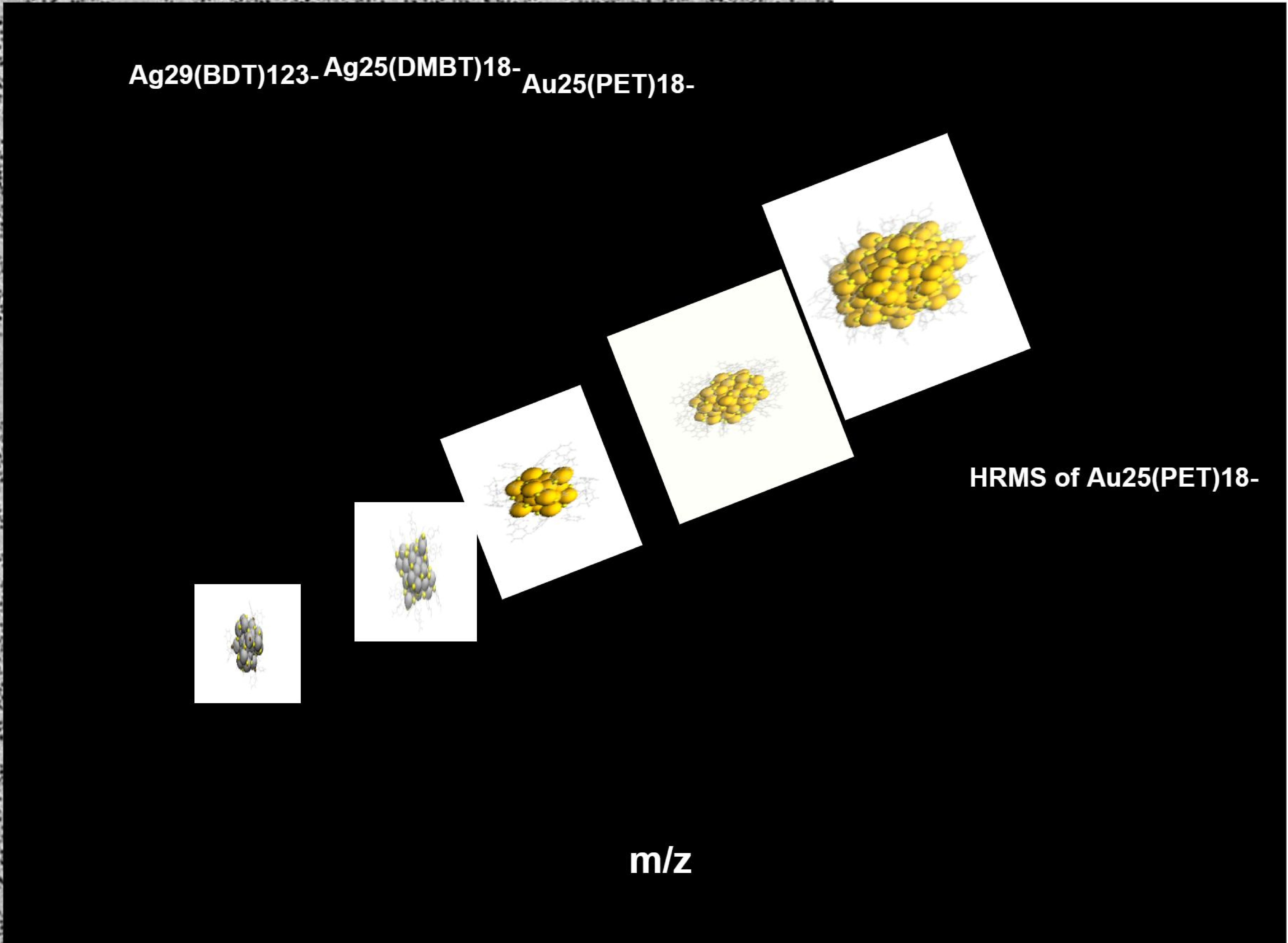


New molecule
s

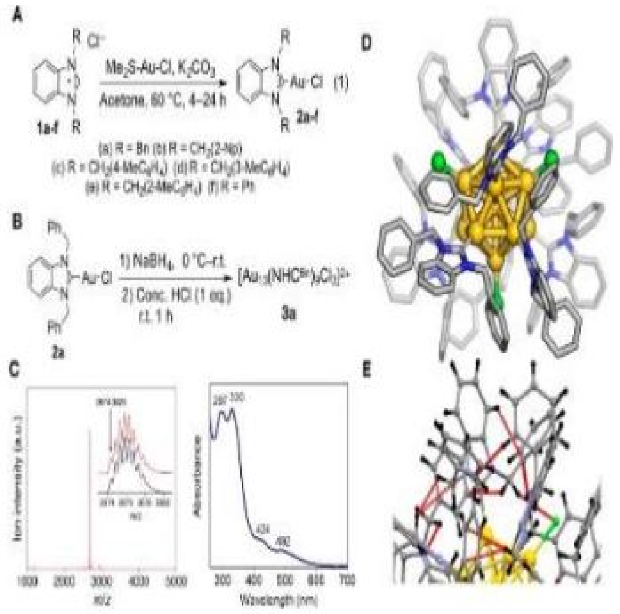


Au25, Ag25, A
g29

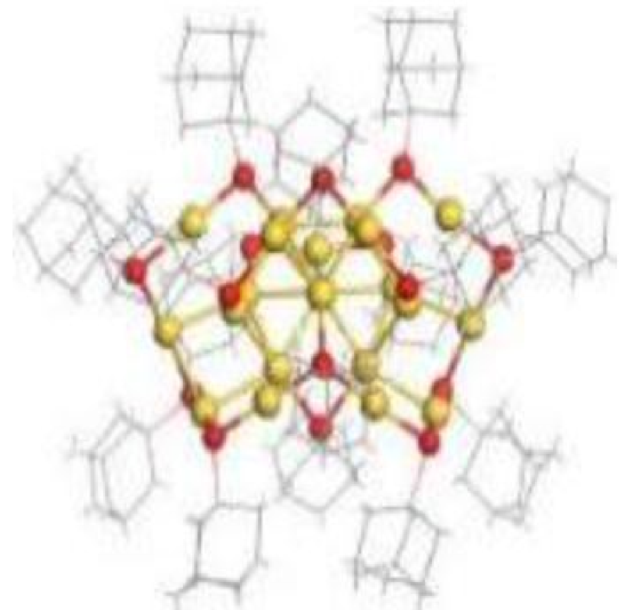

0.2 μm


Ag29(BDT)123-
Ag25(DMBT)18-
Au25(PET)18-
HRMS of Au25(PET)18-
m/z

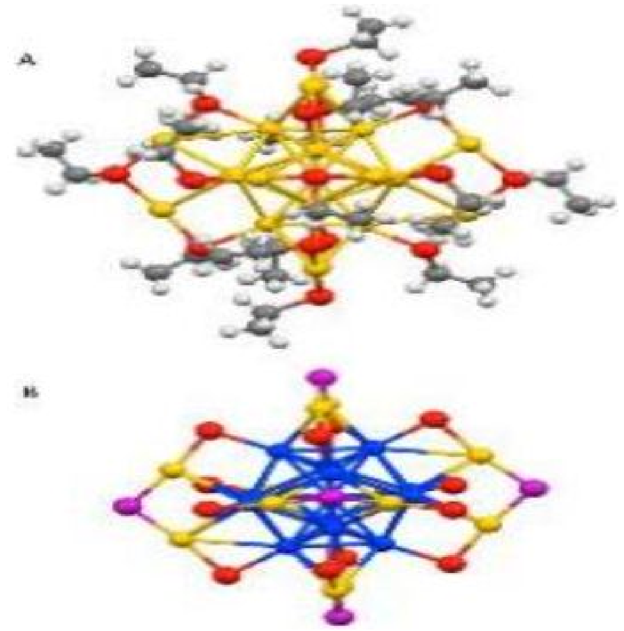
Expanding the cluster landscape



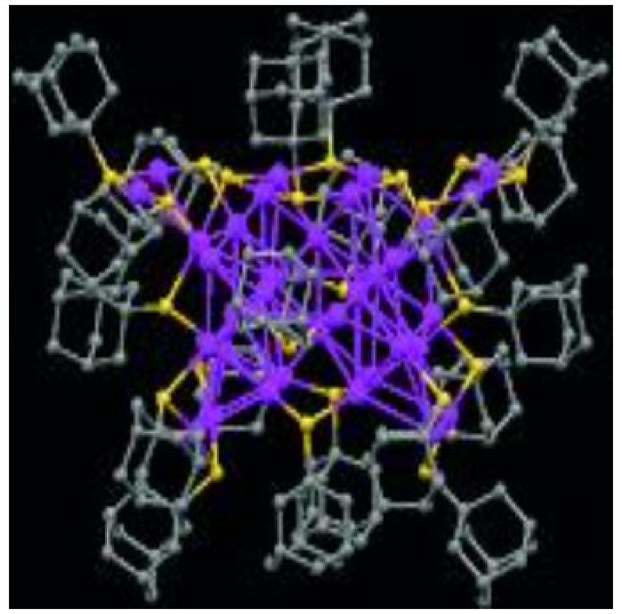
Au13(NHC)7



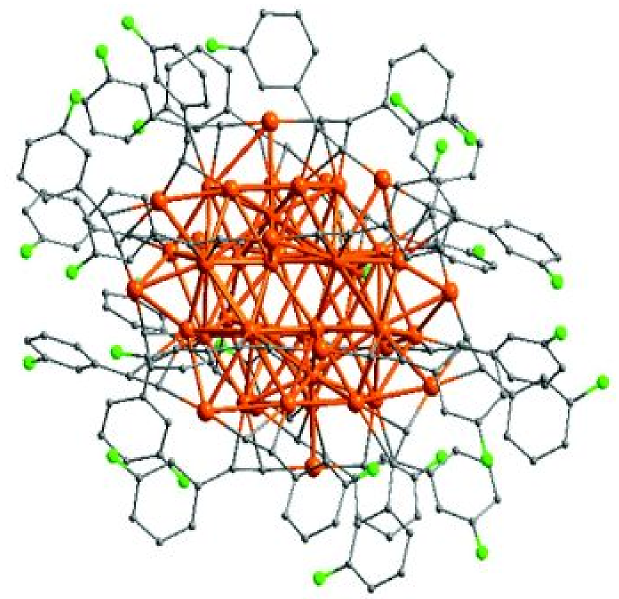
Au21(SR)15



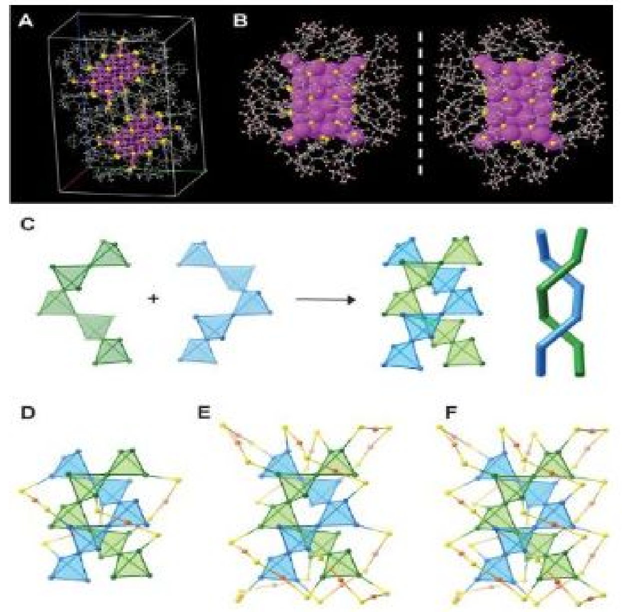
Au25(SR)18



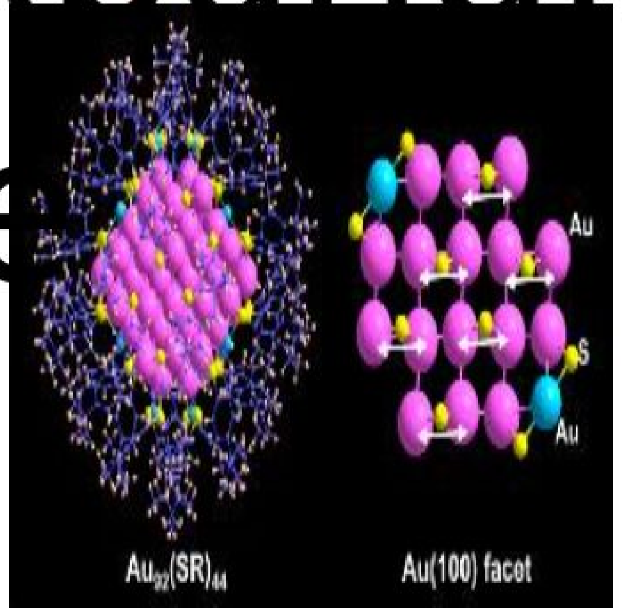
Au38(SR)24



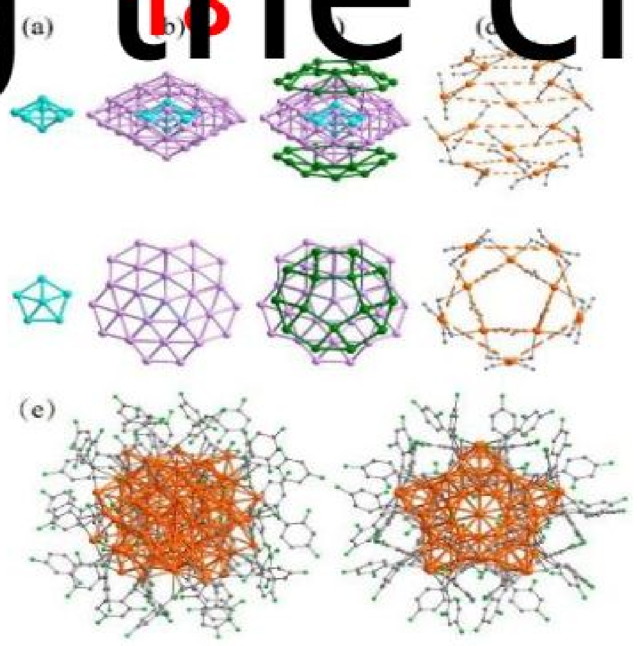
Au50(C≡C)26



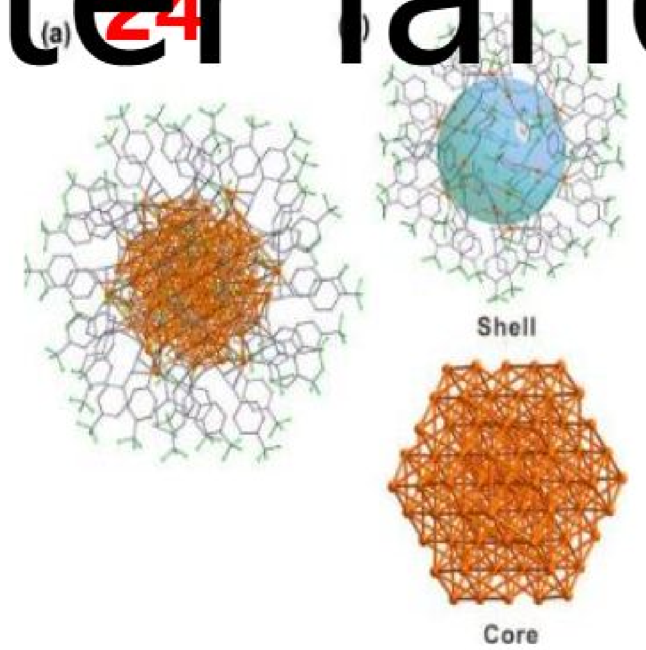
Au52(SR)32



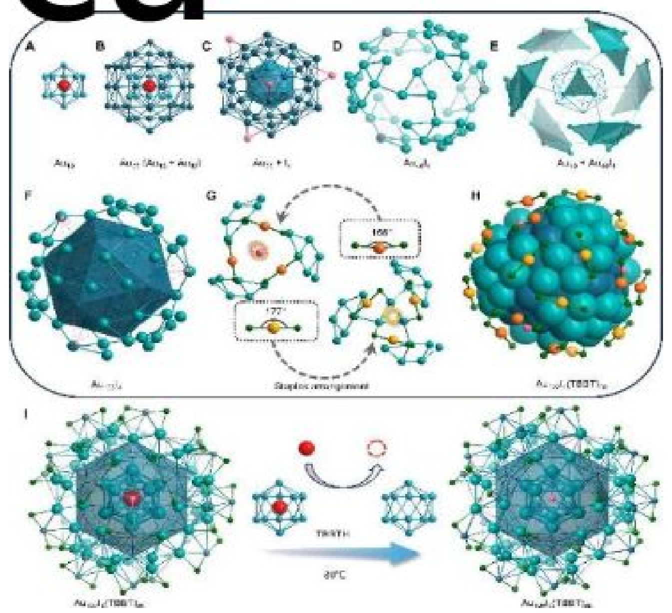
Au92(SR)44



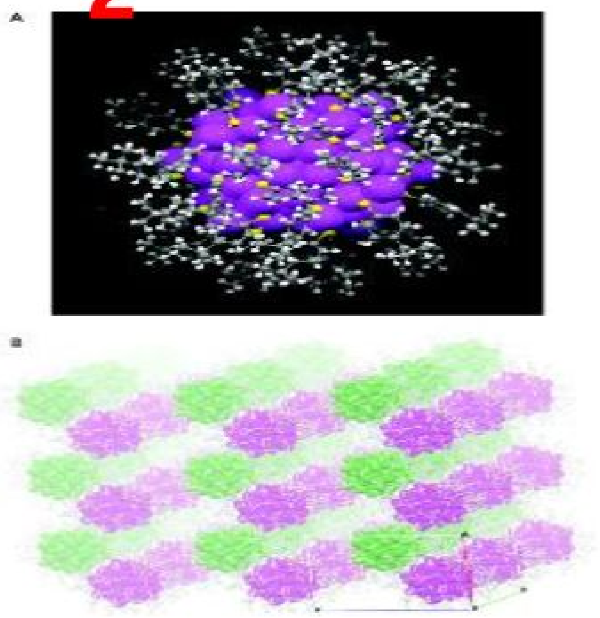
Au99(C≡C)40



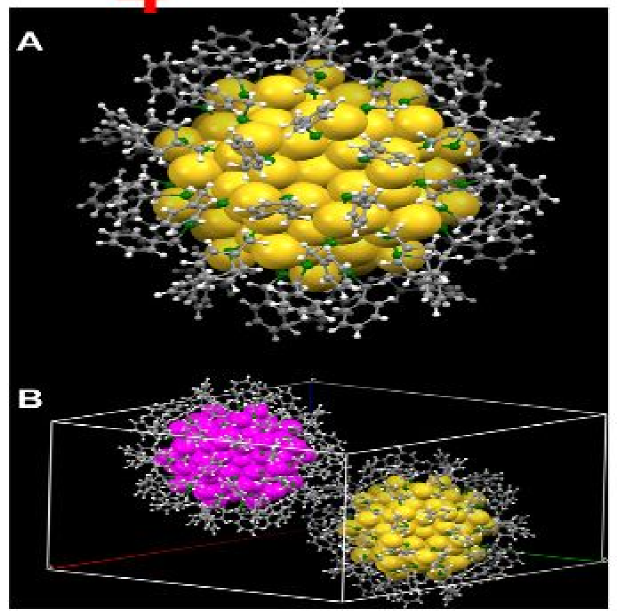
Au110(C≡C)44



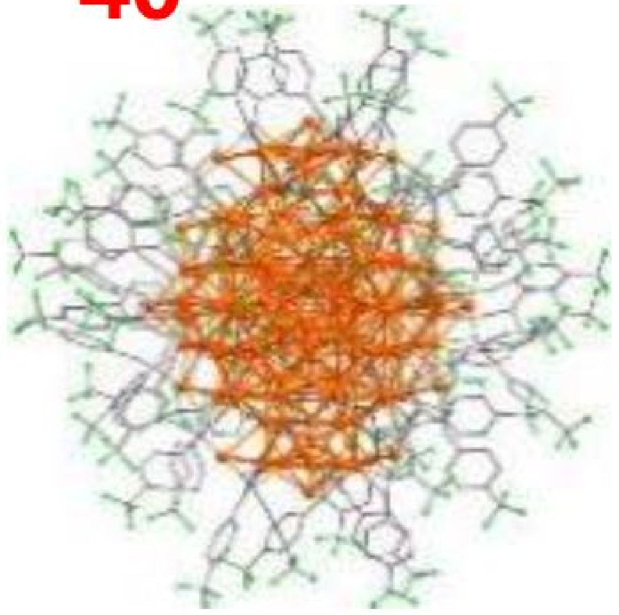
Au127I4(SR)48



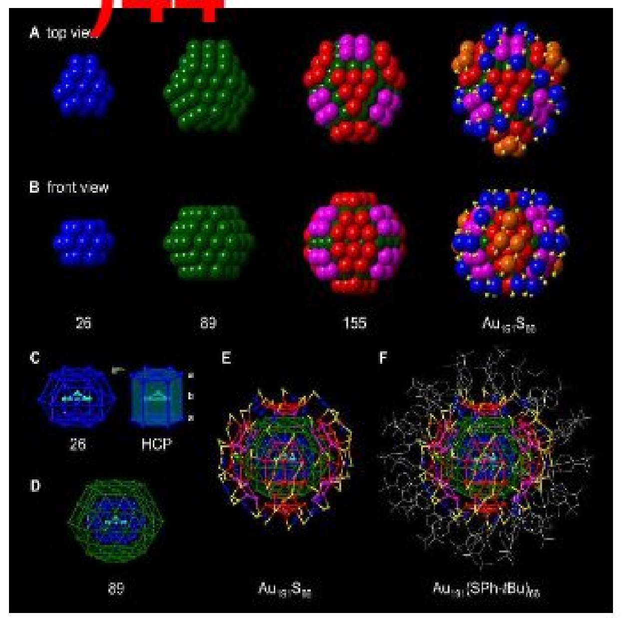
Au133(SR)52



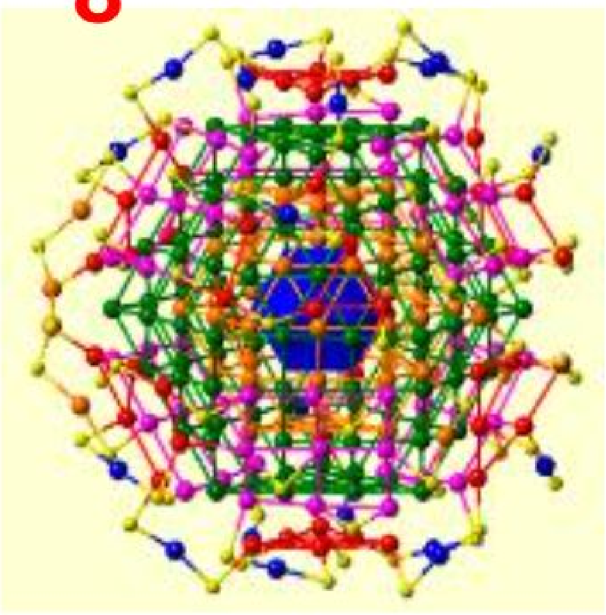
Au144(SR)60



Au156(C≡C)60

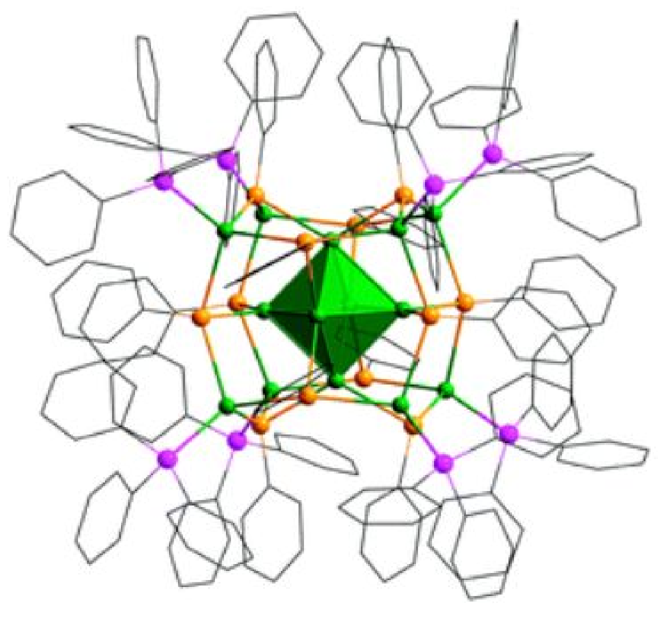


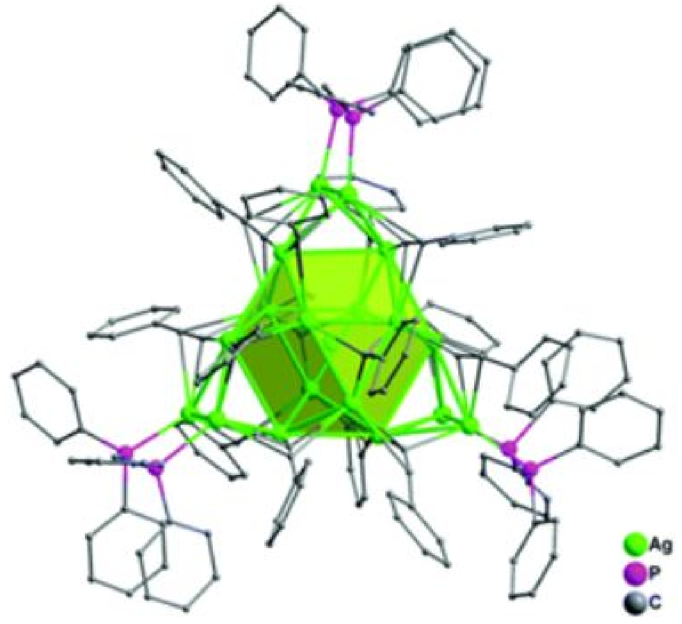
Au191(SR)66



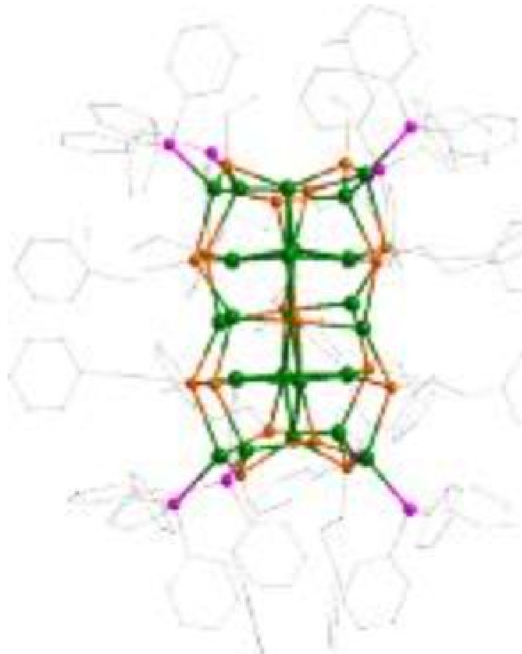
Au279(SR)84

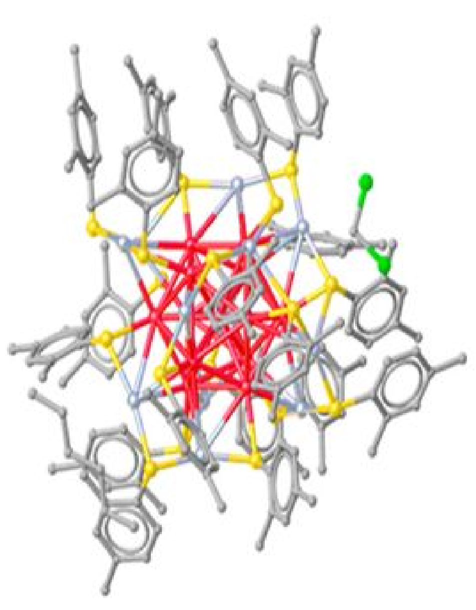
Expanding the cluster landscape

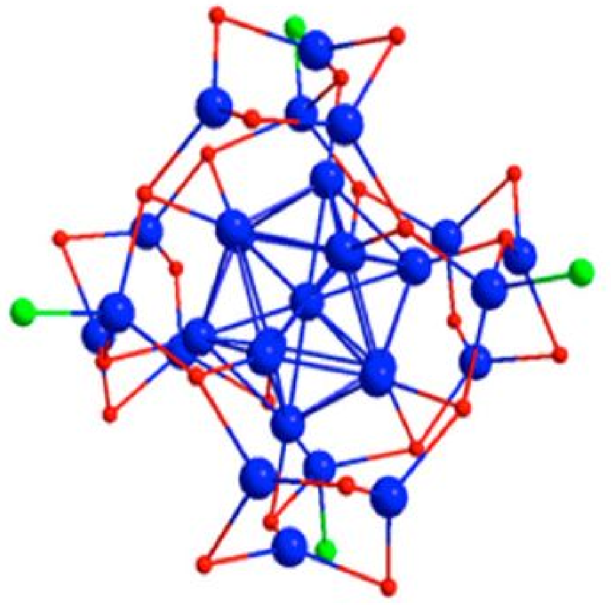

Ag14(SR)12(PPh3)4

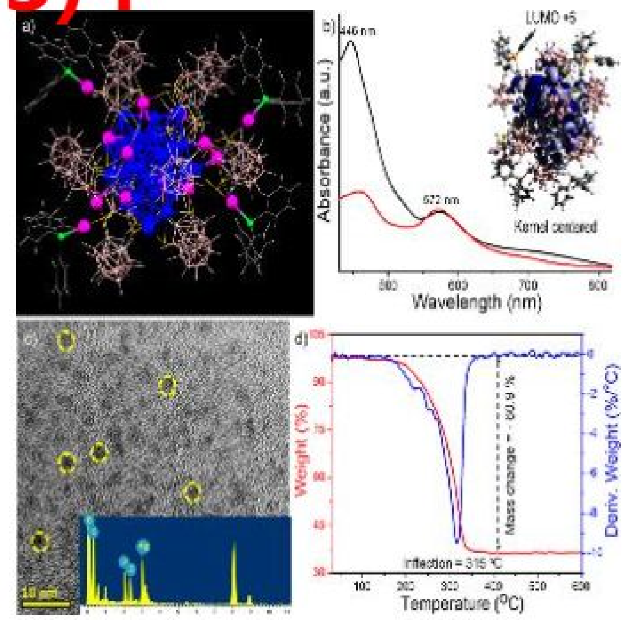


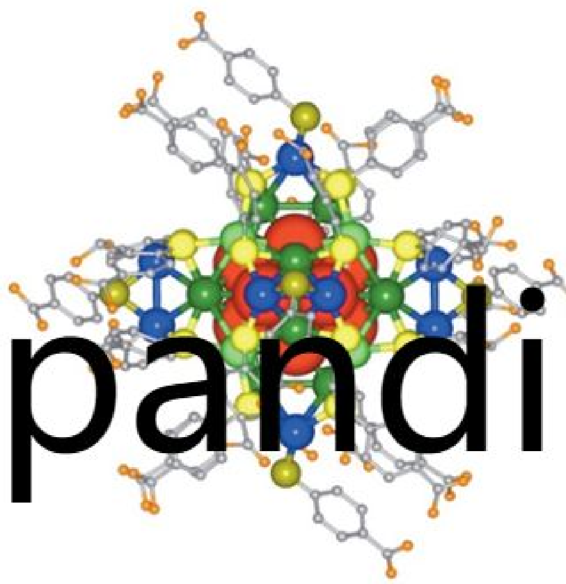
Ag19(dppm)3(PhC≡C)14

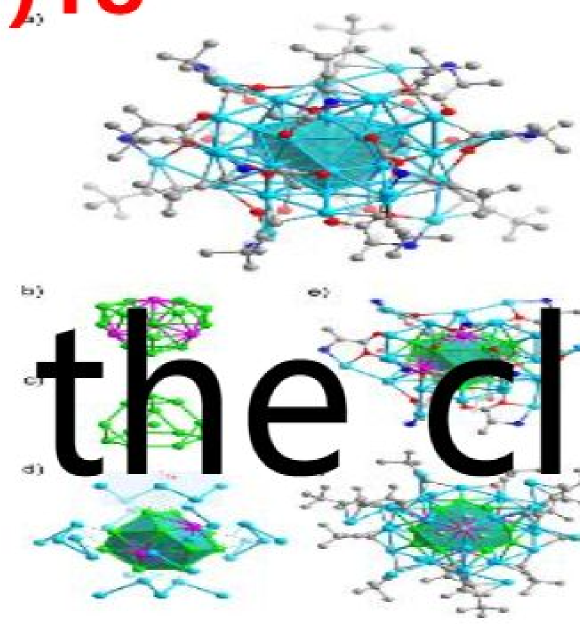

Ag23(PPh3)8(SR)18

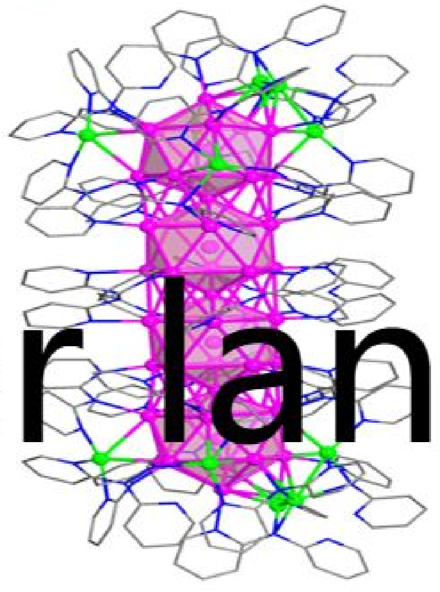

Ag25(SR)18

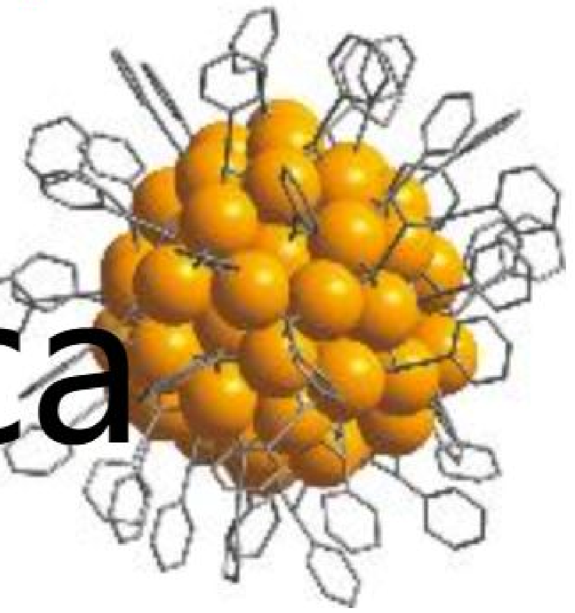

Ag29(SR)12(TPP)4

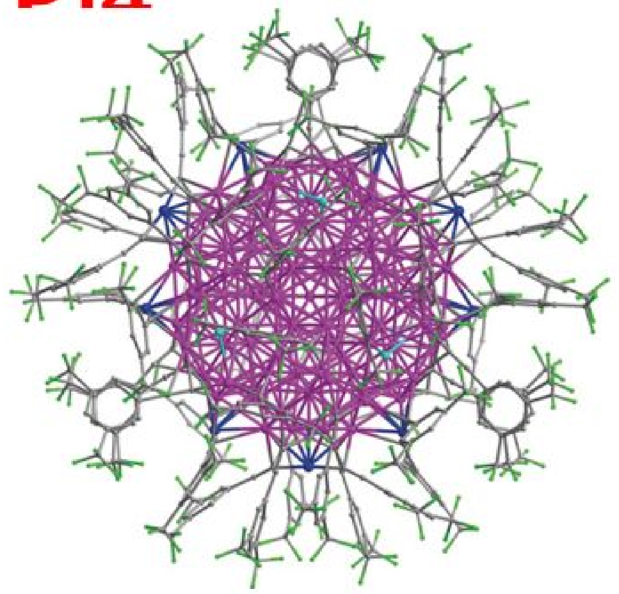

Ag42(SR)15(TPP)4

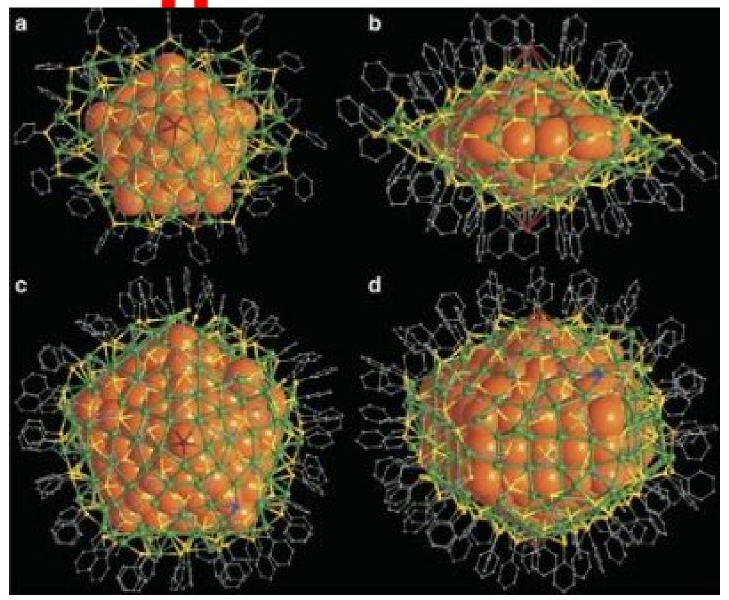

Ag44(SR)30

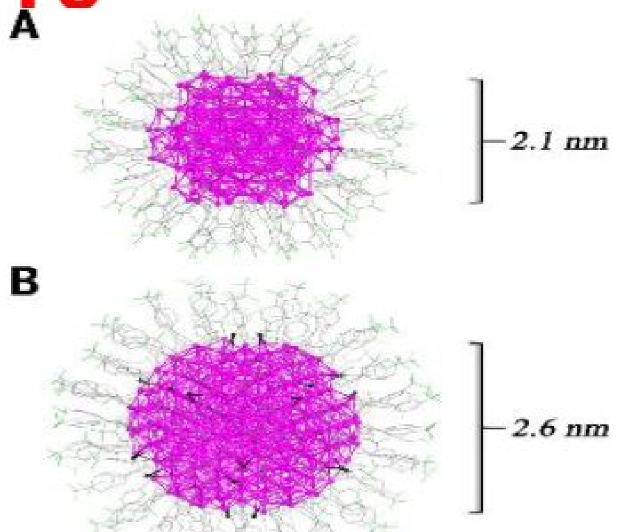

Ag47L12(C≡CtBu)16


Ag61(dpa)44

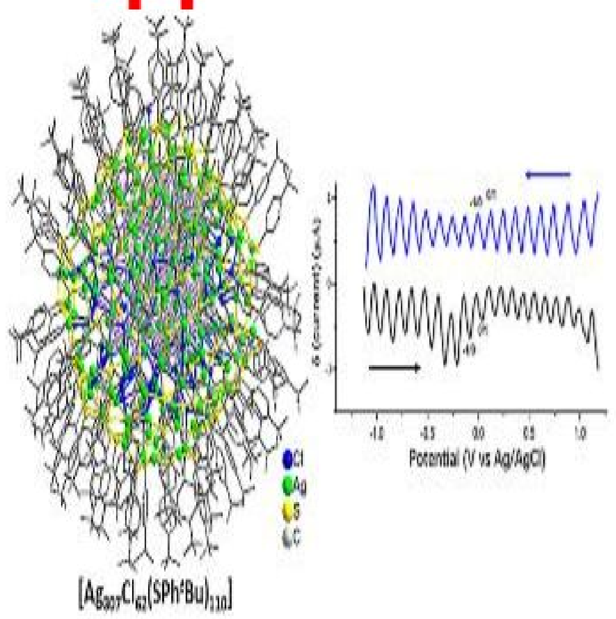

Ag74(C≡C)44

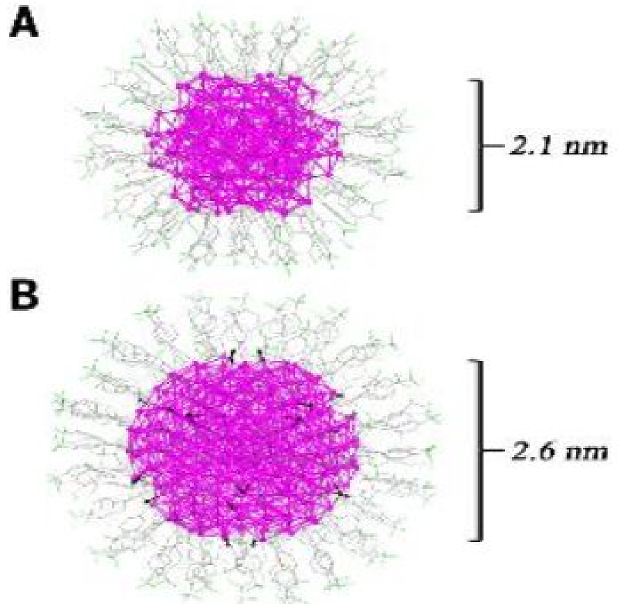

Ag112(C≡C)51


Ag136(SR)64



Ag213(C≡CR)96


Ag307Cl62(SR)110



Ag429Cl24(C≡CR)150

Molecular materia
ls

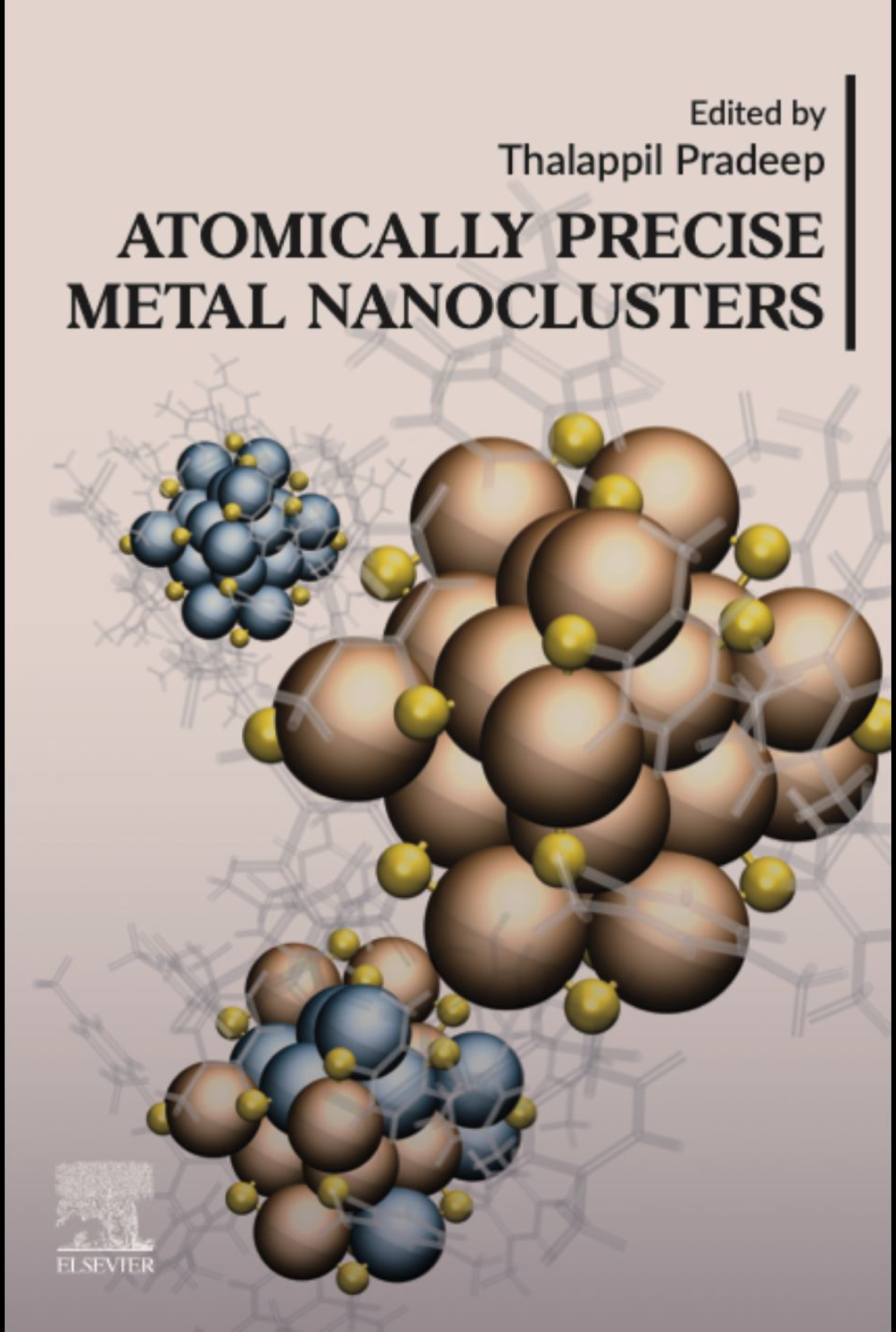
Molecules and their properties

Chemical formula	H_2O
Molecular weight	18.0148
Critical temperature	373.91°C
Critical pressure	22.05 MPa
Critical density	315.0 kg/m^3
Triple point temperature	0.01°C
Triple point pressure	615.066 Pa
Normal boiling point	100.0°C
Normal freezing point	0.0°C
Density of ice at normal melting point	918.0 kg/m^3
Maximum density, 3.98°C	999.973 kg/m^3
Viscosity, 25°C	0.889 mN s/m^2
Surface tension, 25°C	72 mN/m
Heat Capacity, 25°C	4.1796 kJ/kg.K
Enthalpy of vaporisation, 100°C	2,257.7 kJ/kg
Enthalpy of fusion, 0°C	333.8 kJ/kg
Velocity of sound, 0°C	1.403 km/s
Dielectric constant, 25°C	78.40
Electrical conductivity, 25°C	8 μS/m
Refractive index, 25°C	1.333
Liquid compressibility, 10°C	$480. \times 10^{-12}$m^2/N
Coefficient of thermal expansion, 25°C	256.32×10^{-6} K^{-1}
Thermal Conductivity, 25°C	0.608 W/m.K

Molecular formula
Molecular weight
Molecular structure
Molecular absorption and emission
Molecular reactions
Molecular assembly
Molecular co-crystals

Phases - phase transitions
Physical properties
Electrical, magnetic
Mechanical properties
Electrochemical properties

Future?



Gordon Rese
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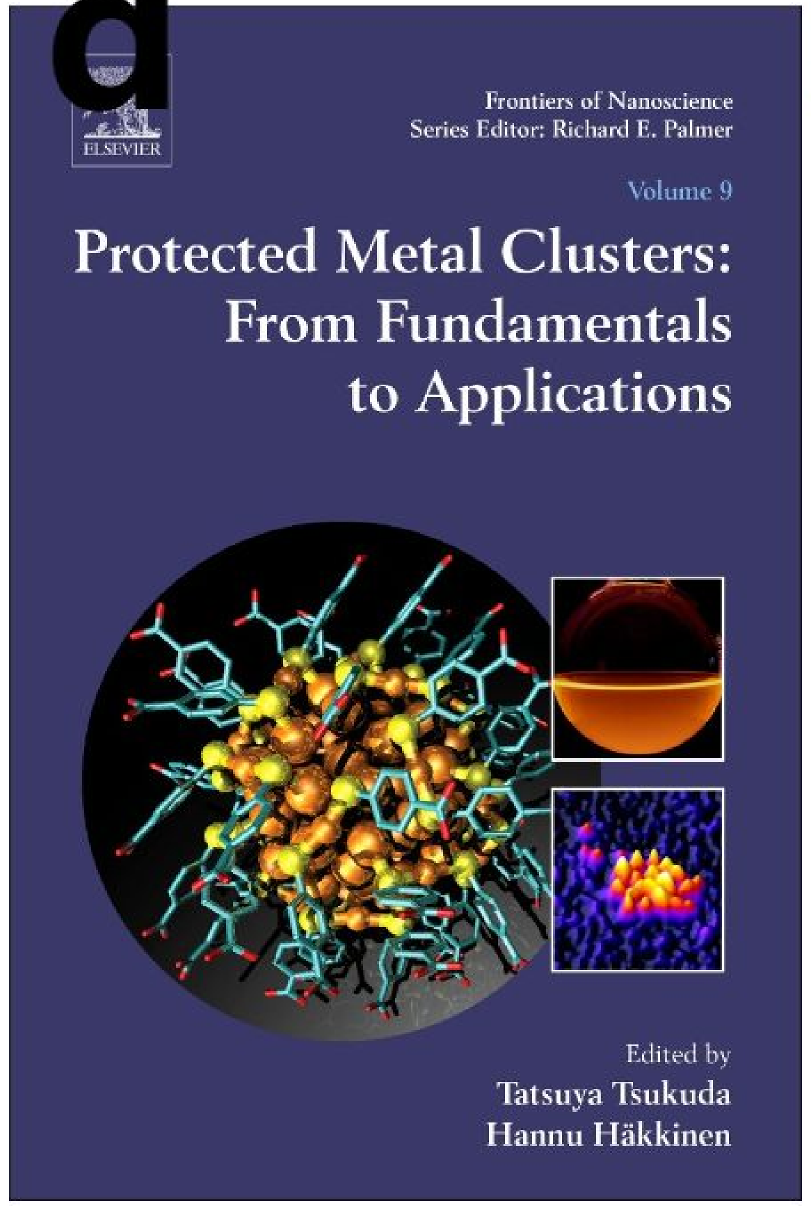
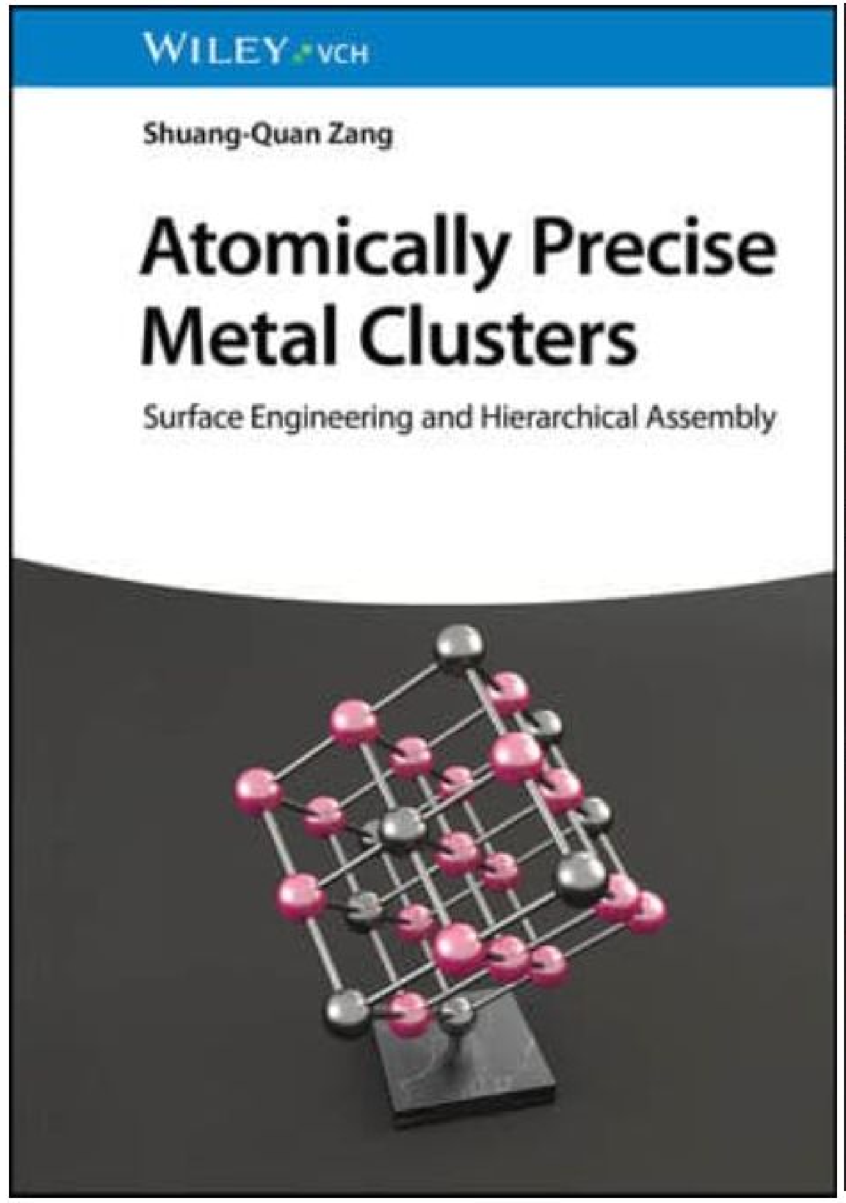
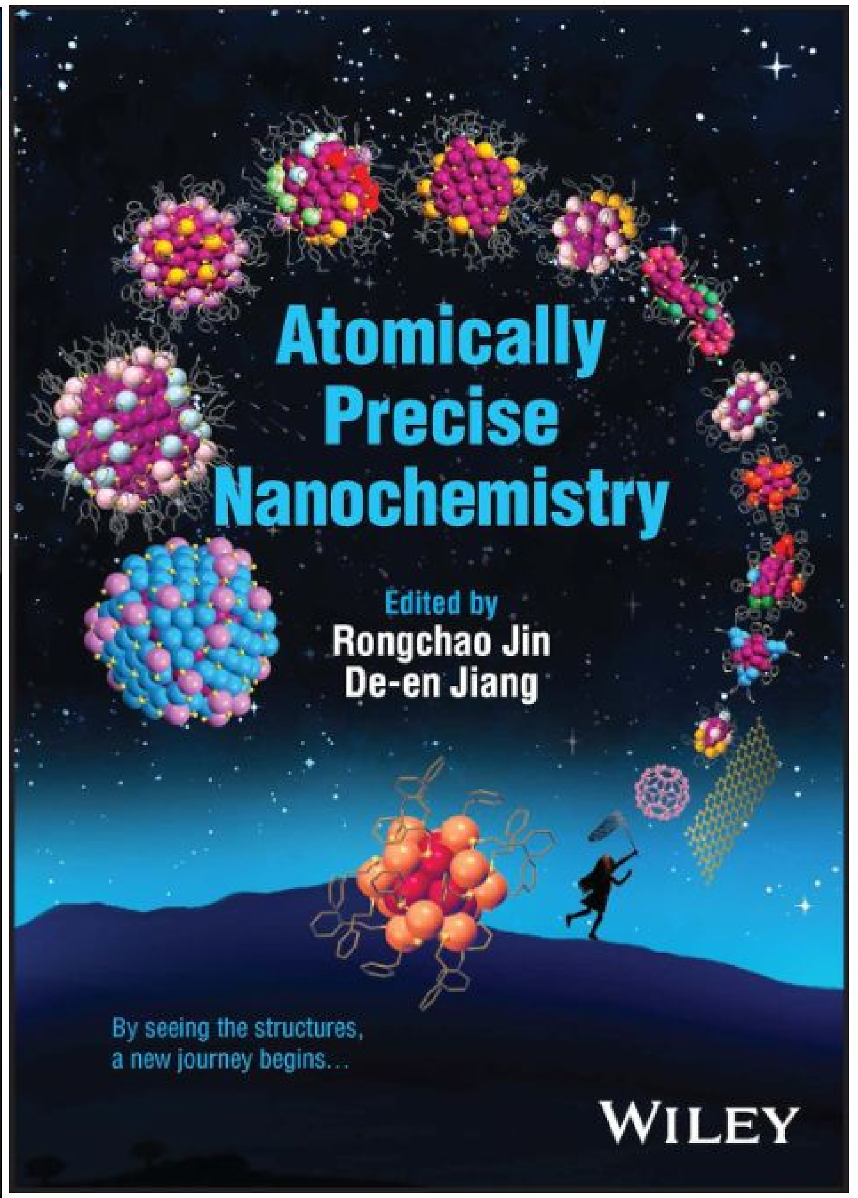
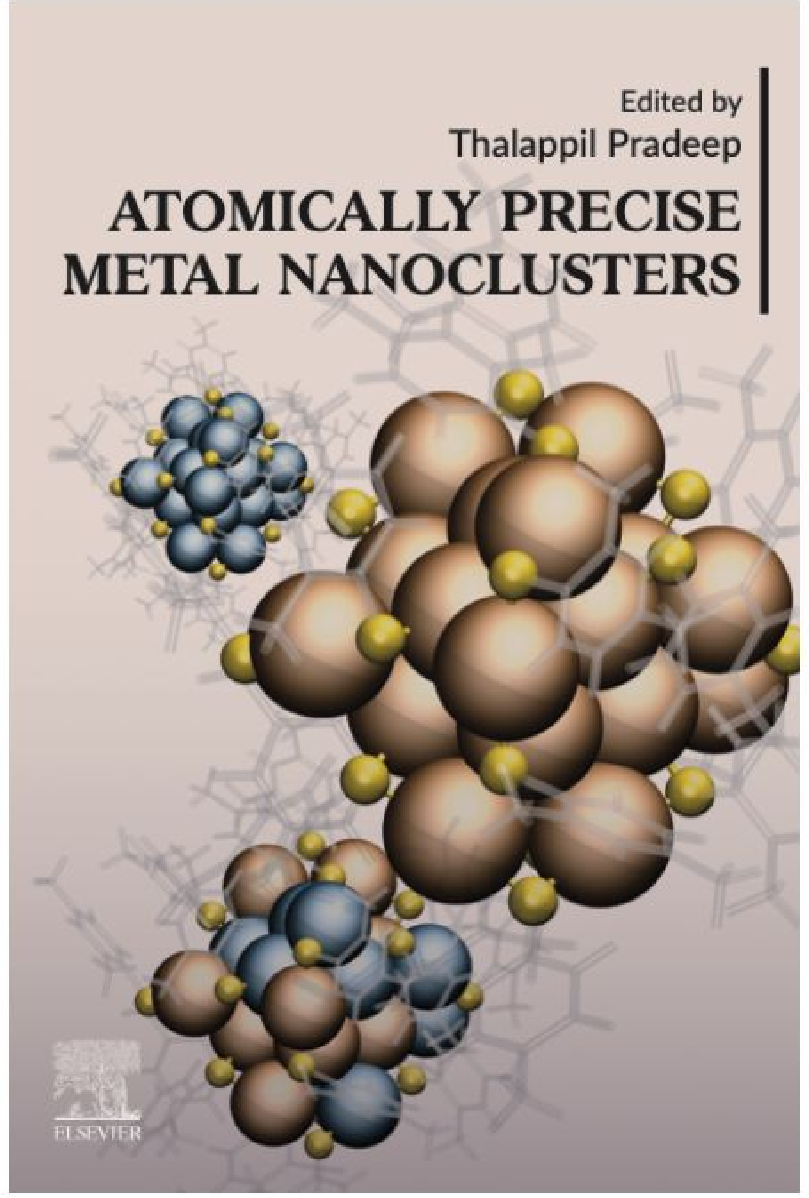
The area has exploded









Molecular reaction
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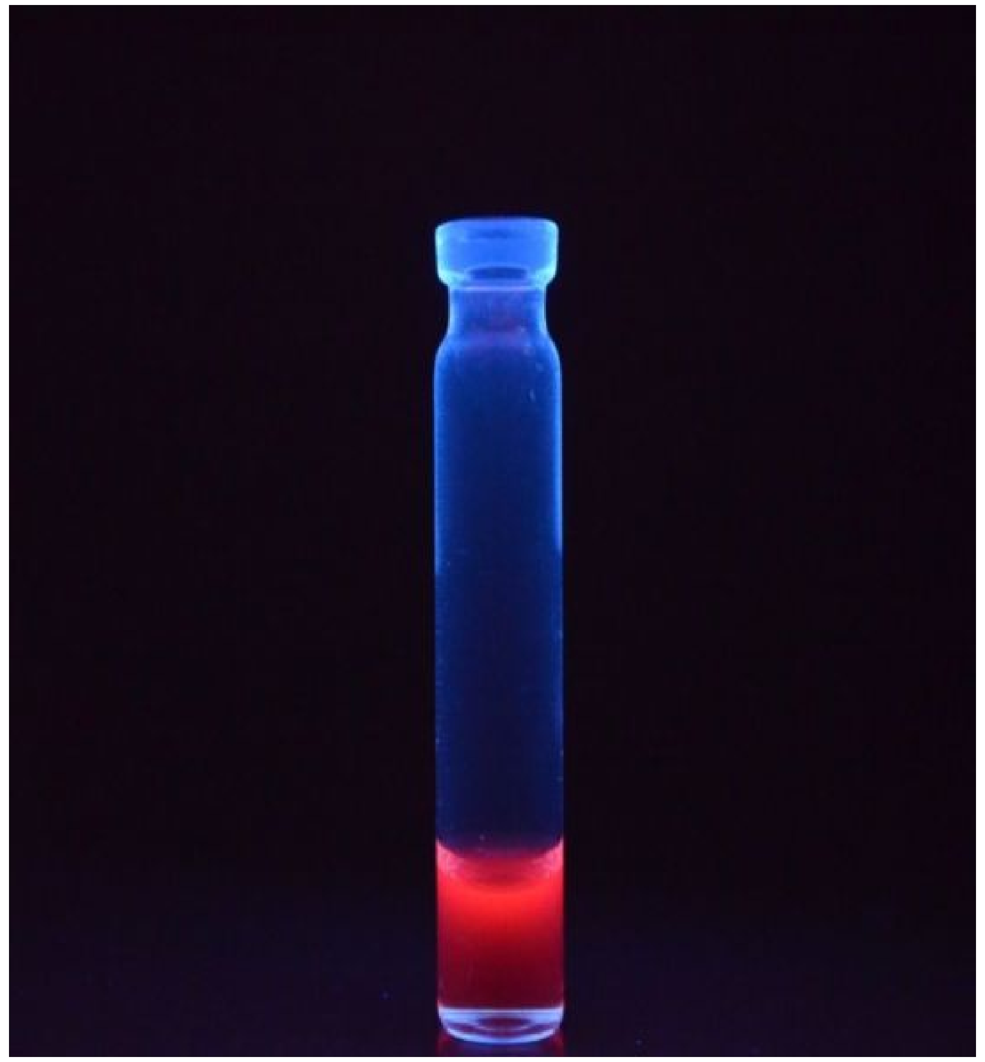


Reactions on clusters

Reactions between cluste
rs

Inter-cluster reactions

JOURNAL OF THE AMERICAN CHEMICAL SOCIETY
Article
pubs.acs.org/JACS

Intercluster Reactions between $Au_{25}(SR)_{18}$ and $Ag_{44}(SR)_{30}$

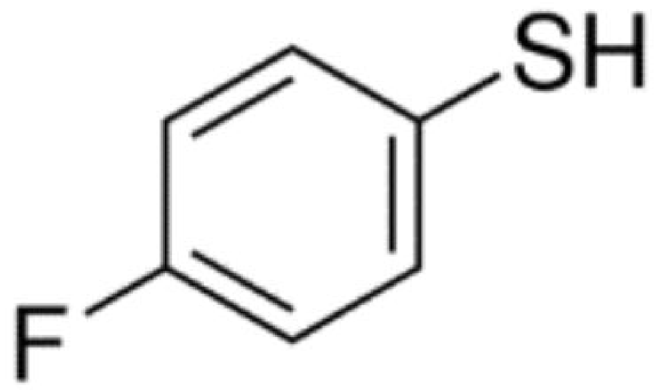
K. R. Krishnadas, Atanu Ghosh, Ananya Baksi, Indranath Chakraborty,[†] Ganapati Natarajan, and Thalappil Pradeep*

DST Unit of Nanoscience (DST UNS) and Thematic Unit of Excellence, Department of Chemistry, Indian Institute of Technology Madras, Chennai, 600 036, India

Supporting Information

$A + B \rightarrow C + D$

$Au_{25}(FTP)_{18} + Ag_{44}(FTP)_{30}$ $Au_{25-x}Ag_x(FTP)_{18}$



Energies for the substitution reaction of (A) Au in $Ag_{44}(SR)_{30}$, (B) Ag in $Au_{25}(SR)_{18}$ and (C) the overall reaction energies (in eV) as a function of their positions in product clusters, $Au_xAg_{44-x}(SR)_{30}$ and $Au_{25-x}Ag_x(SR)_{18}$ for x=1

Ag25-Au25 experiments

K. R. Krishnadas et al. *Nature Commun.* 2016

Reaction between Au25(PET)18 and Ag25(DMBT)18

DMBT

PE
T

[Ag25(DMBT)18+Au25(PET)18]2-

DMBT

PE
T

Ag25(DMBT)
18

[Ag25(DMBT)18+Au25(PET)1
8]2-

Au25(PET)
18

Evolution of alloy clusters from the dianionic adduct, [Ag25Au25(DMBT)18(PET)18]2-

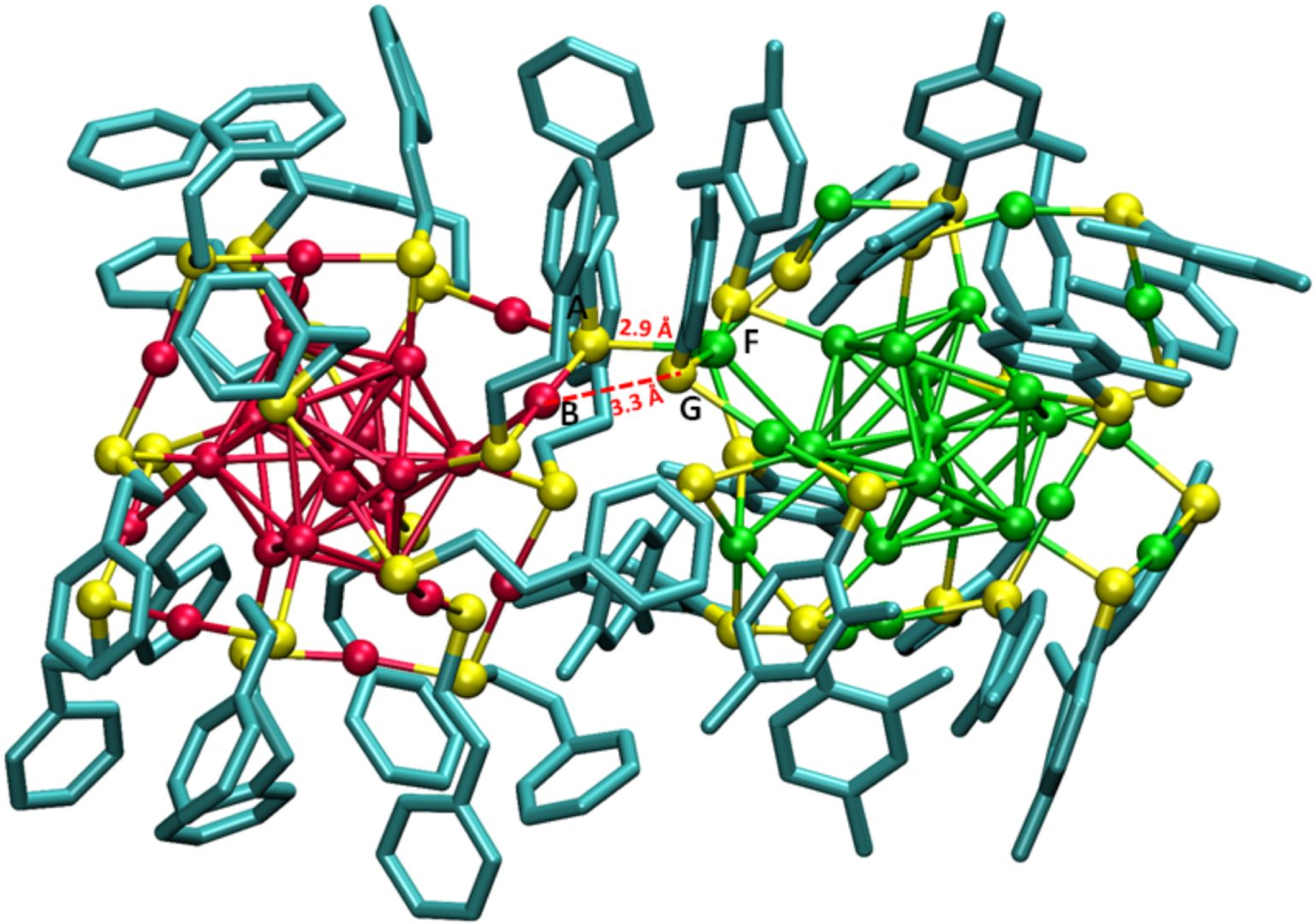
within 5 min

Ag25(DMBT)18:Au25(PET)18

0.3:1.0

within 2 min

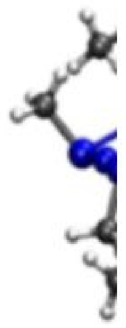
Optimised structure of [Ag25Au25(DMBT)18(PET)18]2-



How do we comprehend this?

Nomenclature

i)



18(methylt

ii)

32°

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PROJECTS

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PROJECT SUBMISSION FORM AND GUIDELINES

ADVICE FOR PROJECT REVIEWERS

PROJECT REVIEW PROCEDURE

INFORMATION FOR TASK GROUP CHAIRS

Naming naked and monolayer protected atomically precise metal nanoclusters

Project No.:	2024-014-2-500
Start Date:	1 Apr 2025
End Date:	
Cite:	https://iupac.org/project/2024-014-2-500
Division:	Analytical Chemistry Division

Objective | Description | Progress | Partners

Objective

The subject of atomically precise clusters (APCs), especially the sub-group of atomically precise metal clusters, and even more specifically, atomically precise noble metal clusters, is expanding tremendously. From the discovery of new APCs and their characterisation, the subject is expanding to their properties and applications.

This project will attempt the development of a systematic method for understanding APCs in terms of their (a) classification into various chemical groups, (b) terminologies and (c) naming, taking diverse views into consideration. As the field is growing to include distinct groups of chemical substances in

Chair

Thalappil Pradeep

Members

Ananya Baksi
Tomas Base
Ngong Kodiah Beyeh
Thomas Bürgi
Indranath Chakraborty
Anindita Das
Stefanie Dehnen
De-en Jiang
Manfred Kappes
Julia Laskin
Sukhendu Mandal
Ganapati Natarajan
Yuichi Negishi
Nonappa Nonappa
Joanna Olesiak-Banska
Sarah Sunah Park
Di Sun
Tatsuya Tsukuda
Robert L. Whetten
Jianping Xie

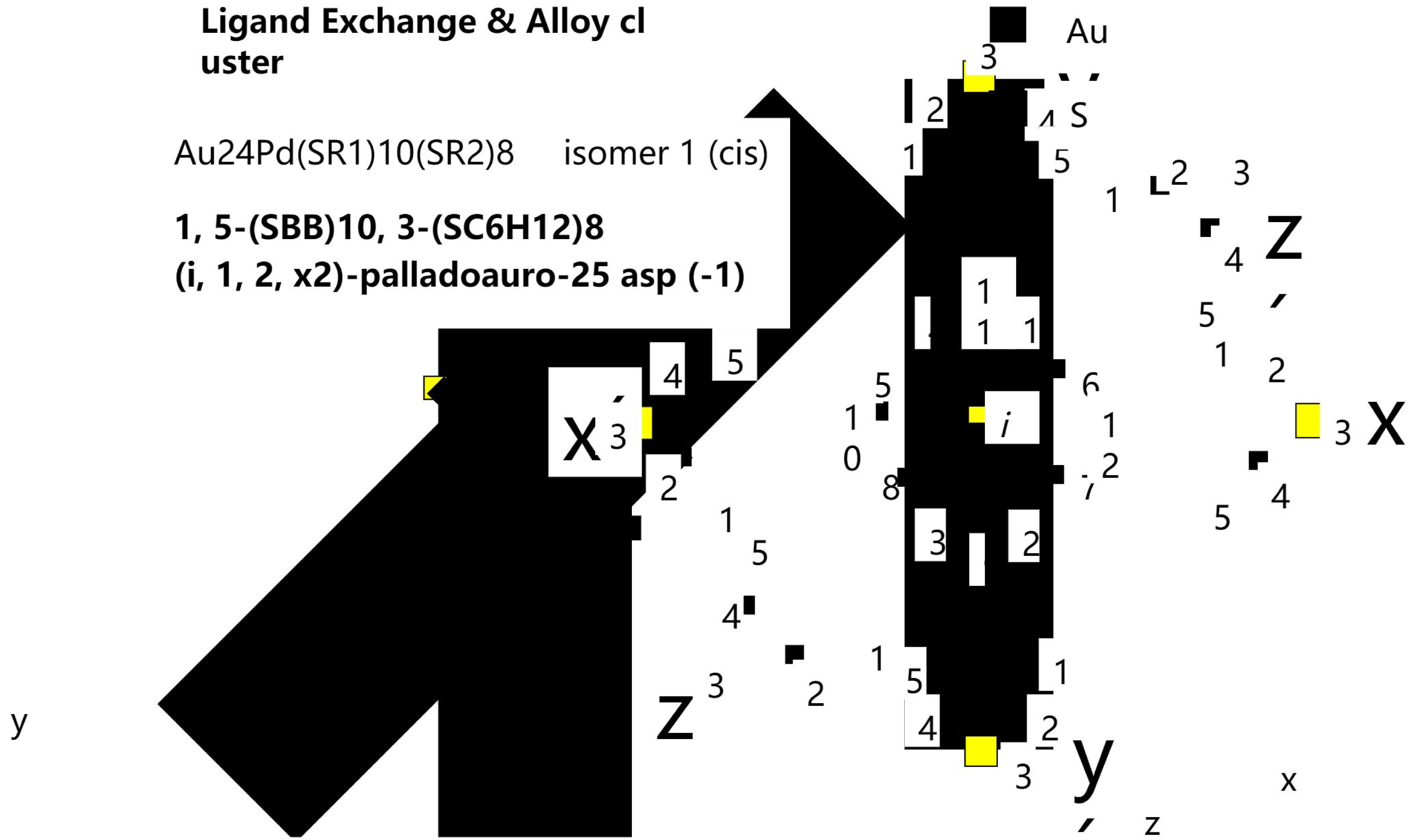
Aspicule
s

Ligand Exchange & Alloy cluster

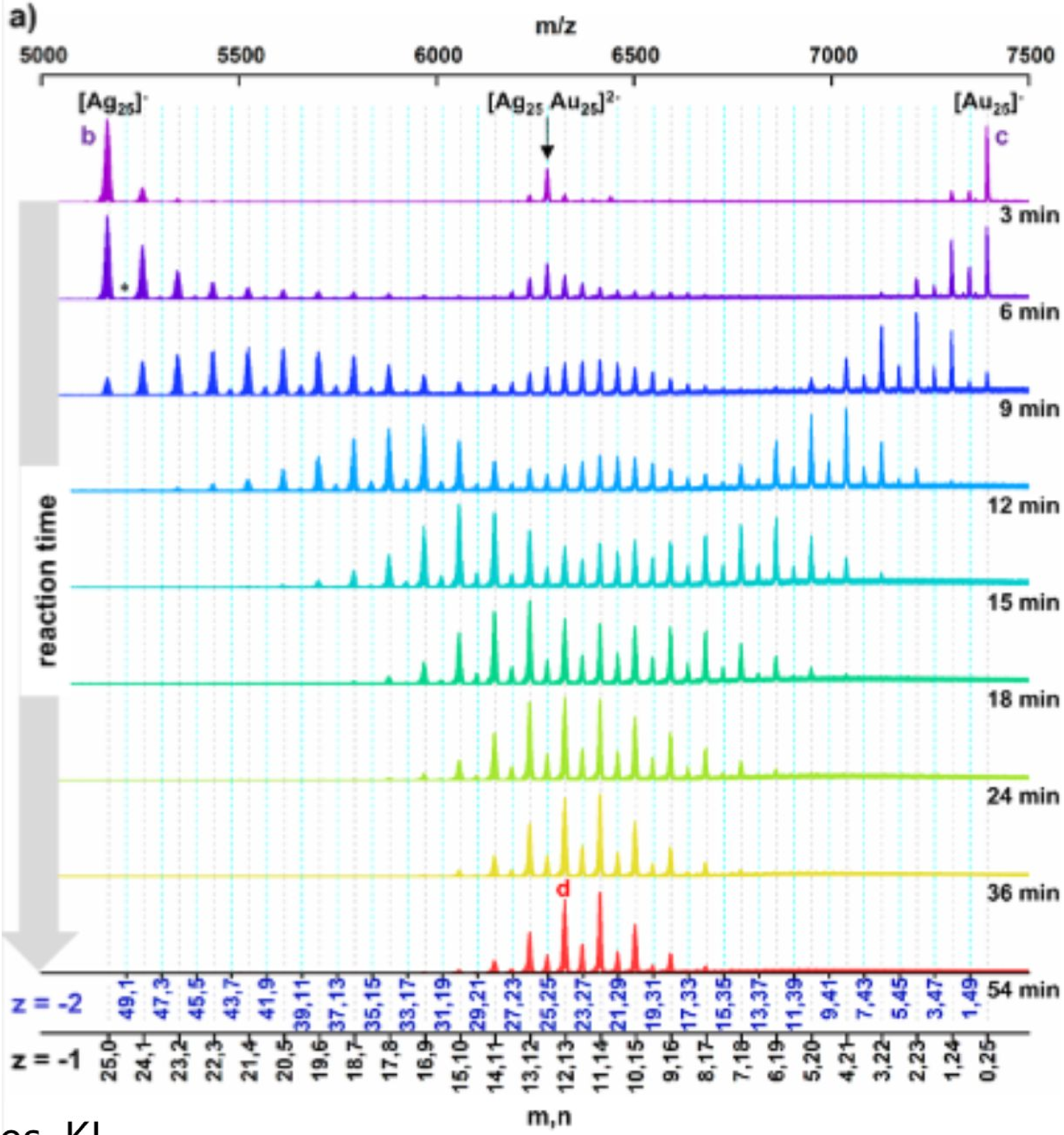
Au24Pd(SR1)10(SR2)8 isomer 1 (cis)

1, 5-(SBB)10, 3-(SC6H12)8

(i, 1, 2, x2)-palladoauro-25 asp (-1)



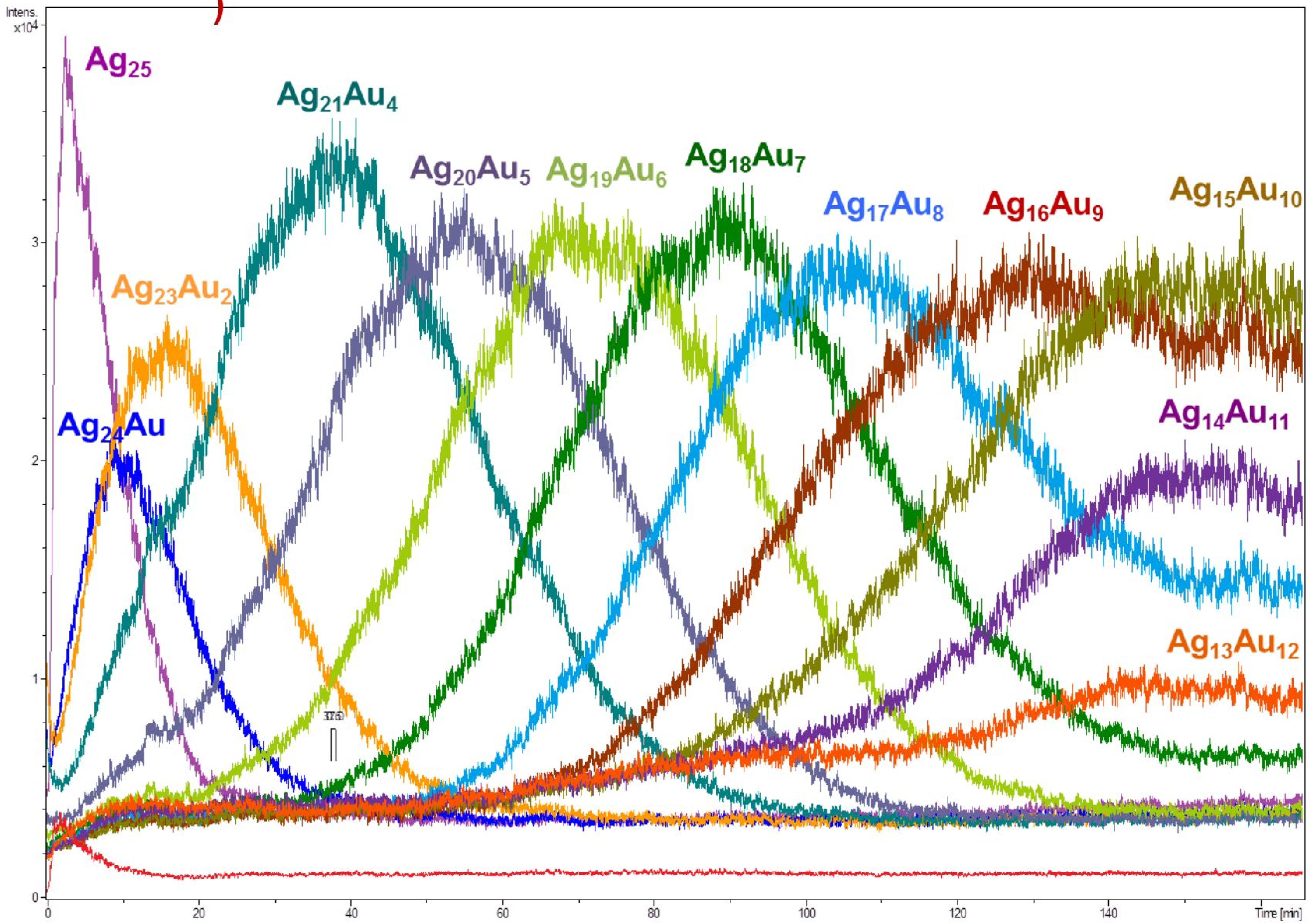
(D1-3,D2-3)-di(2-phenylethylthiolato),16(methylthiolato)-auro-25 aspicule(1-)



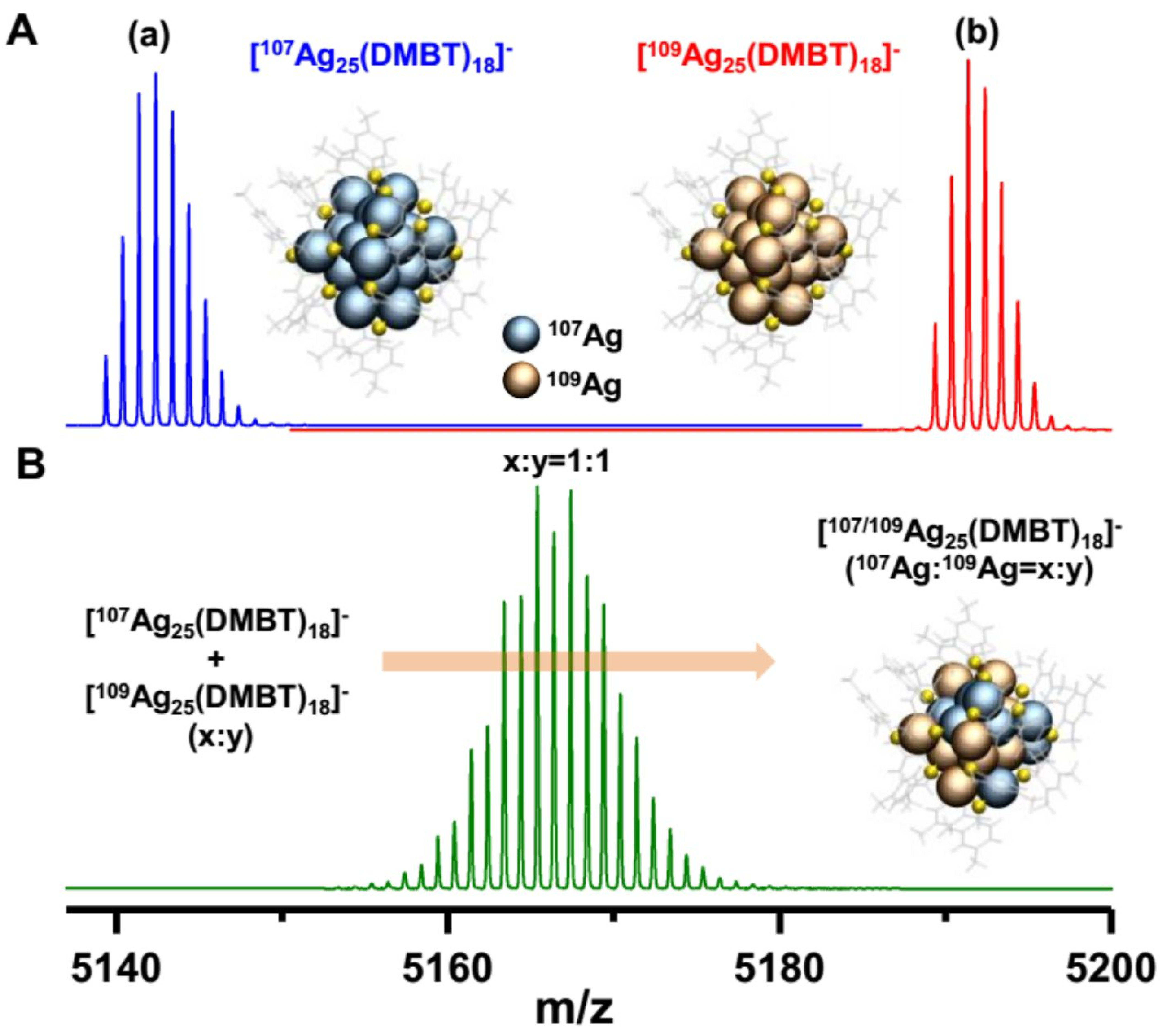
Manfred Kappes, KIT

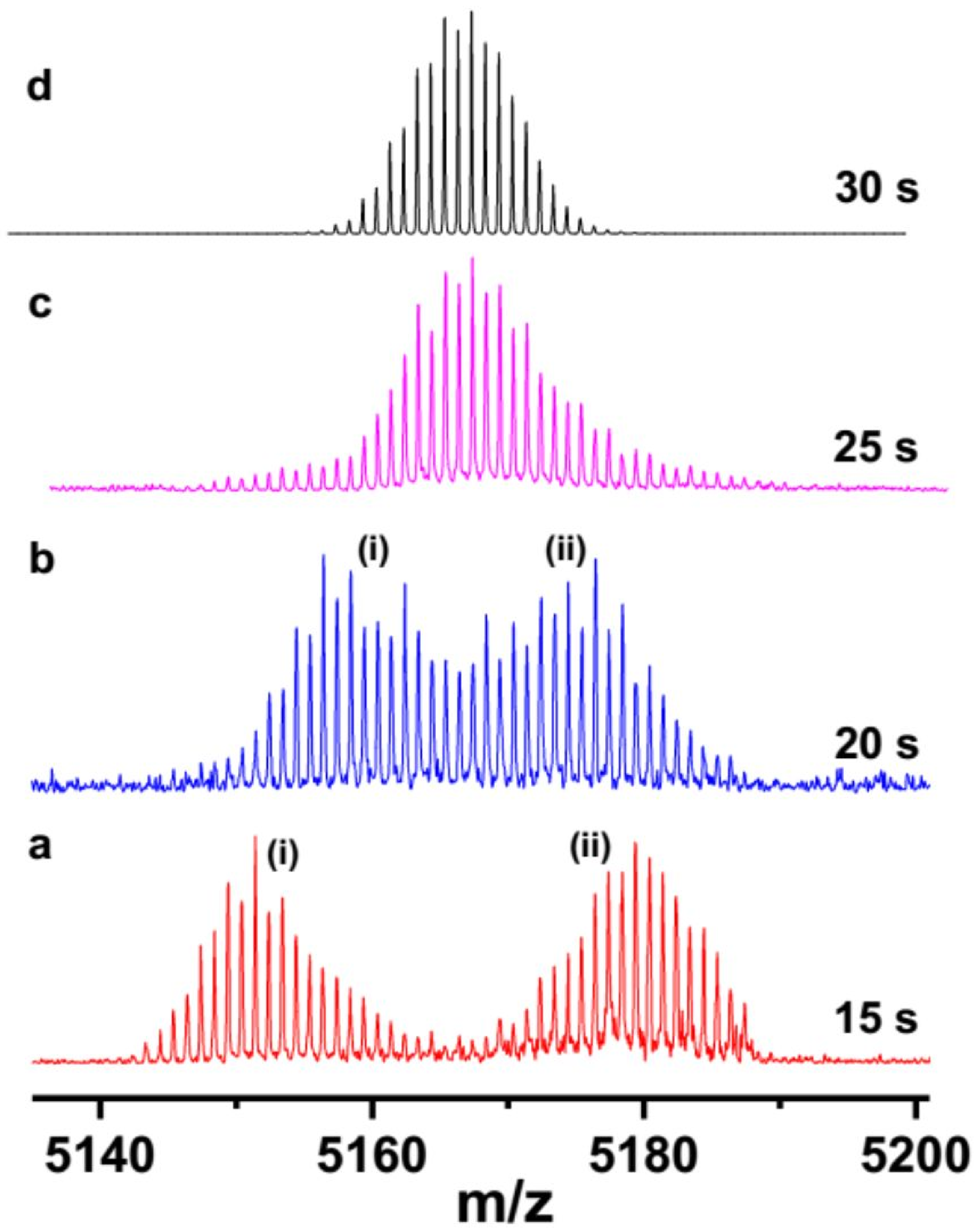
M. Neumaier, A. Baksi, et. al., *JACS* 2021

Kinetics of the exchange (monitored on the Ag25 side)

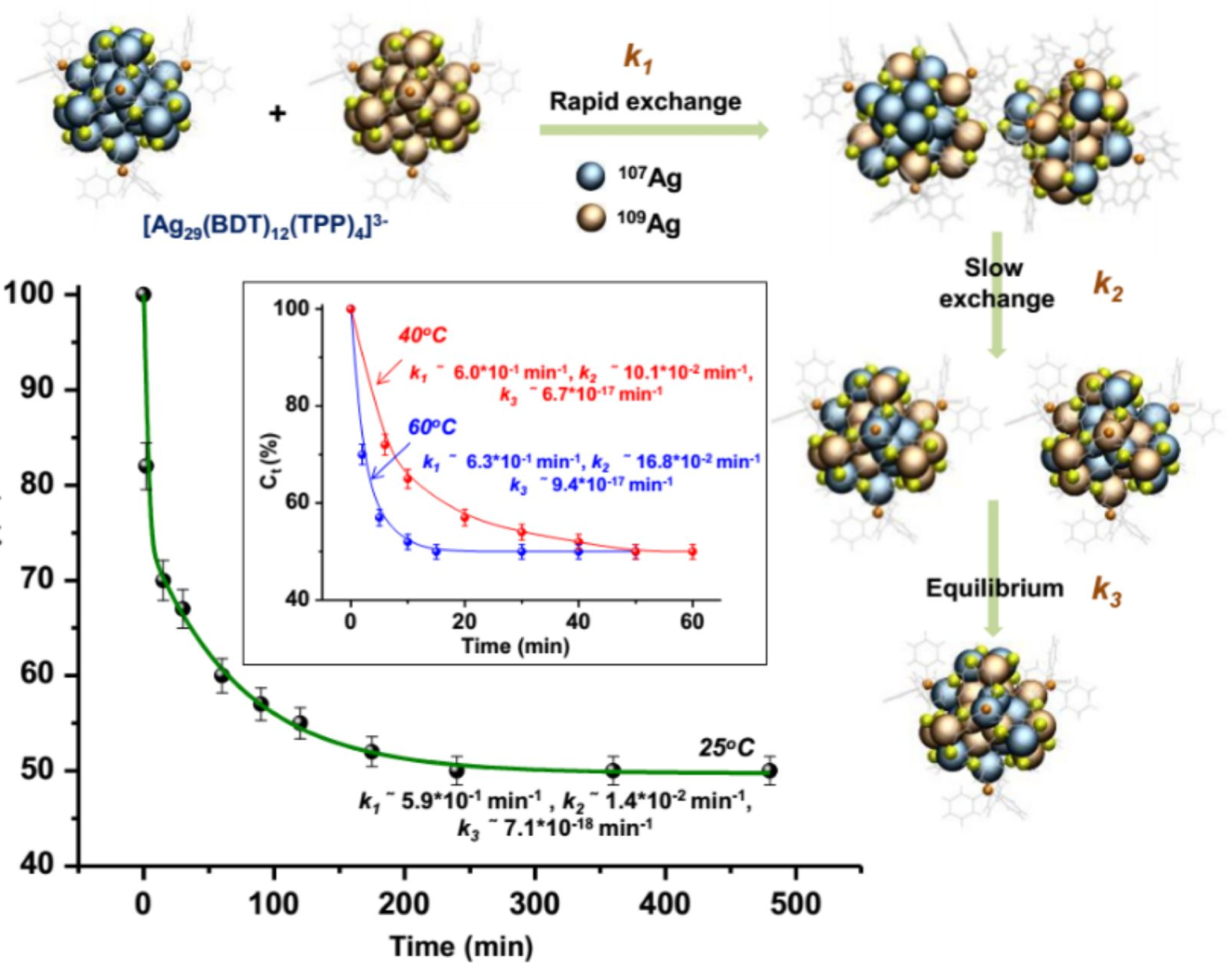


ESI MS of **A)** 107Ag25(DMBT)18 and **B)**109Ag25(DMBT)18. Insets shows the respective isotope patte rns.


A
(a)
$[^{107}Ag_{25}(DMBT)_{18}]^-$
$[^{109}Ag_{25}(DMBT)_{18}]^-$
(b)
^{107}Ag
^{109}Ag
B
x:y=1:1
$[^{107/109}Ag_{25}(DMBT)_{18}]^-$
(^{107}Ag:^{109}Ag=x:y)
$[^{107}Ag_{25}(DMBT)_{18}]^-$
+
$[^{109}Ag_{25}(DMBT)_{18}]^-$
(x:y)
5140
5160
5180
5200
m/z



Papri Chakraborty, et. al. *Science Advances* 2019

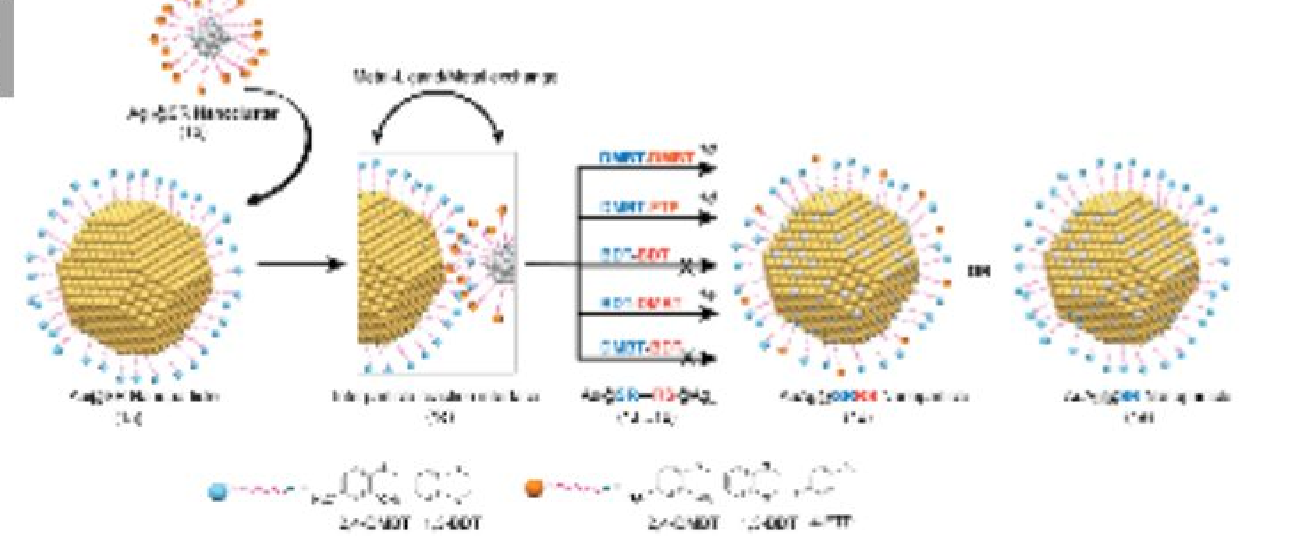


[Ag29(BDT)12(TPP)4]3-
+
k1
Rapid exchange
107Ag
109Ag
Slow exchange
k2
Equilibrium
k3
Ct (%)
Time (min)
25oC
k1 ~ 5.9*10-1 min-1 , k2 ~ 1.4*10-2 min-1,
k3 ~ 7.1*10-18 min-1
40oC
k1 ~ 6.0*10-1 min-1, k2 ~ 10.1*10-2 min-1,
k3 ~ 6.7*10-17 min-1
60oC
k1 ~ 6.3*10-1 min-1, k2 ~ 16.8*10-2 min-1
k3 ~ 9.4*10-17 min-1

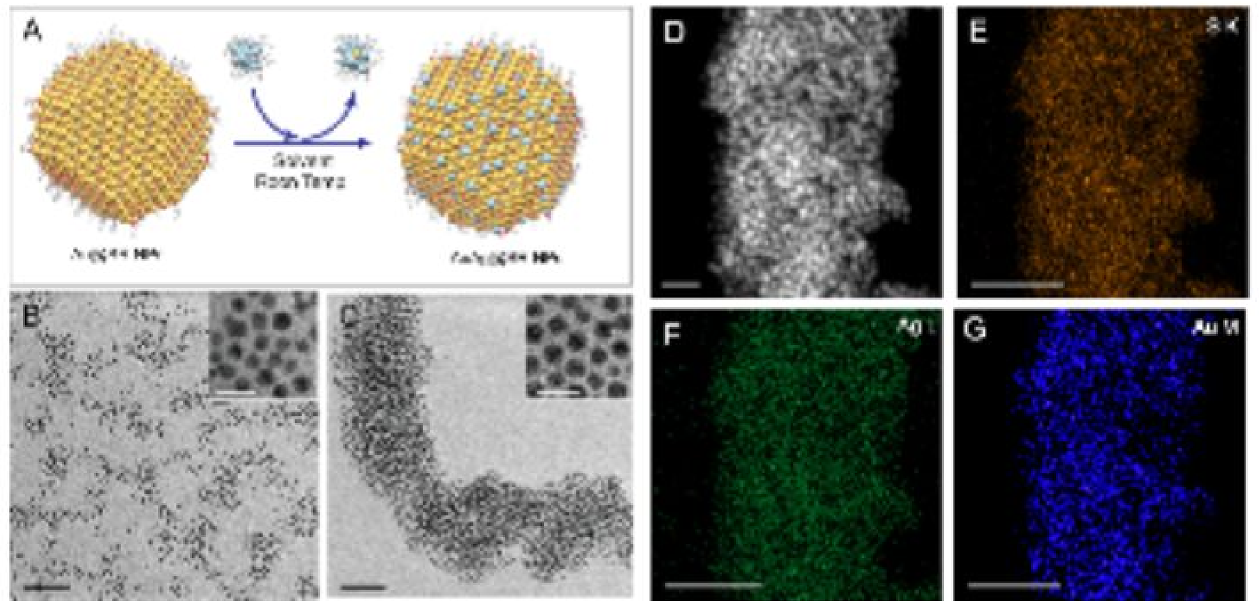
Can clusters react with nanoparticles ?

Ag25 with Au nanoparticles

1

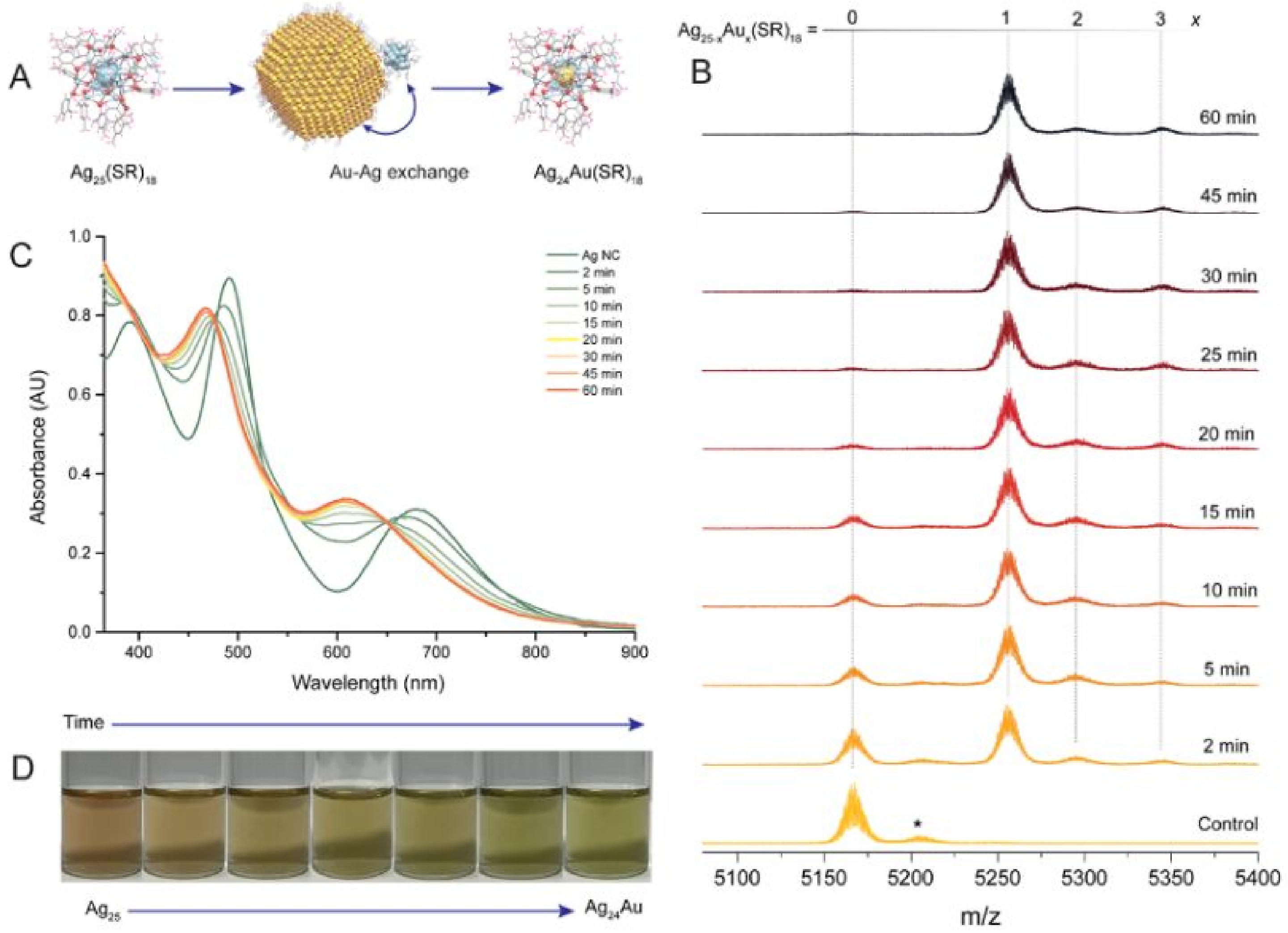


2



Scale bars: 50 nm (B-G) and 10 nm (insets of B and C).

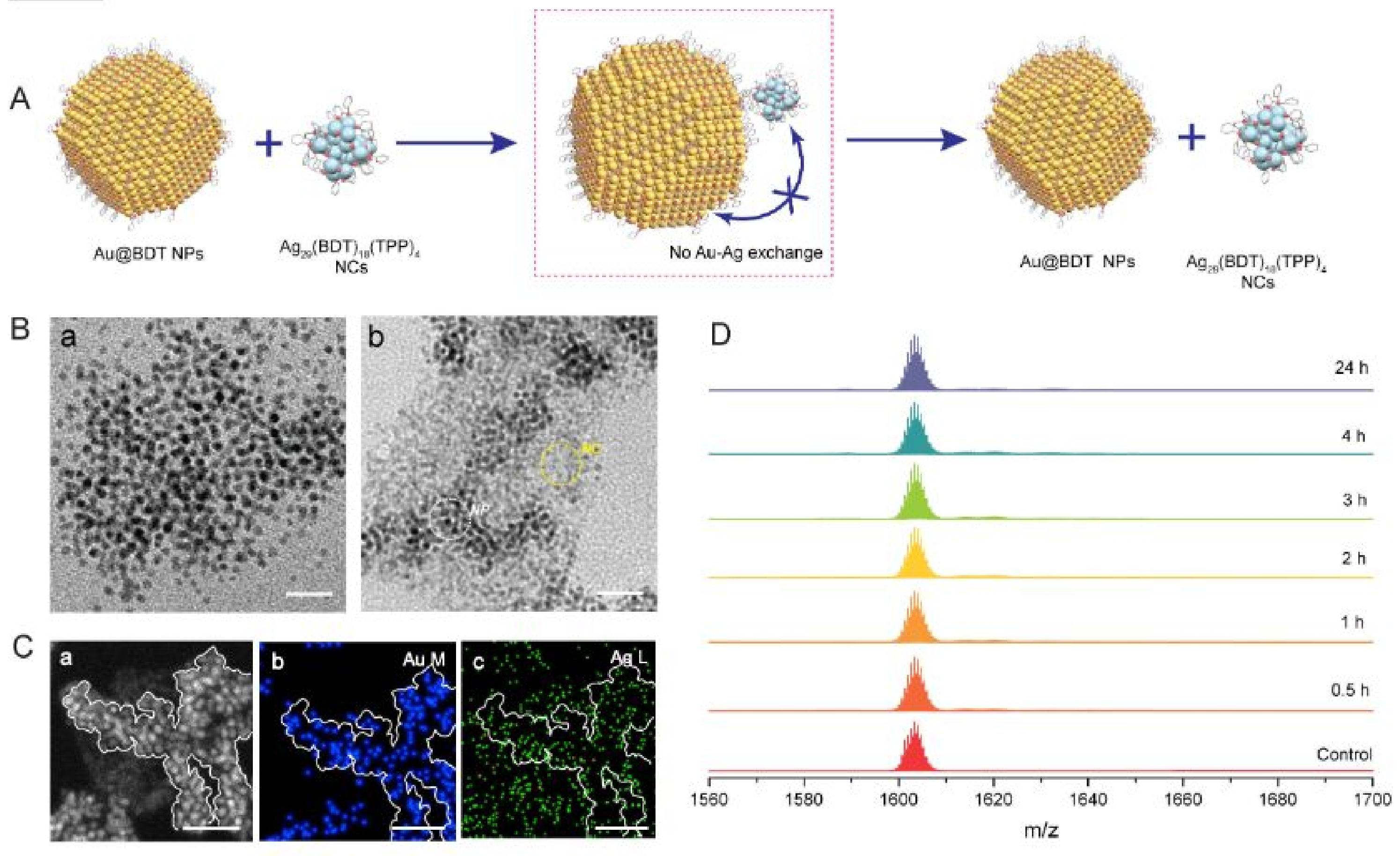
3



Paulami Bose, et al. *Chem. Mat.* 2024

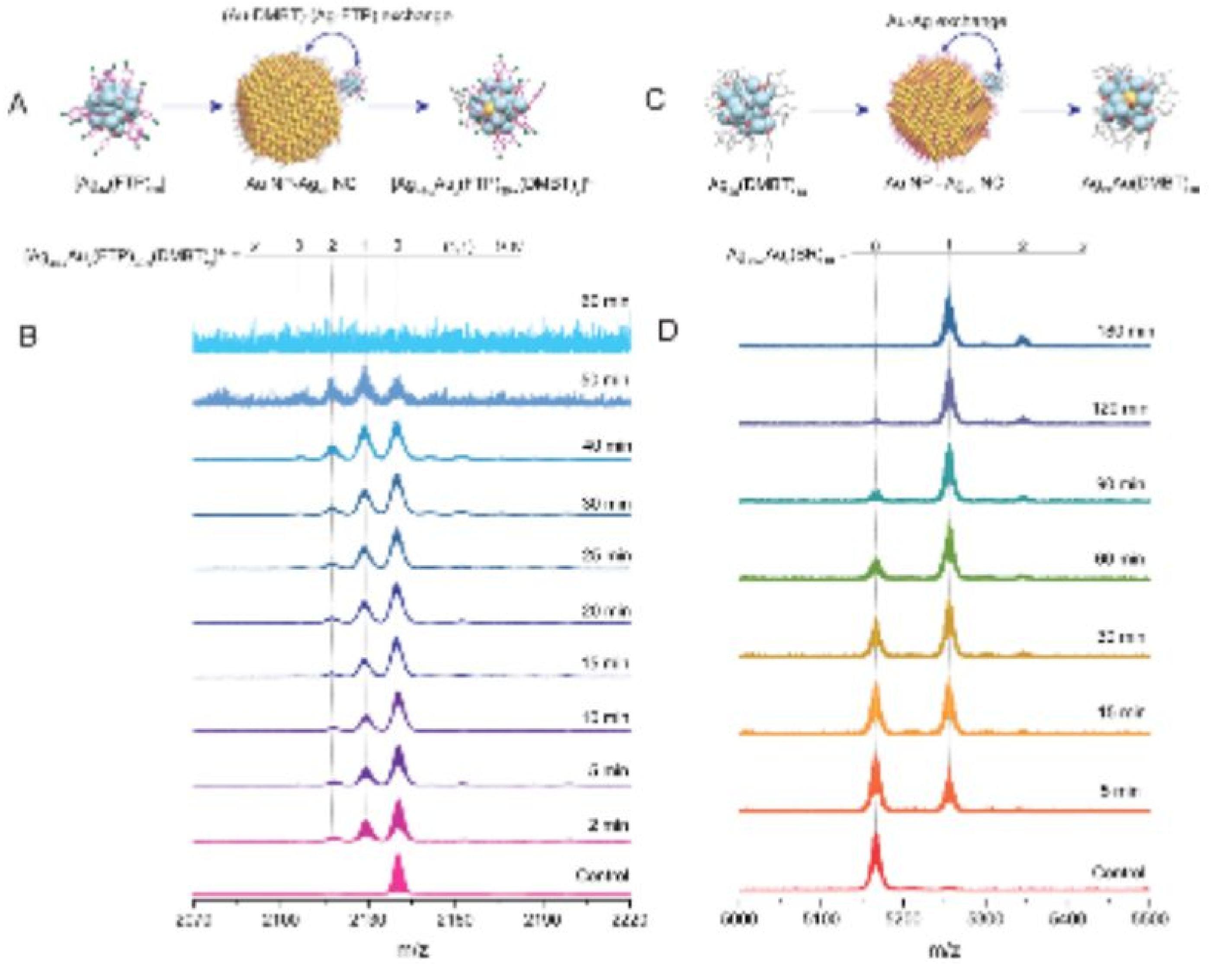
Interface controls the reaction

4



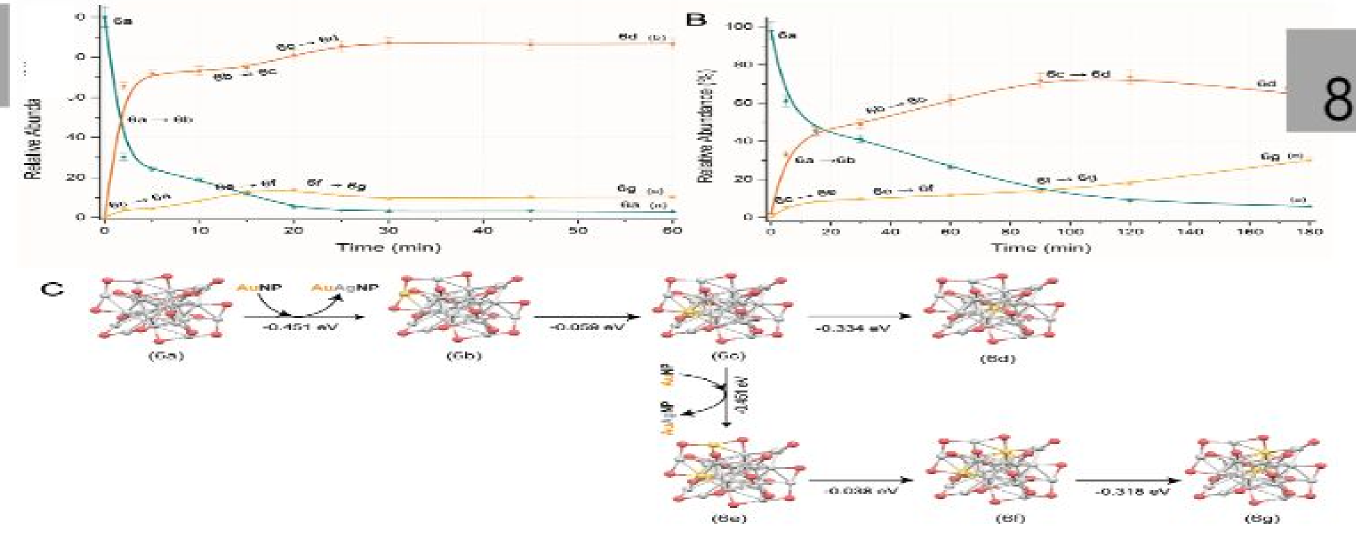
Scale bars: 20 nm

5

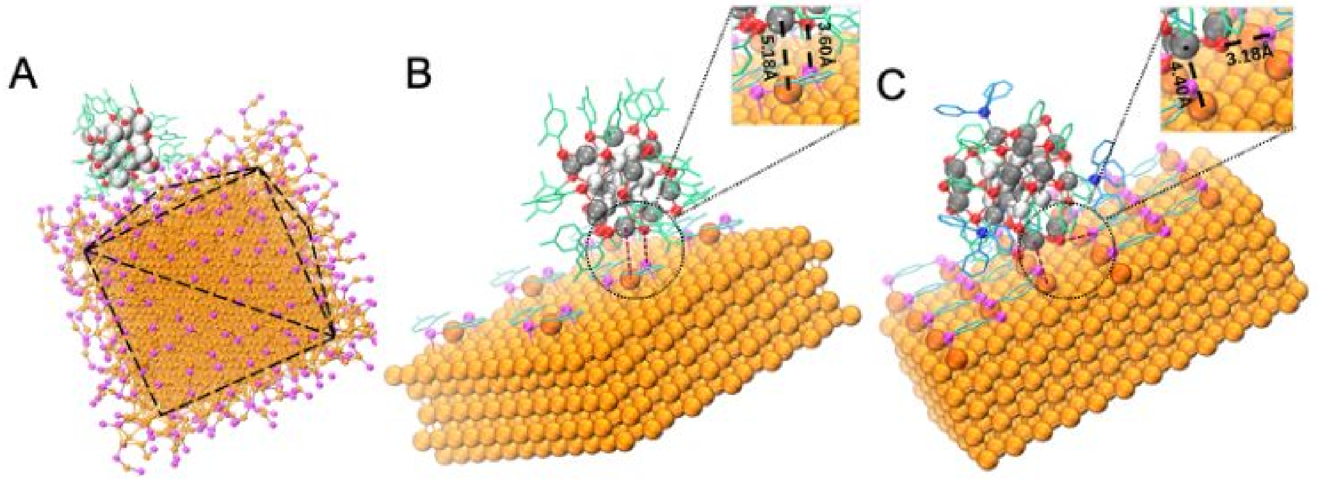


Computational insigh ts

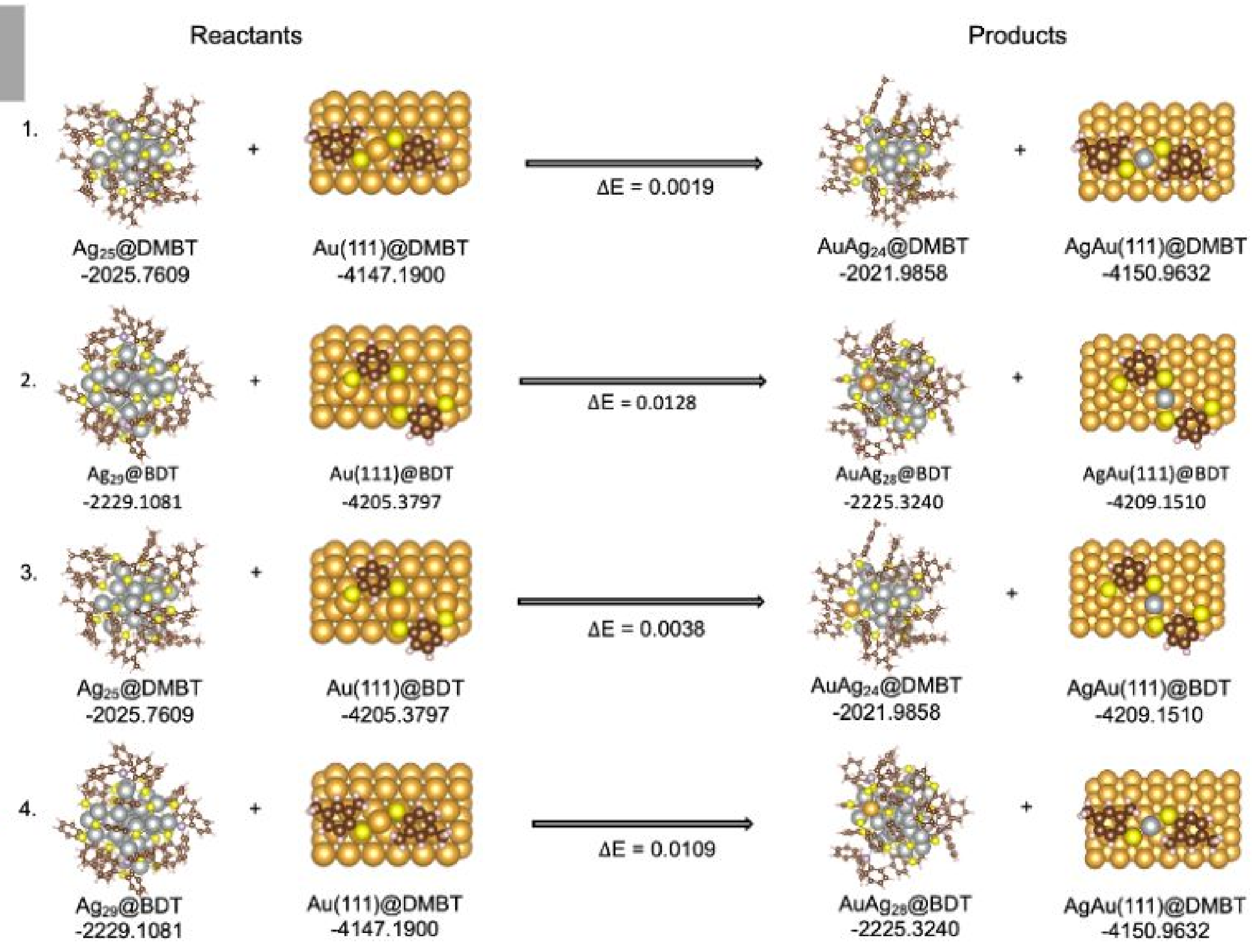
6



7



8



Reactions and new materia
ls

Reactions leading to co-crystals

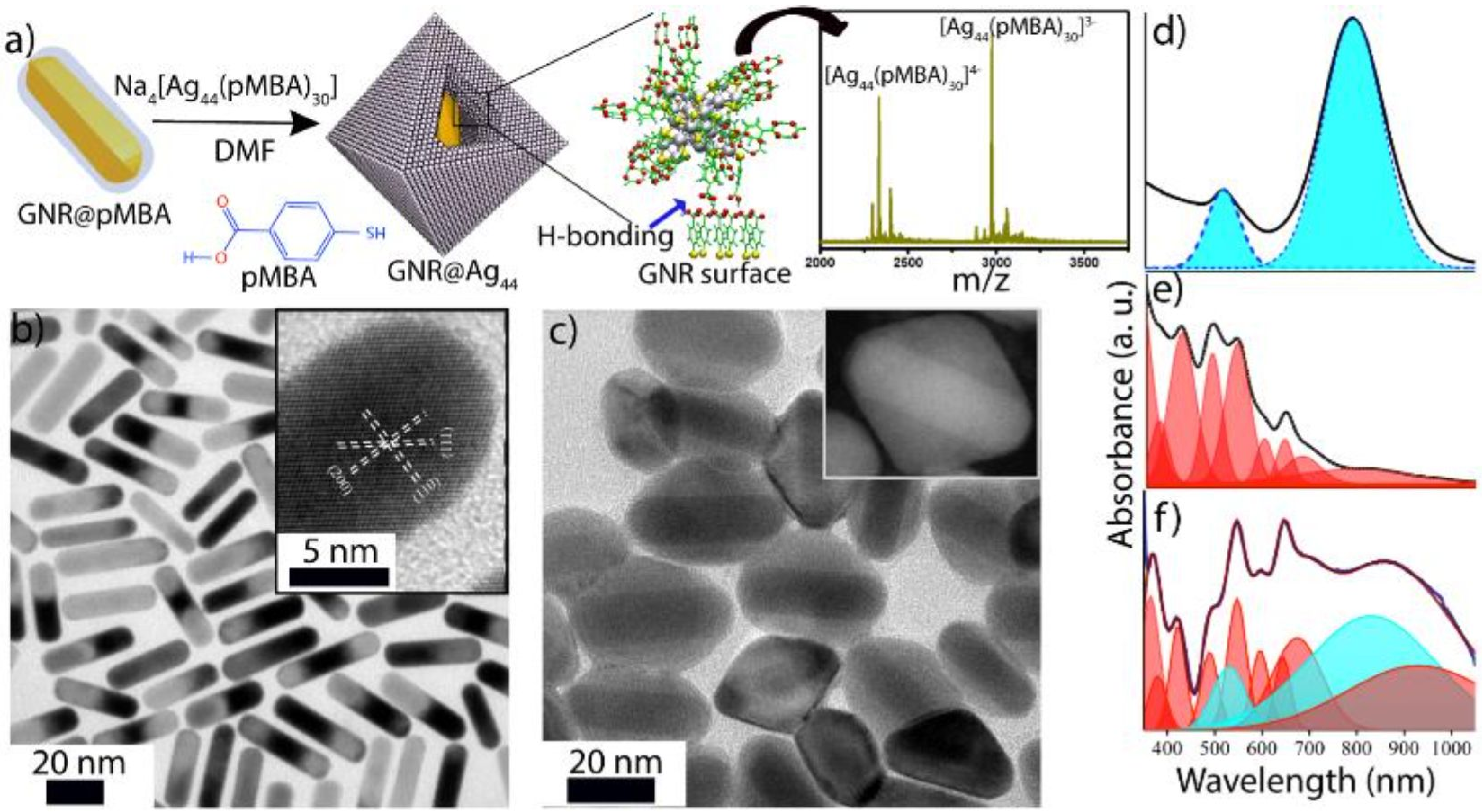
Supramolecular chemistry

Papri Chakraborty, et,. al. *ACS Nano* 2018

Figure 1. A) (a) Full range ESI MS, **(b)** experimental and calculated isotope patterns and **(c)** DFT optimized structure of [Ag29(BDT)12]3- cluster. **B) (a)** ESI MS of [Ag29(BDT)12(C60)n]3- (n=1-4) complexes, **(b)** experimental and calculated isotope patterns of [Ag29(BDT)12(C60)4]3- and **(c)** schematic of the possible structure of [Ag29(BDT)12(C60)4]3-.

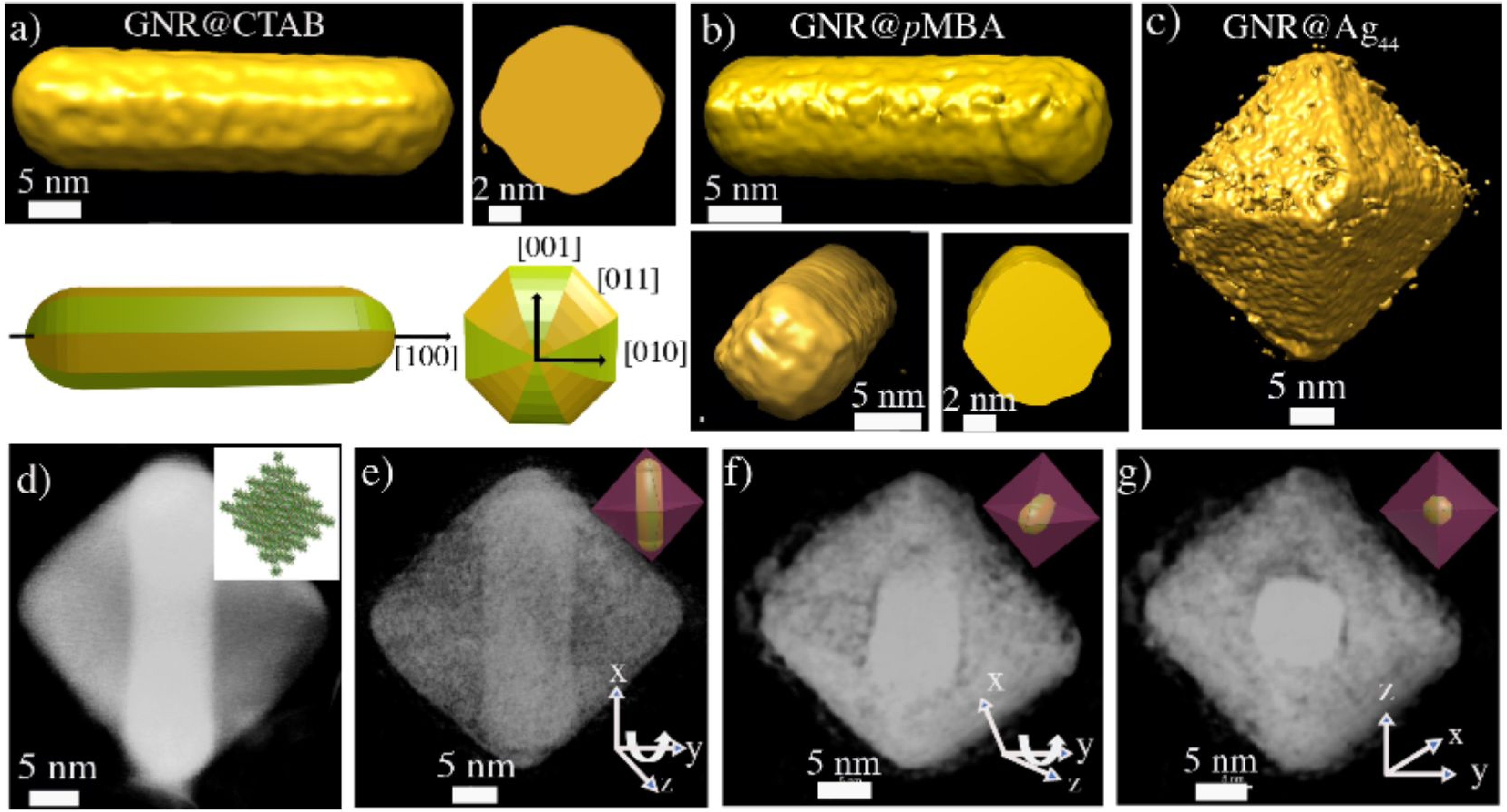
Assemblies and superstructure s

Atomically precise nanocluster assemblies encapsulating plasmonic gold nanorods

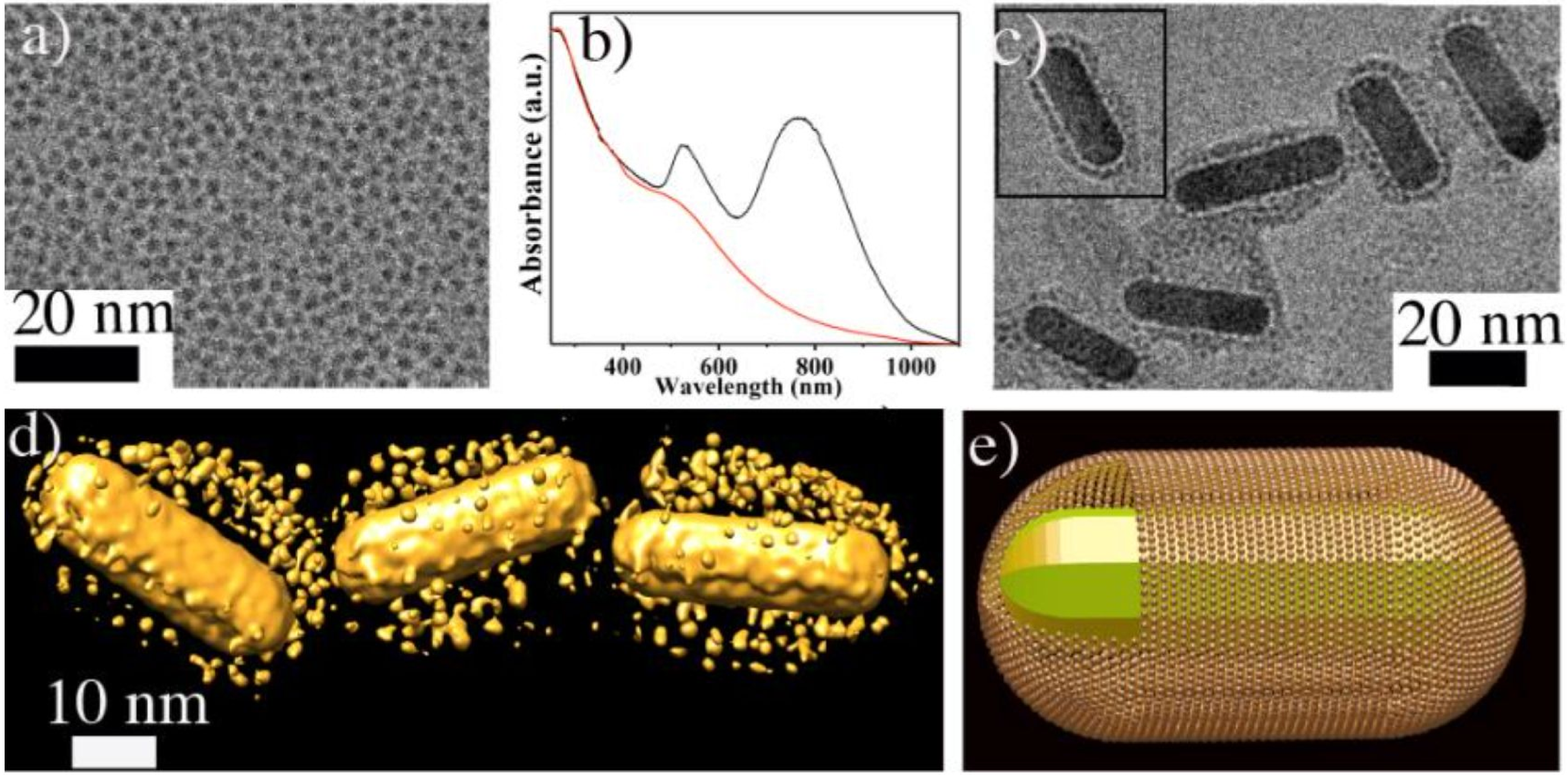


Chakraborty, A. et al., *Angew. Chem. Int. Ed.* **2018,** *57*, 6522–6526.

3D morphological analysis



Works for Au250(*p*MBA)n and aqueous solvent

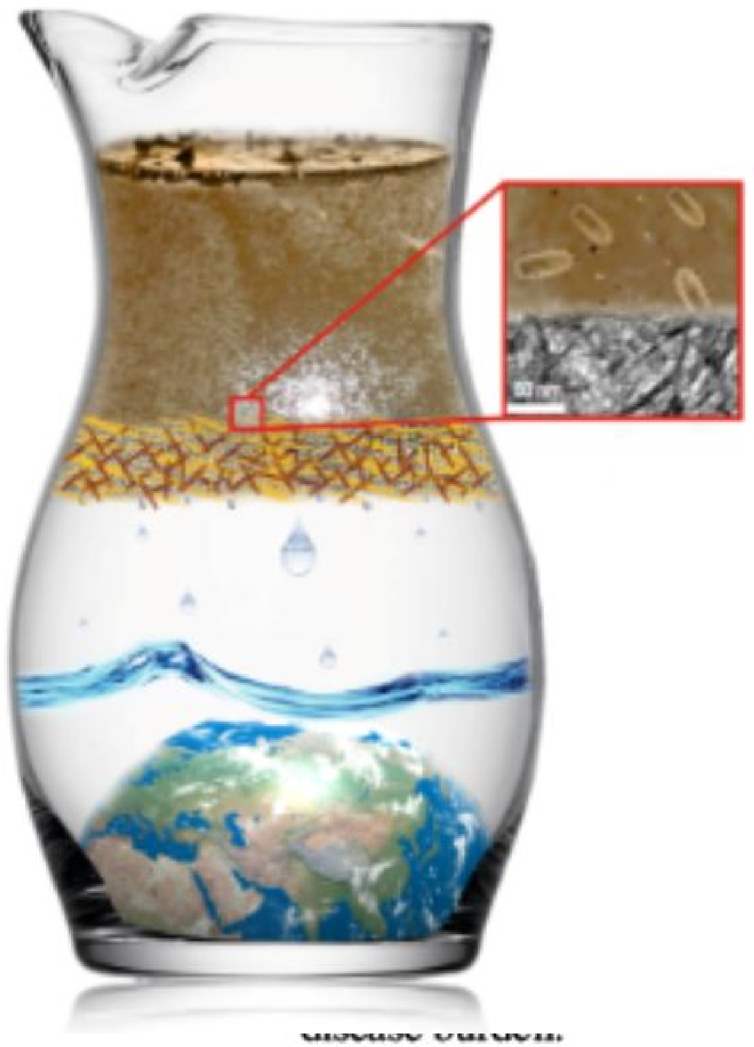


Co-crystals

Ag40 and Ag46 with the same shell

M. Bodiuzzaman, et. al. *Angew. Chem. Int. Ed.* **2018**

Where are they taking us to?



PNAS PNAS PNAS PNAS

Biopolymer-reinforced synthetic granular nanocomposites for affordable point-of-use water purification

Mohan Udhaya Sankar[1], Sahaja Aigal[1], Shihabudheen M. Maliyekkal[1], Amrita Chaudhary, Anshup, Avula Anil Kumar, Kamalesh Chaudhari, and Thalappil Pradeep[2]

Unit of Nanoscience and Thematic Unit of Ex... Madras, Chennai 600 036, India

Edited by Eric Hoek, University of California, ... (received for review November 21, 2012)

Creation of affordable materials for cons... water is one of the most promising ways... drinking water for all. Combining the... composites to scavenge toxic species ... other contaminants along with the abo... affordable, all-inclusive drinking water... without electricity. The critical proble... synthesis of stable materials that can... uously in the presence of complex s... drinking water that deposit and caus... surfaces. Here we show that such con... be synthesized in a simple and effective ... out the use of electrical power. The na... sand-like properties, such as higher shea... forms. These materials have been used... water purifier to deliver clean drinking ... ily. The ability to prepare nanostructu... ambient temperature has wide releva... water purification.

hybrid | green | appropriate technology | frugal science | developing world

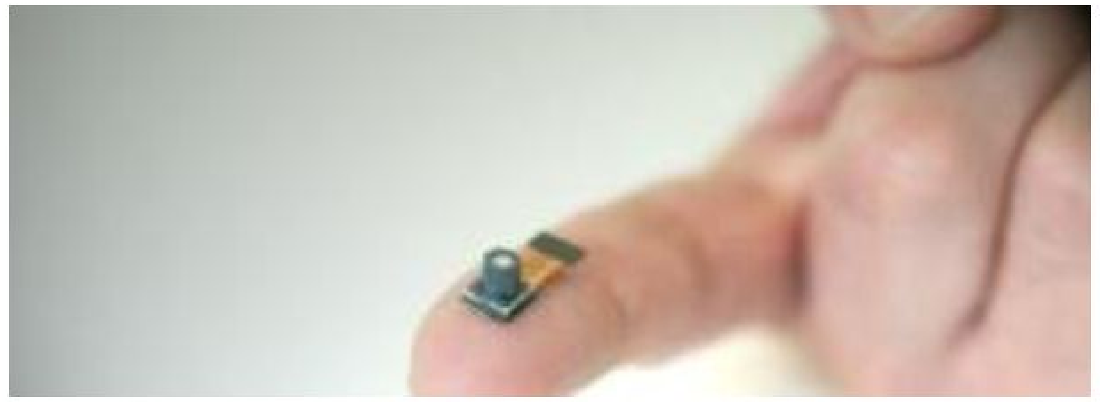
...vailable; and (c) continued retention ... matrix is difficult. ...ate a unique family of nanocrystalline ...n granular composite materials pre... ...ature through an aqueous route. The ...mposition is attributed to abundant -O- ... on chitosan, which help in the crys... ...oxide and also ensure strong covalent ... surface to the matrix. X-ray photo... ...) confirms that the composition is rich ...ps. Using hyperspectral imaging, the ...aching in the water was confirmed. ... to reactivate the silver nanoparticle ...al antimicrobial activity in drinking ...osites have been developed that can ...ts in water. We demonstrate an af... ...device based on such composites de... ...nd undergoing field trials in India, as ...spread eradication of the waterborne disease burden.

Results and Discussion

M. Udhaya Sankar, et. al. *Proc. Natl. Acad. Sci.,* 110 (2013) 8459-8464.

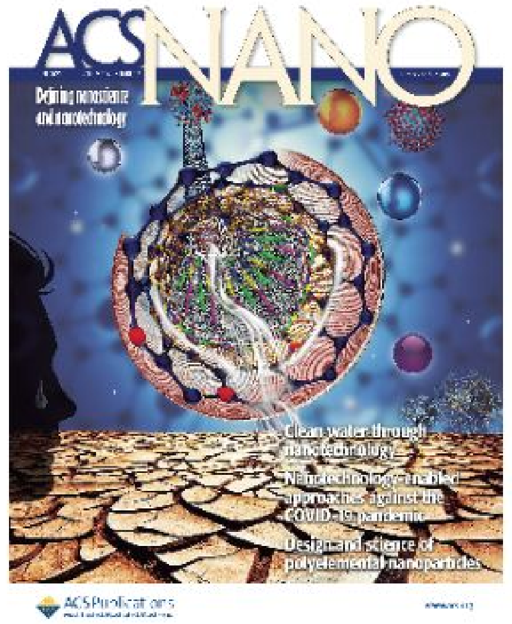

We developed environmentally friendly water positive nanoscale materials for affordable, sustainable and rapid removal of arsenic from drinking water.
There are over 1700 community installations across the country, serving 1.3 million people with arsenic and iron-free water every day.

Sensors and new opportuniti
es



Water quality measurement – In the pipe
line

Smart water purifiers and big data



Ankit Nagar and T. Pradeep 14(2020). *ACS Nano*, 6420-6435.

Cluster-based metal ion sensing

Decrease in the absorption of Au15 as a biofilm is dipped into the cluster soluti
on. Inset: Free standing quantum cluster loaded film in visible light and UV light

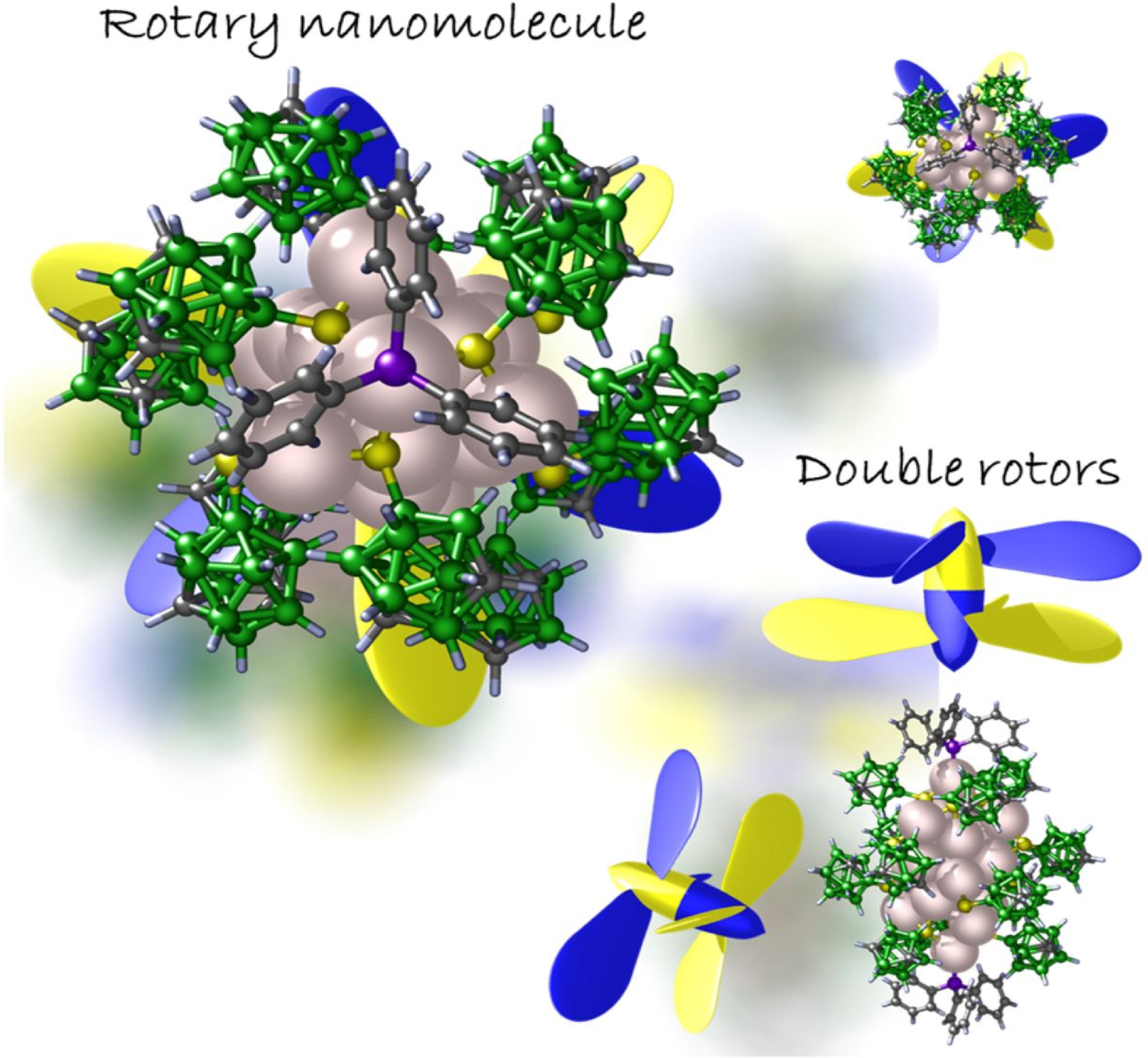
Anu George et al. *ACS Applied Materials & Interfaces*, 2012.

Approaching detection limits of tens of Hg2
+

Atanu Ghosh et al. Anal. Chem. 201
4

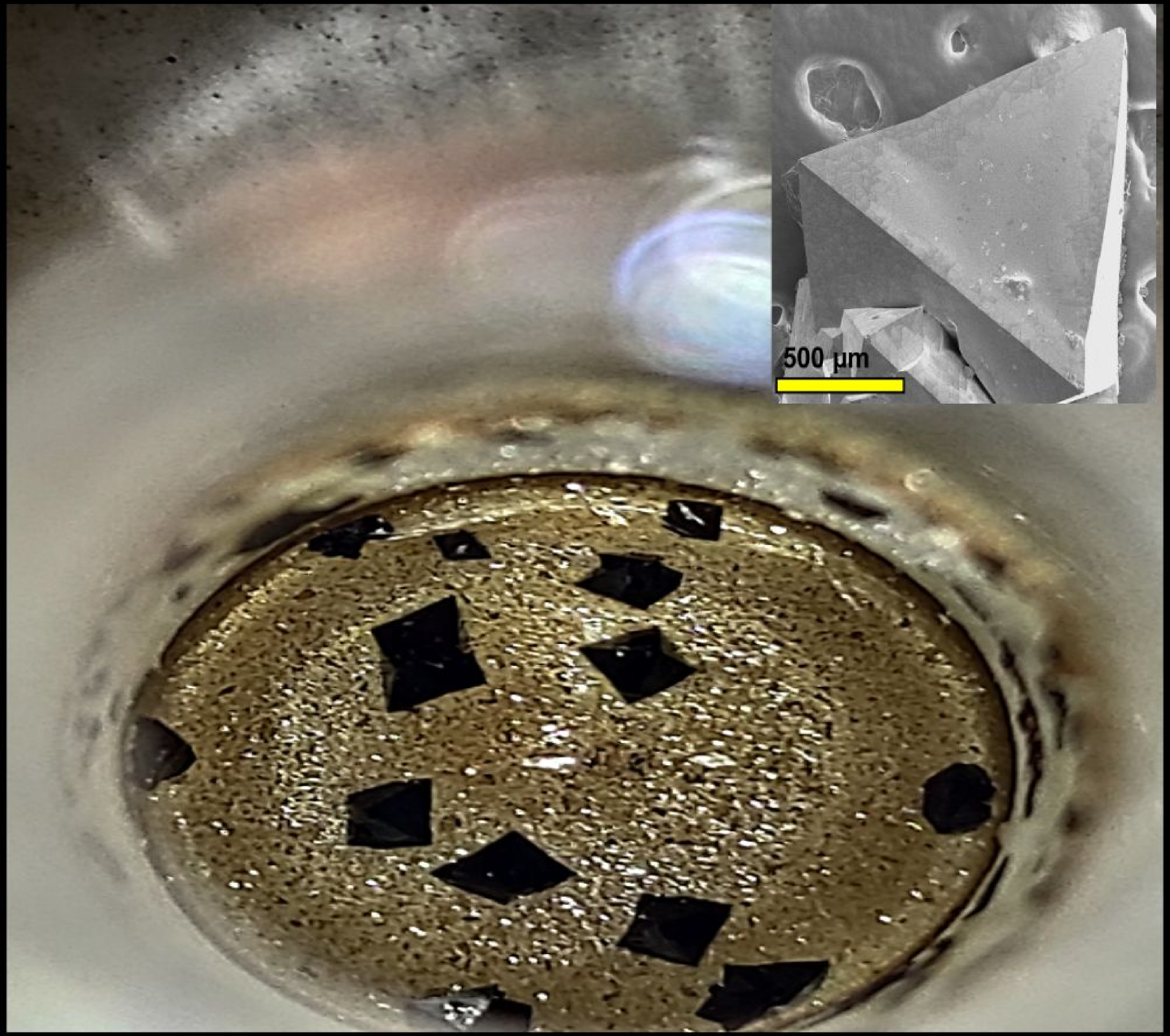
Mercury quenching experiment using nanofiber

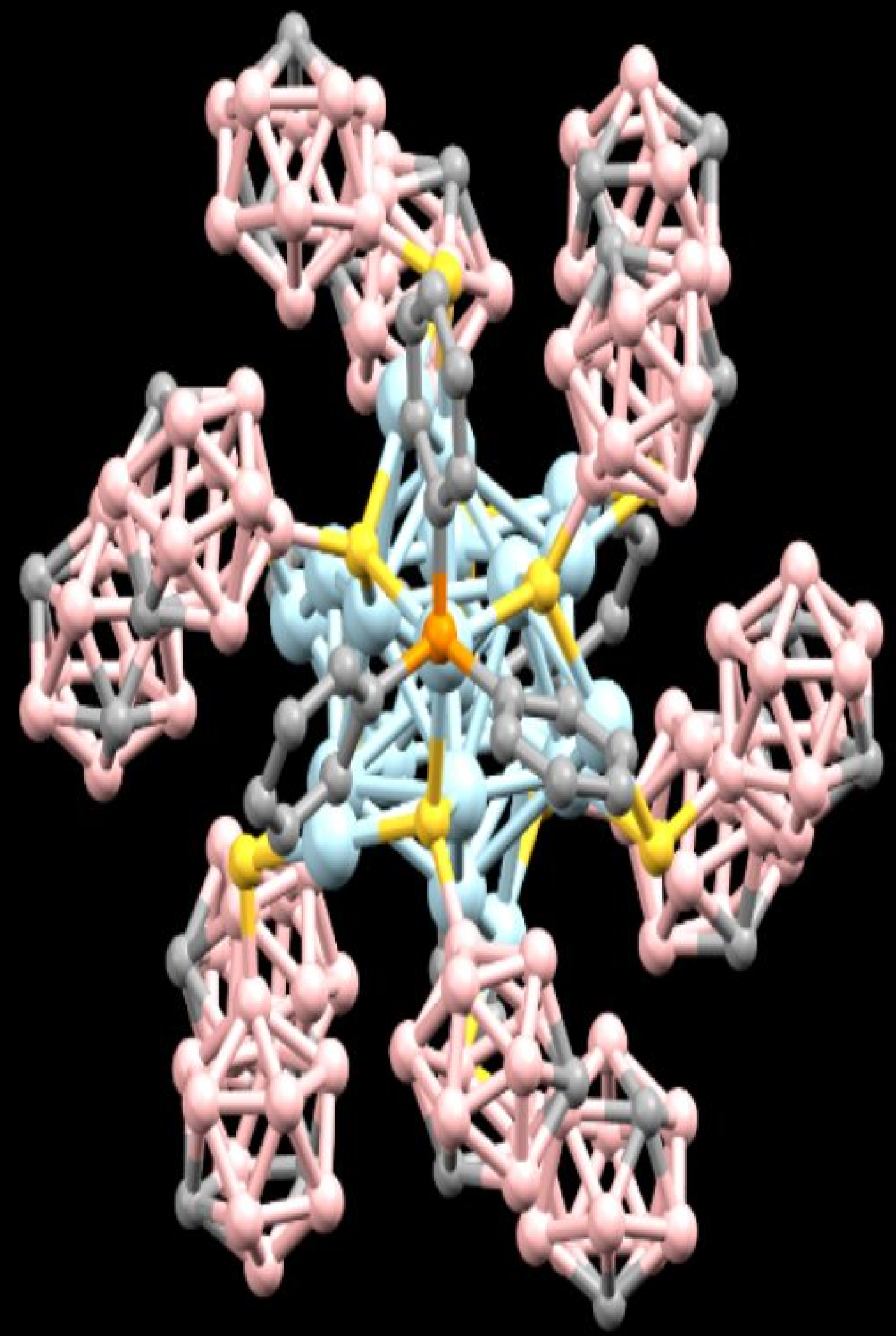
Carborane-thiol protected silver nanomolecule



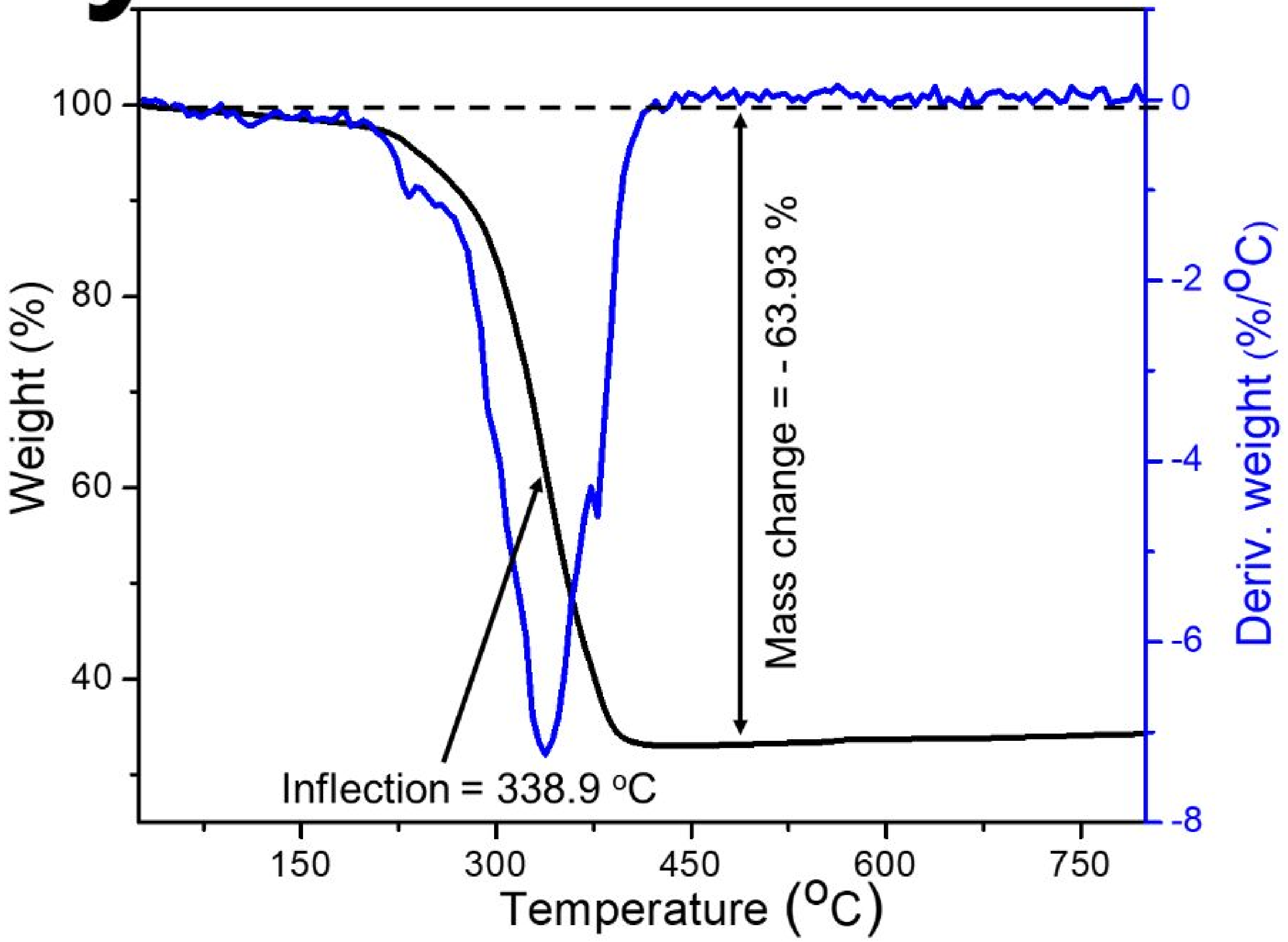
With Tomas Bas
e

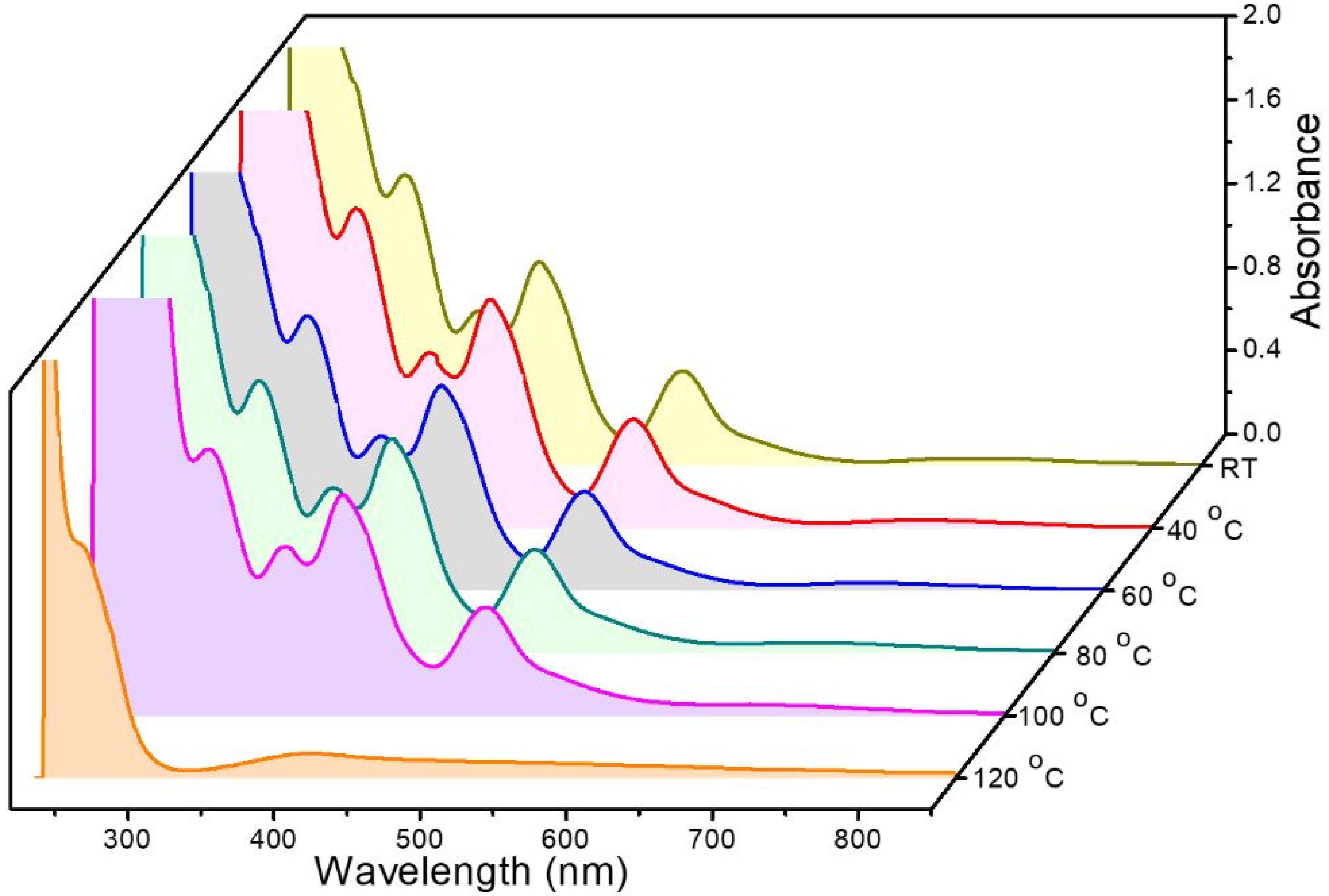
Jana *et. al*, Inorganic Chemistry (2022)


500 µm



Thermal stabilit
y

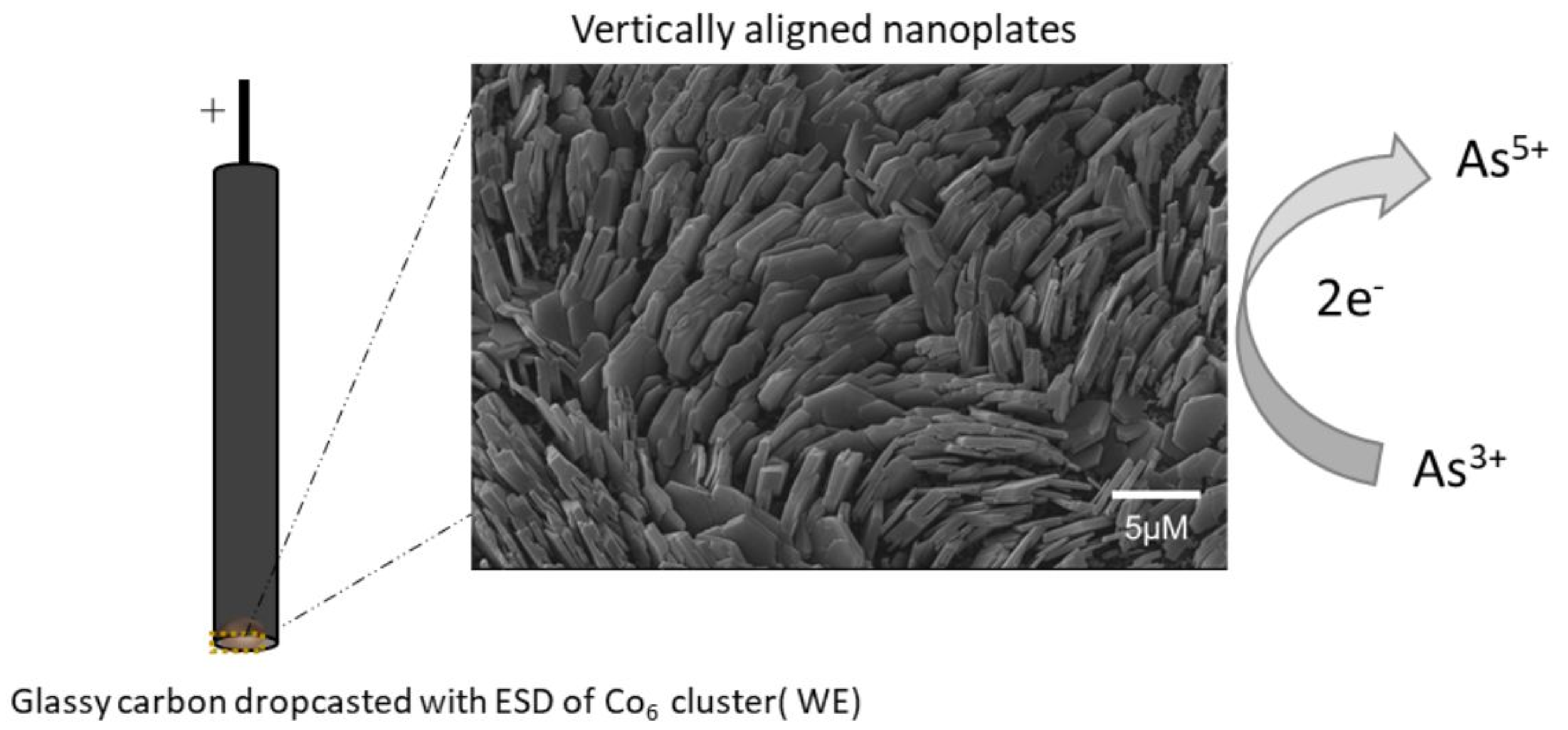


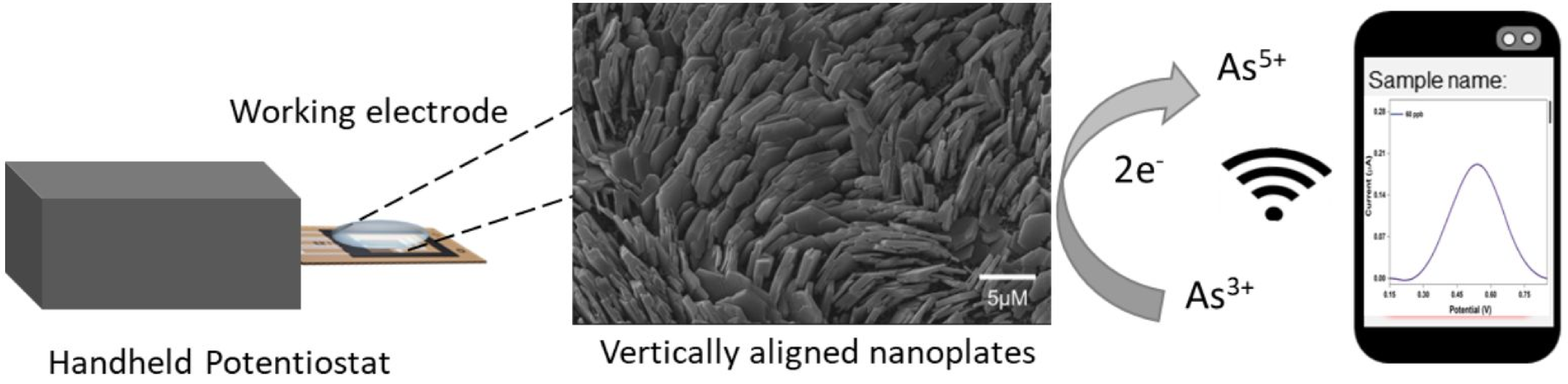


New electrodes - Aligned nanoplates of Co6S
8

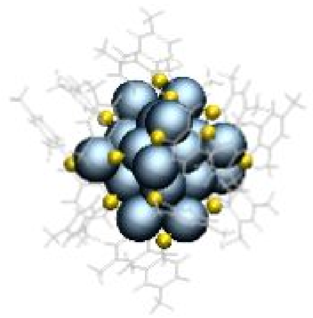
1,2-bis(diphenylphosphino)ethane (DPPE)

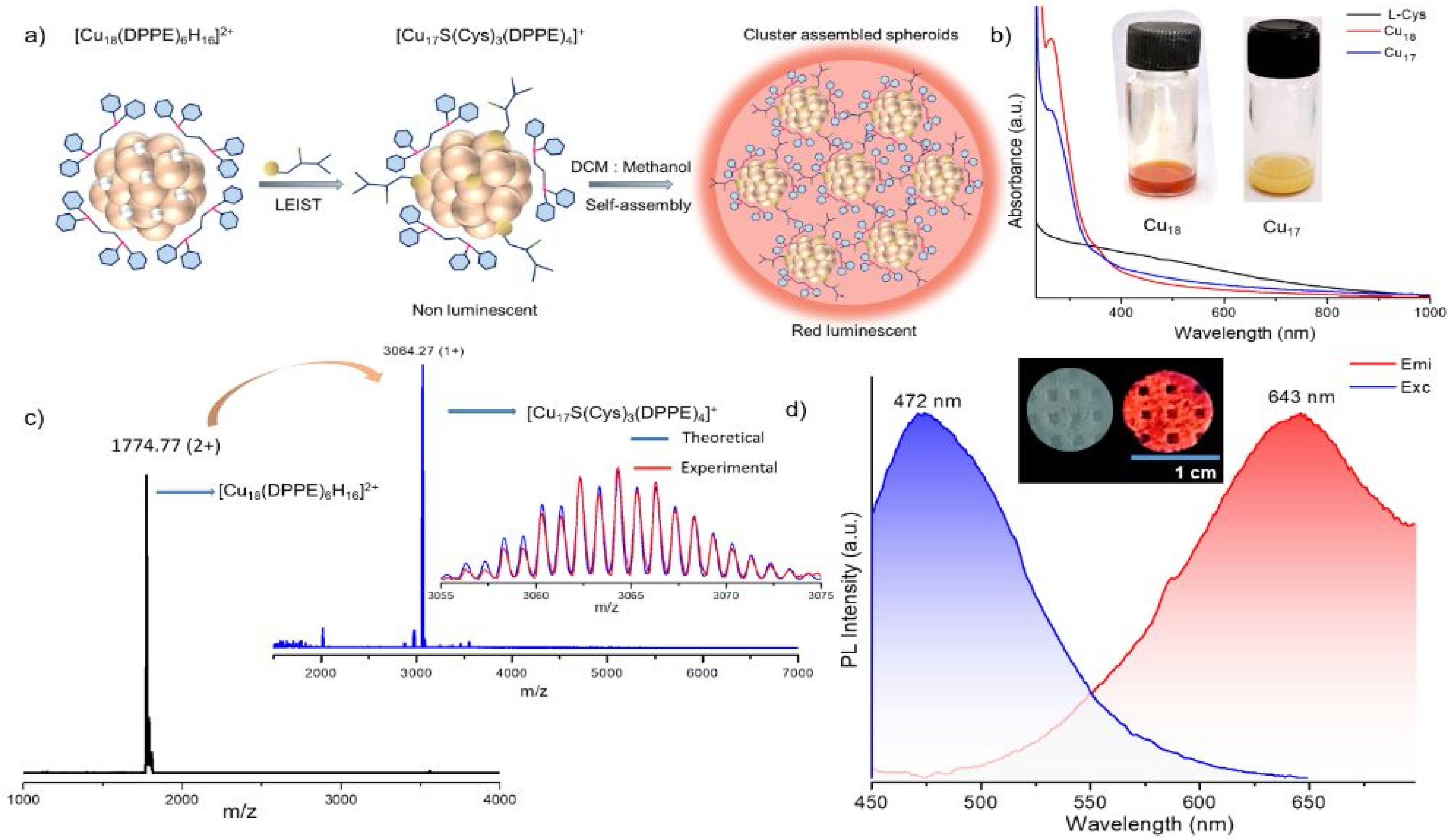
Working electrode





Anagha Jose et al. *ACS Materials Lett.,* 5 (2023) 893–899.





J. S. Kumar, *ES&T Lett.* 2024, 11, 8, 831–837.

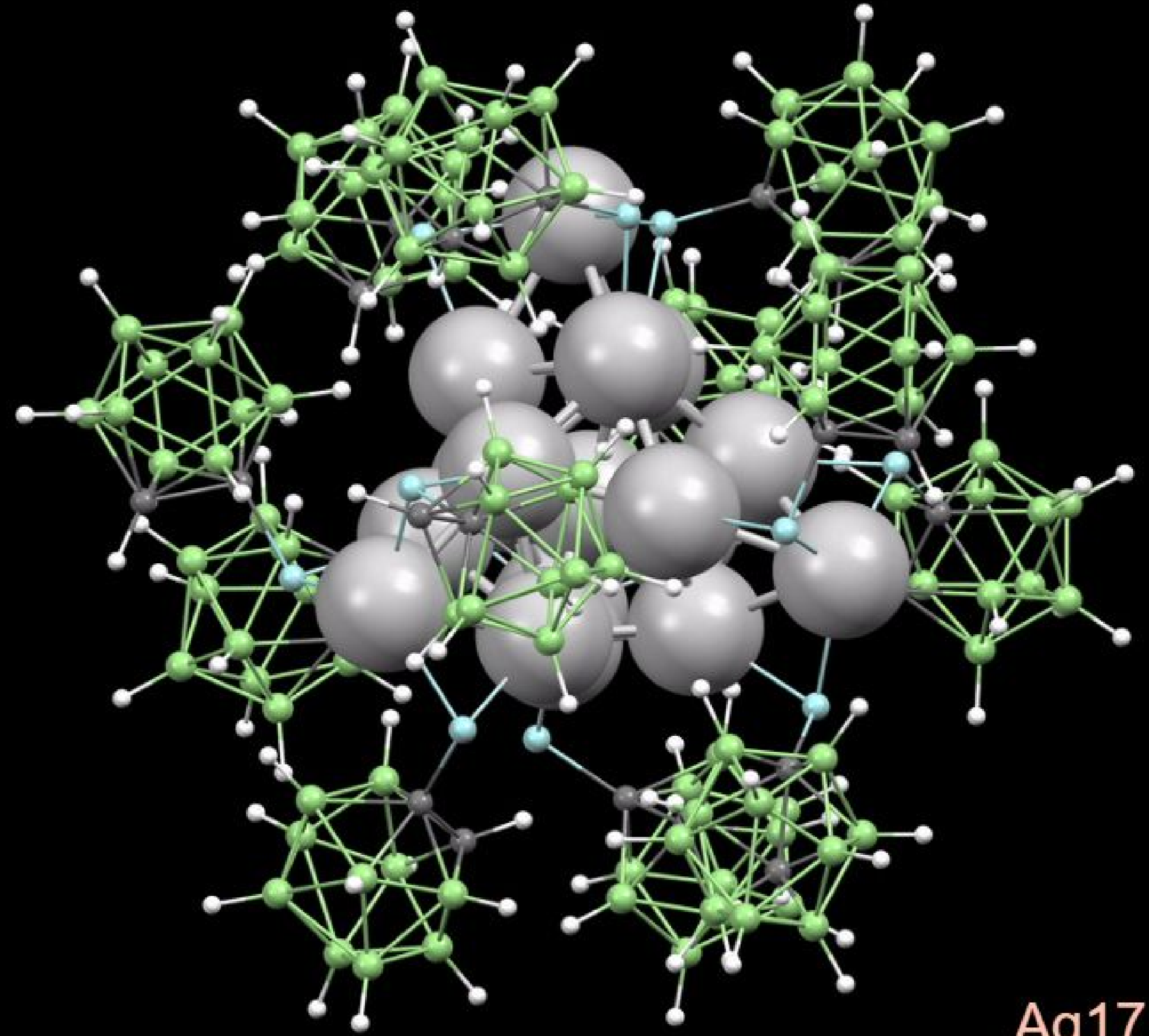
Arsenic poisoning across the world

E. Shaji, M. Santosh, K. V. Sarath, Pranav Prakash, V. Deepch and B. V. Divya, Geoscience Frontiers, 12 (2021) 101079.

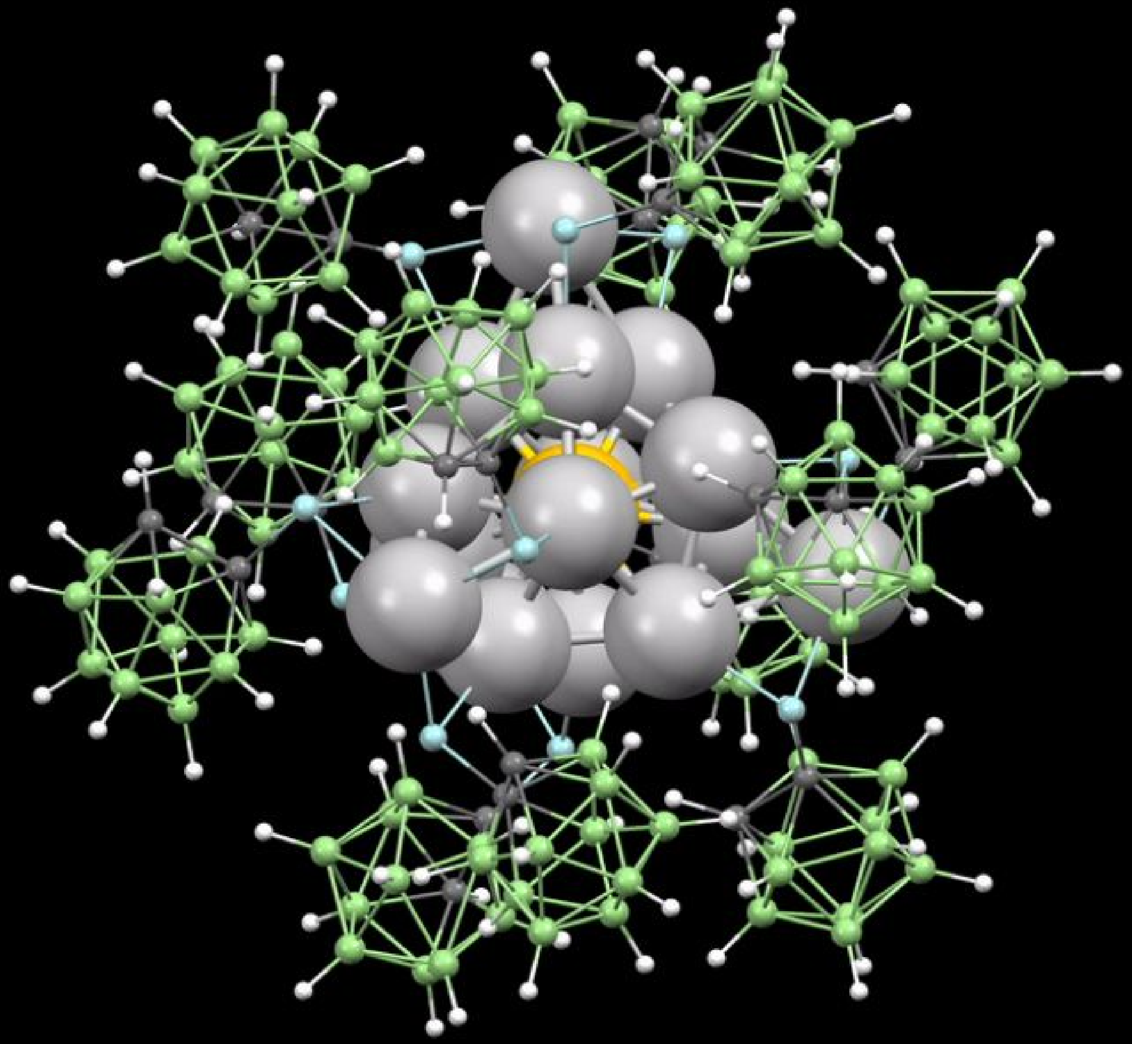
Ag17 **AuAg16** **Ag13Cu4** **AuAg12Cu4**

Vivek Yadav, et. al., *Nature Communications*, 2025

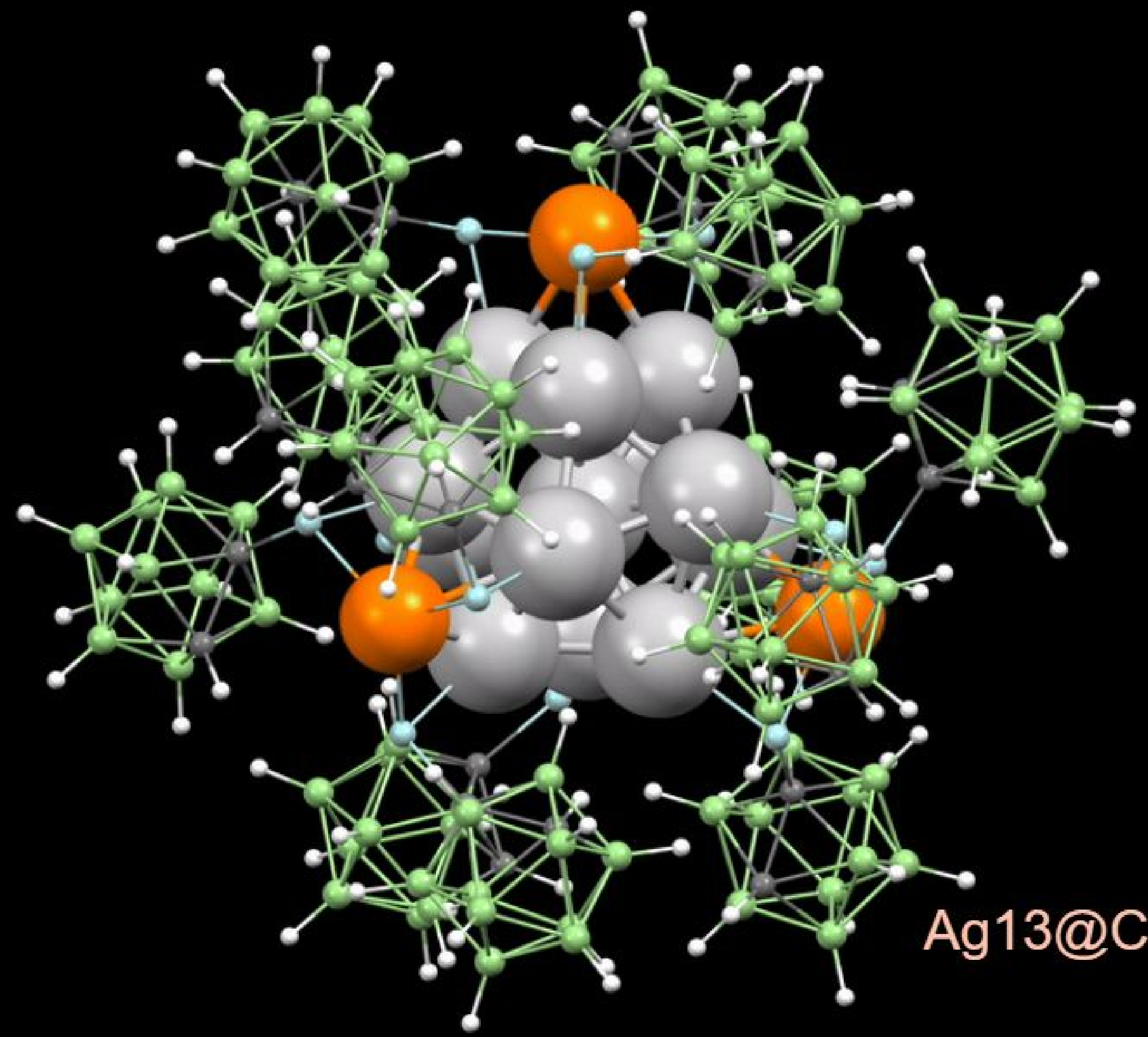
Structure of M17 Nanoclusters



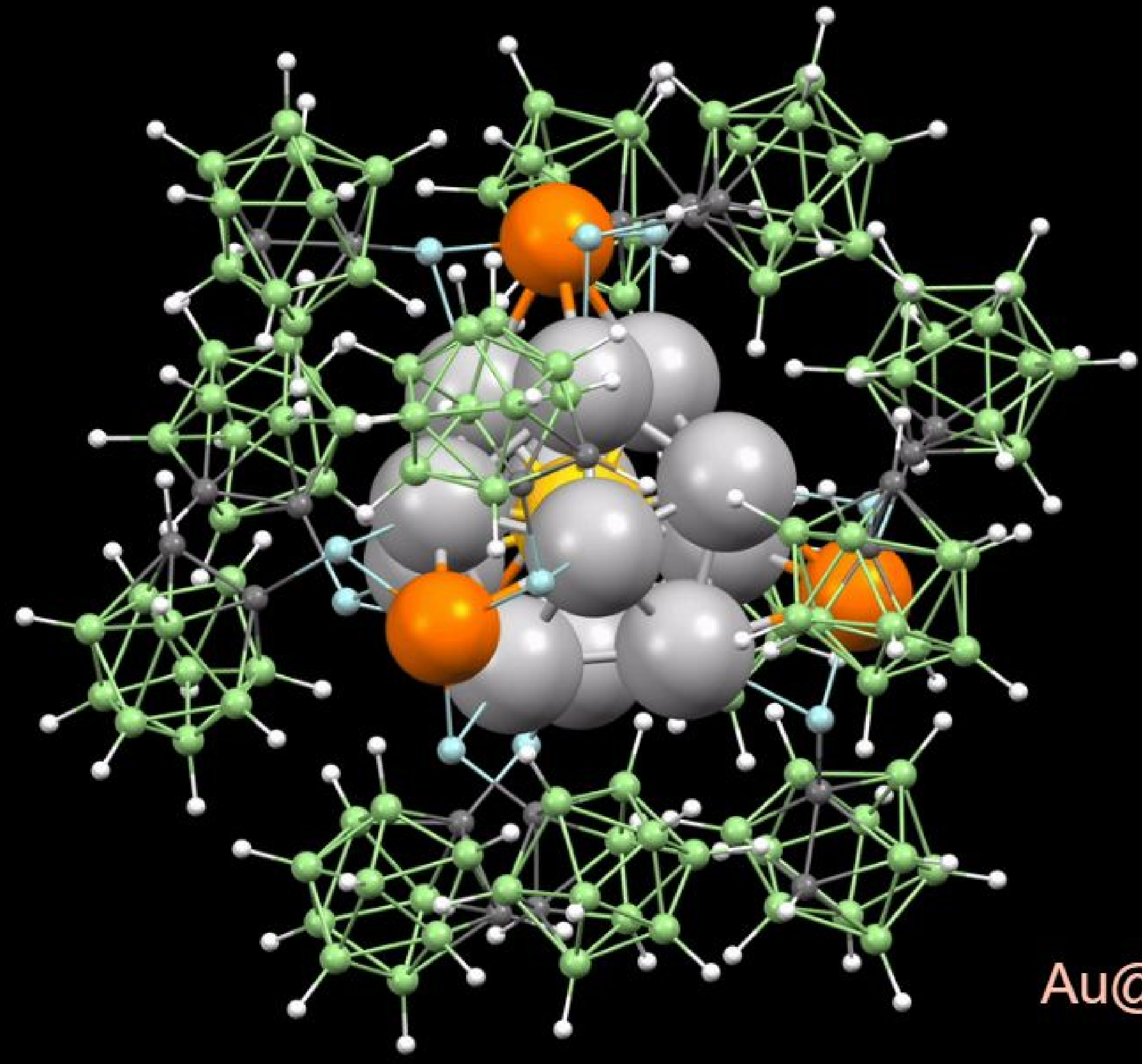
Ag17



Au@Ag16

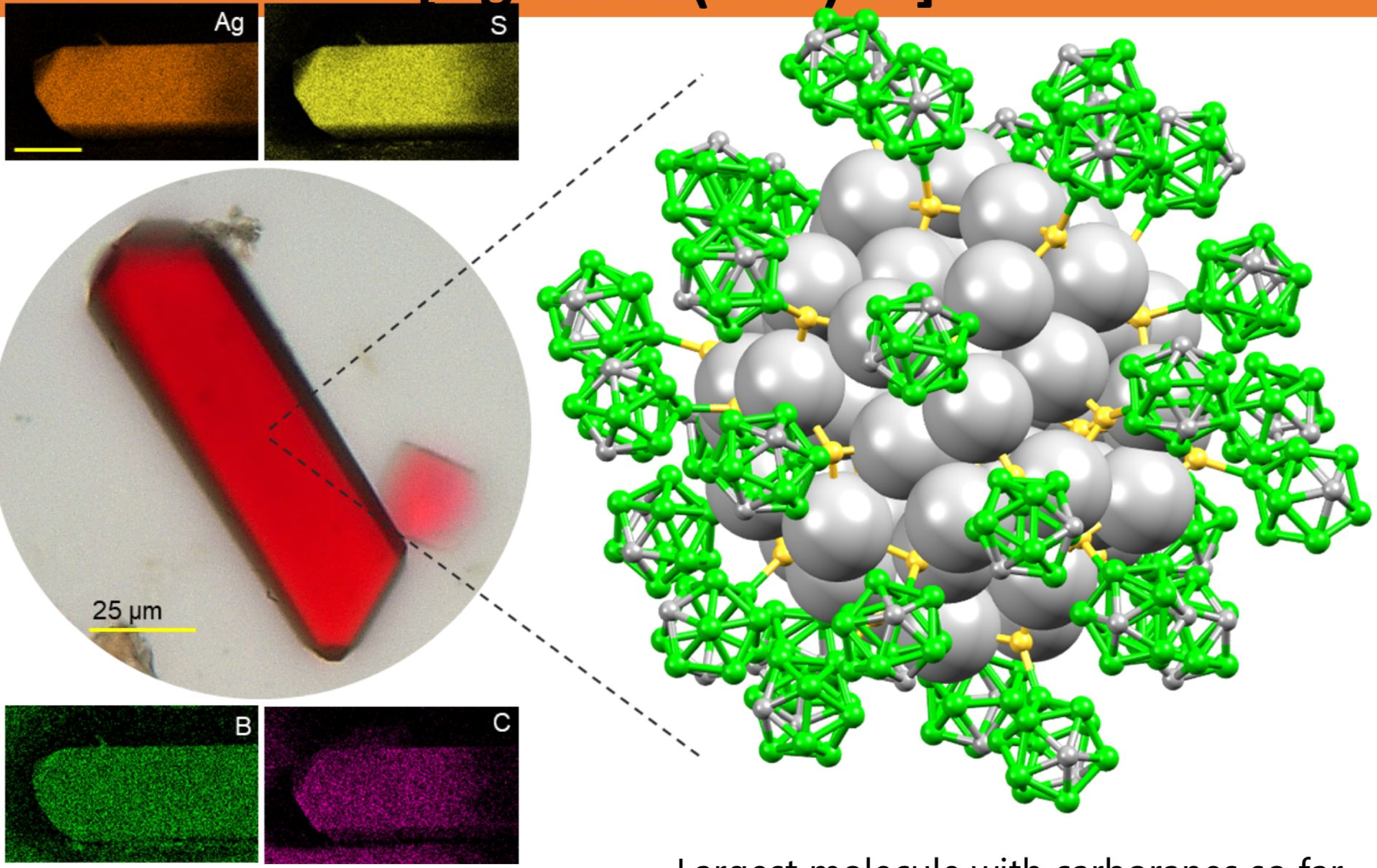


Ag13@Cu4



Au@Ag12@Cu4

[Ag62S12(CBT)32] Nanoclus

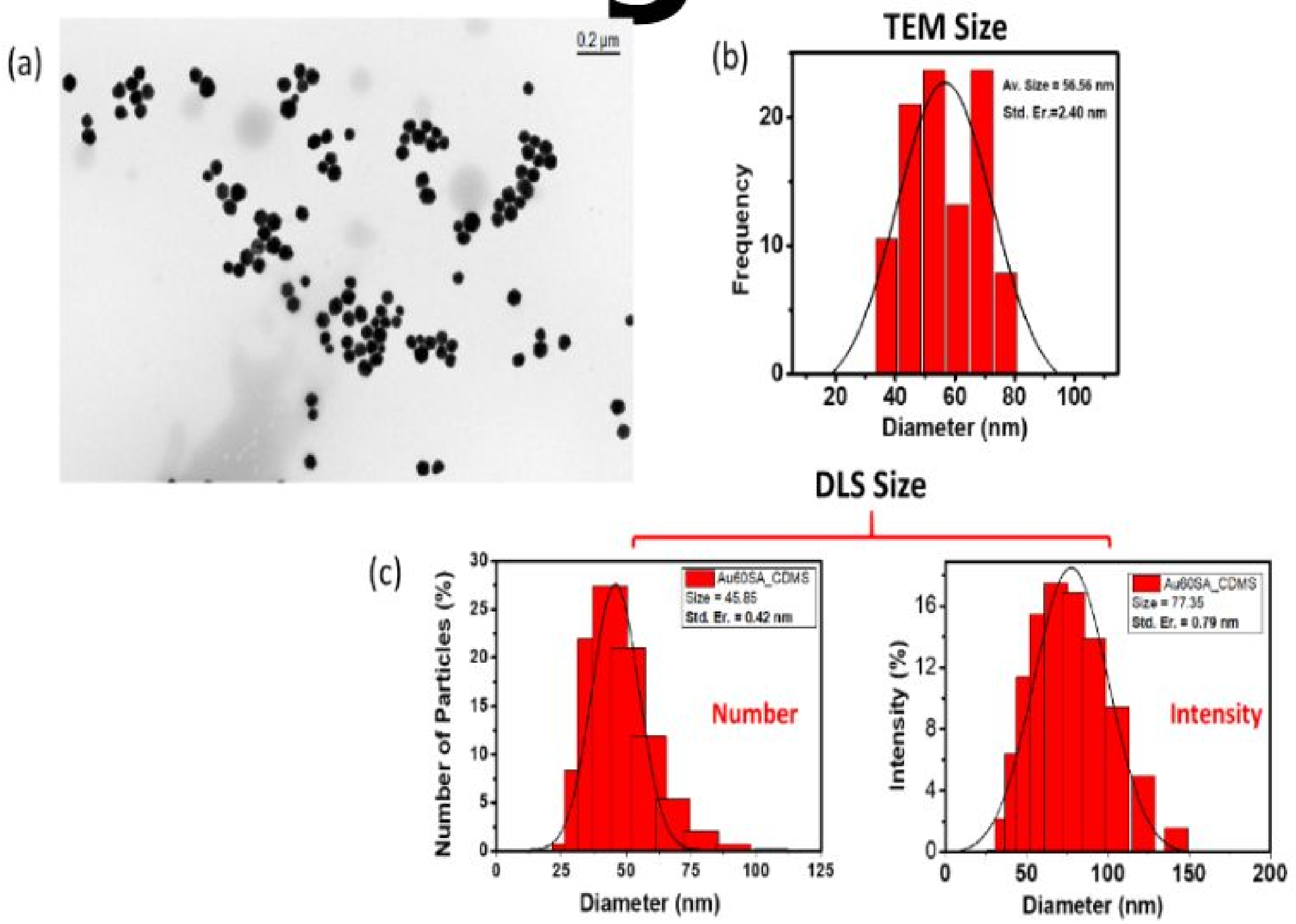


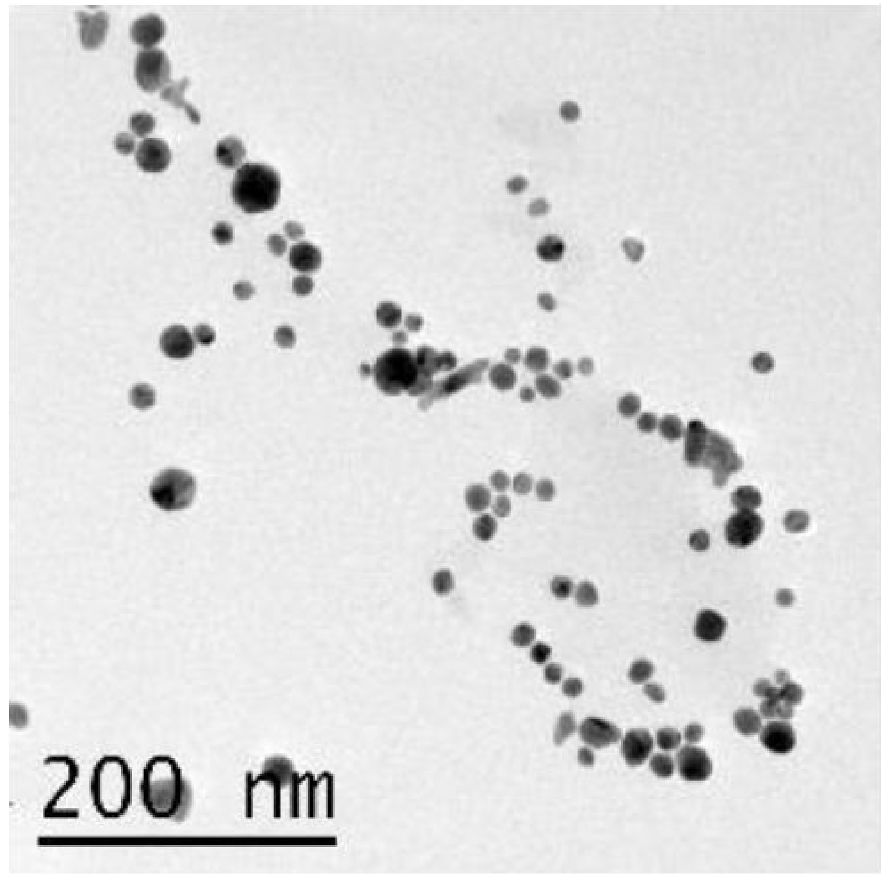
Largest molecule with carboranes so far…

…

Jana *et al.*, ACS Nano (2025), in revision

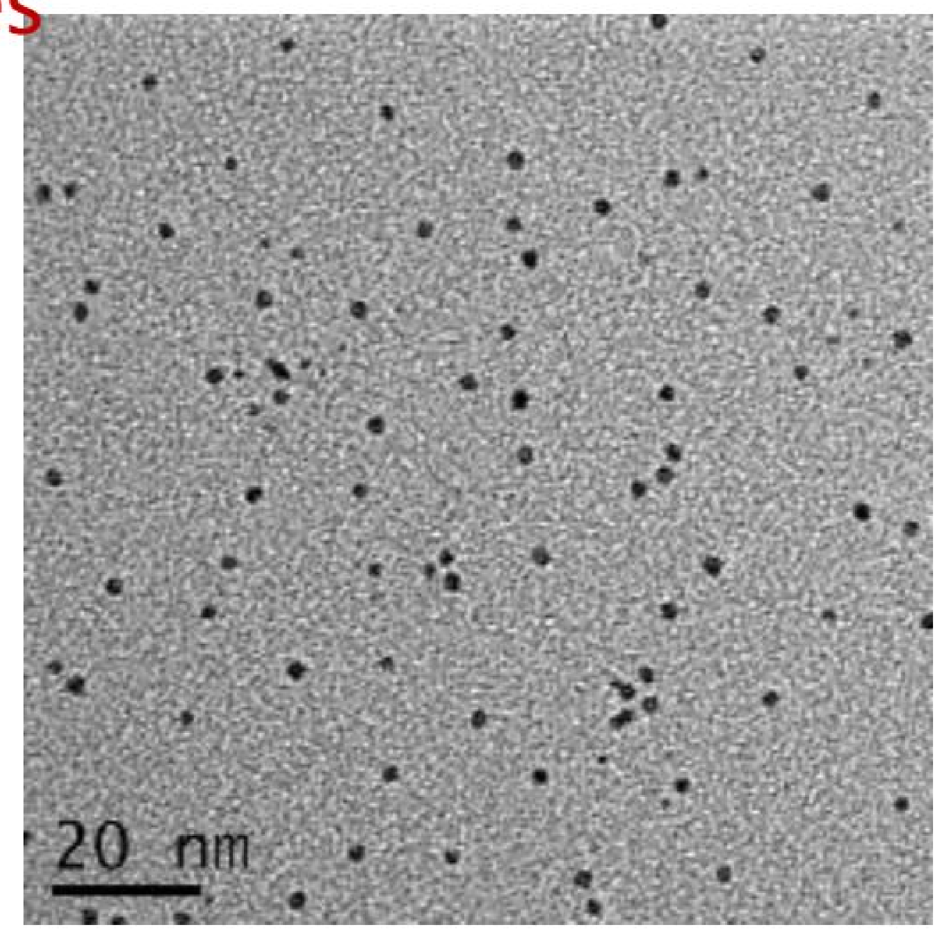
Larger clusters - TE

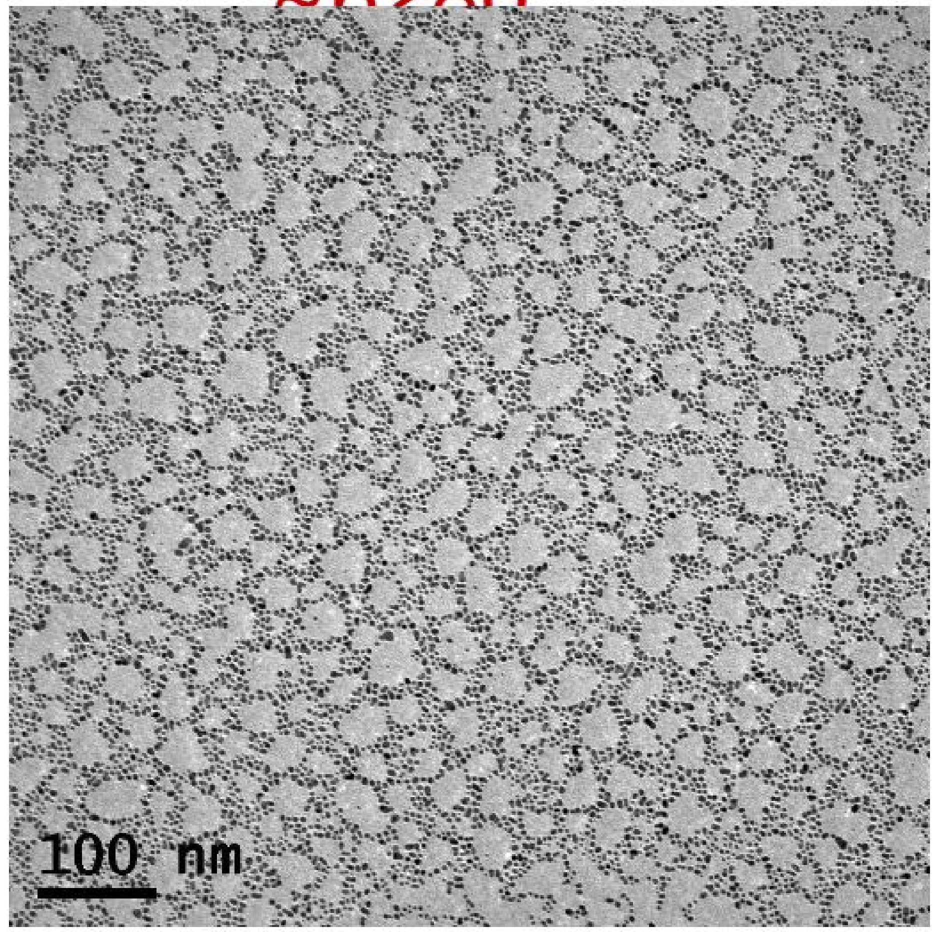


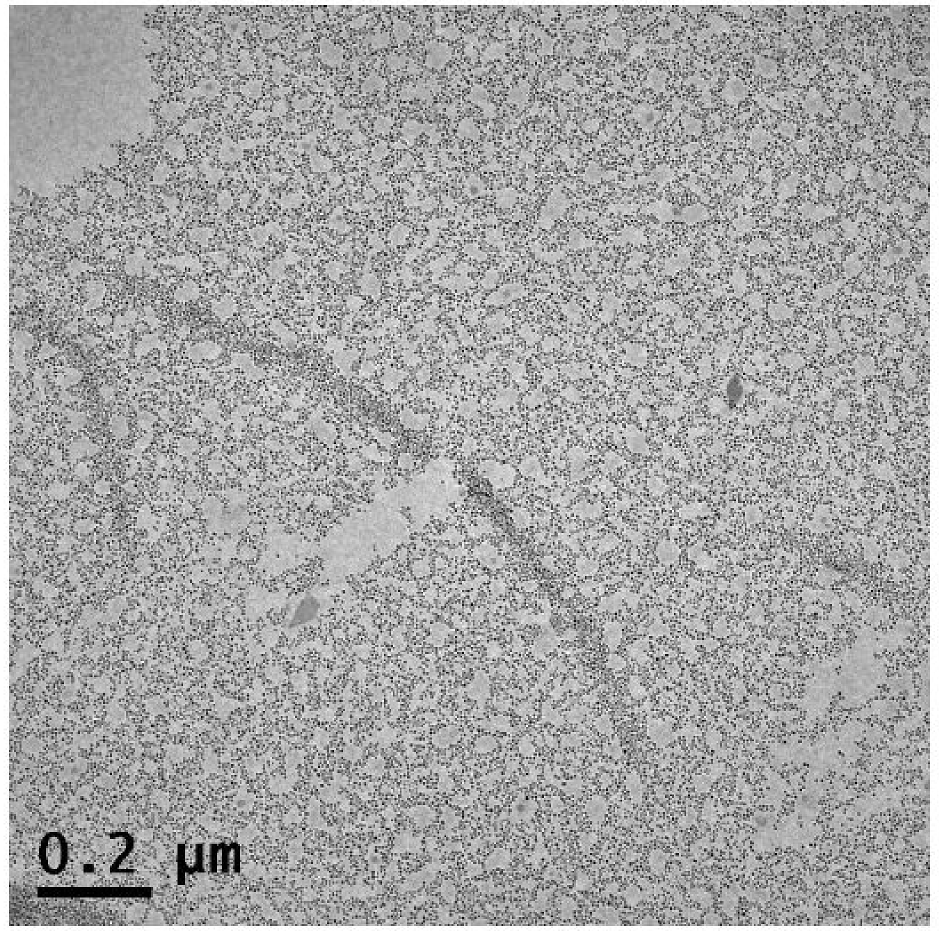


60 nm sized Au-citrate nanopartic les

Au~246000(MUTAB) ~6280







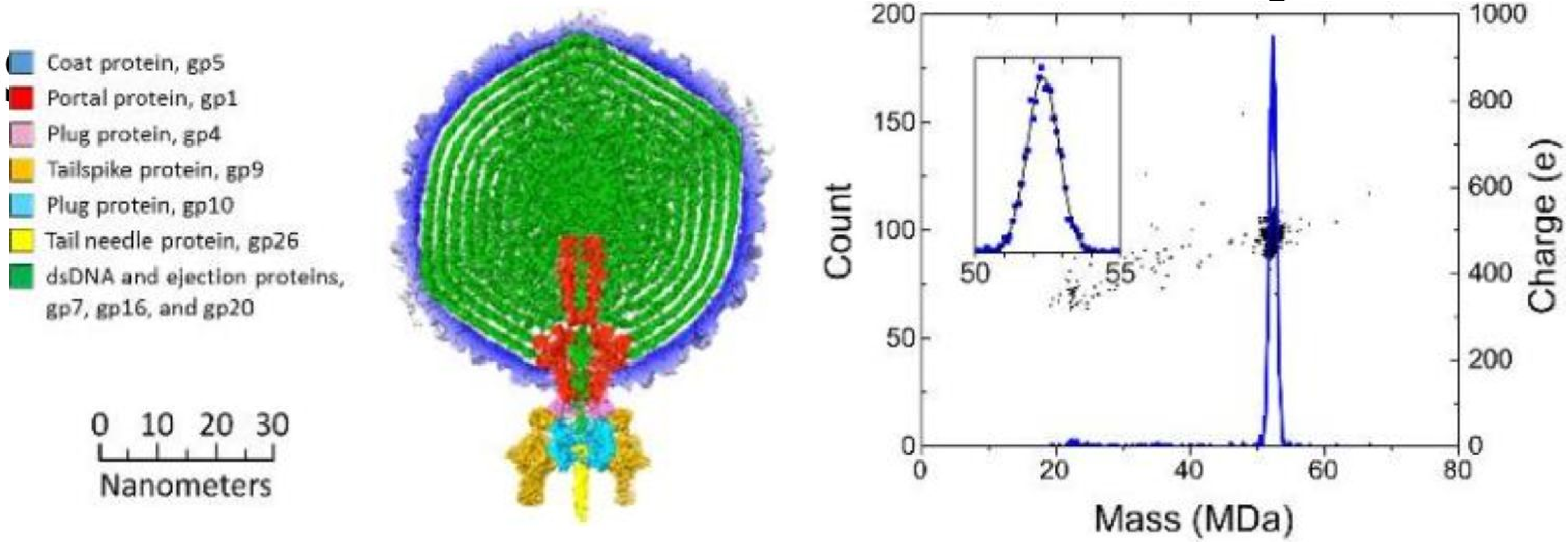
Au279(TBBT)84

Au144(PET)60

Au25(PET)18

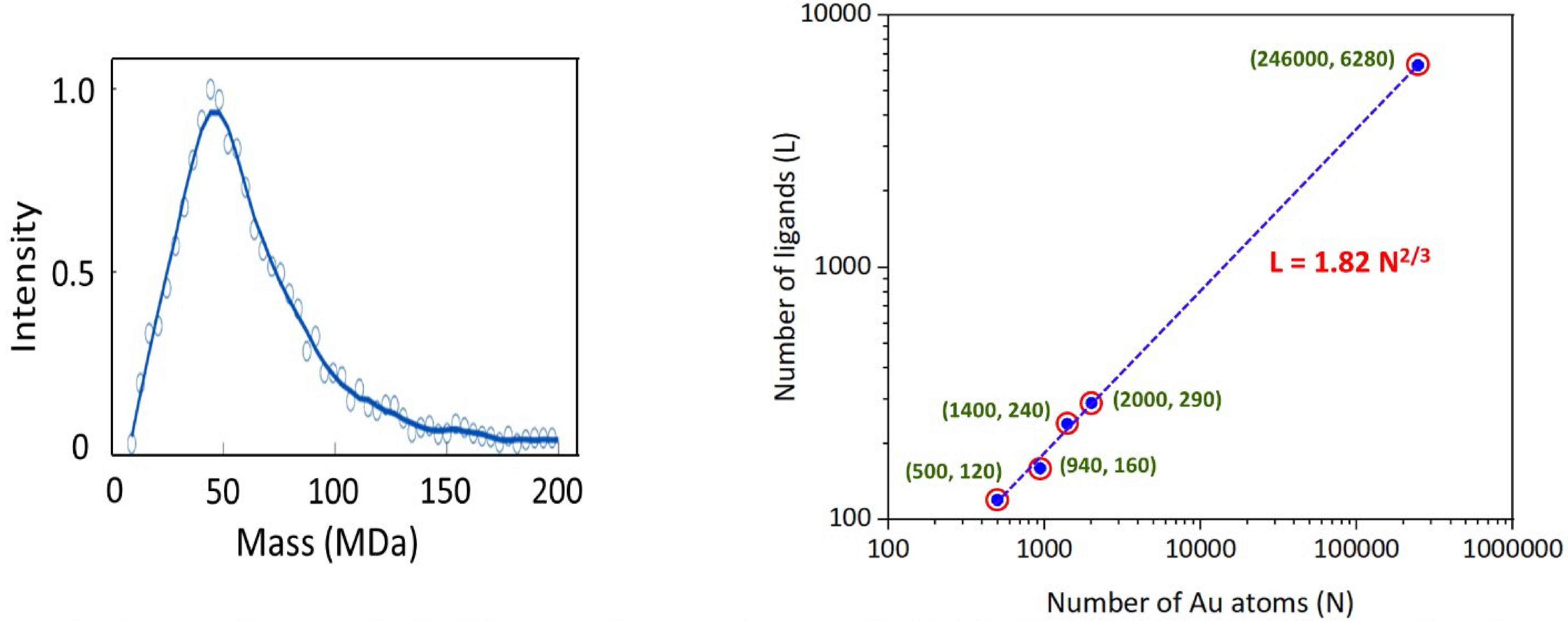
CDMS of viruses and nanoparticles

(a)



Keifer, D. Z.; Motwani, T.; Teschke, C. M.; Jarrold, M. F. Measurement of the Accurate Mass of a 50 MDa Infectious Virus. *Rapid Commun. Mass Spectrom.* **2016**, *30* (17), 1957–1962.

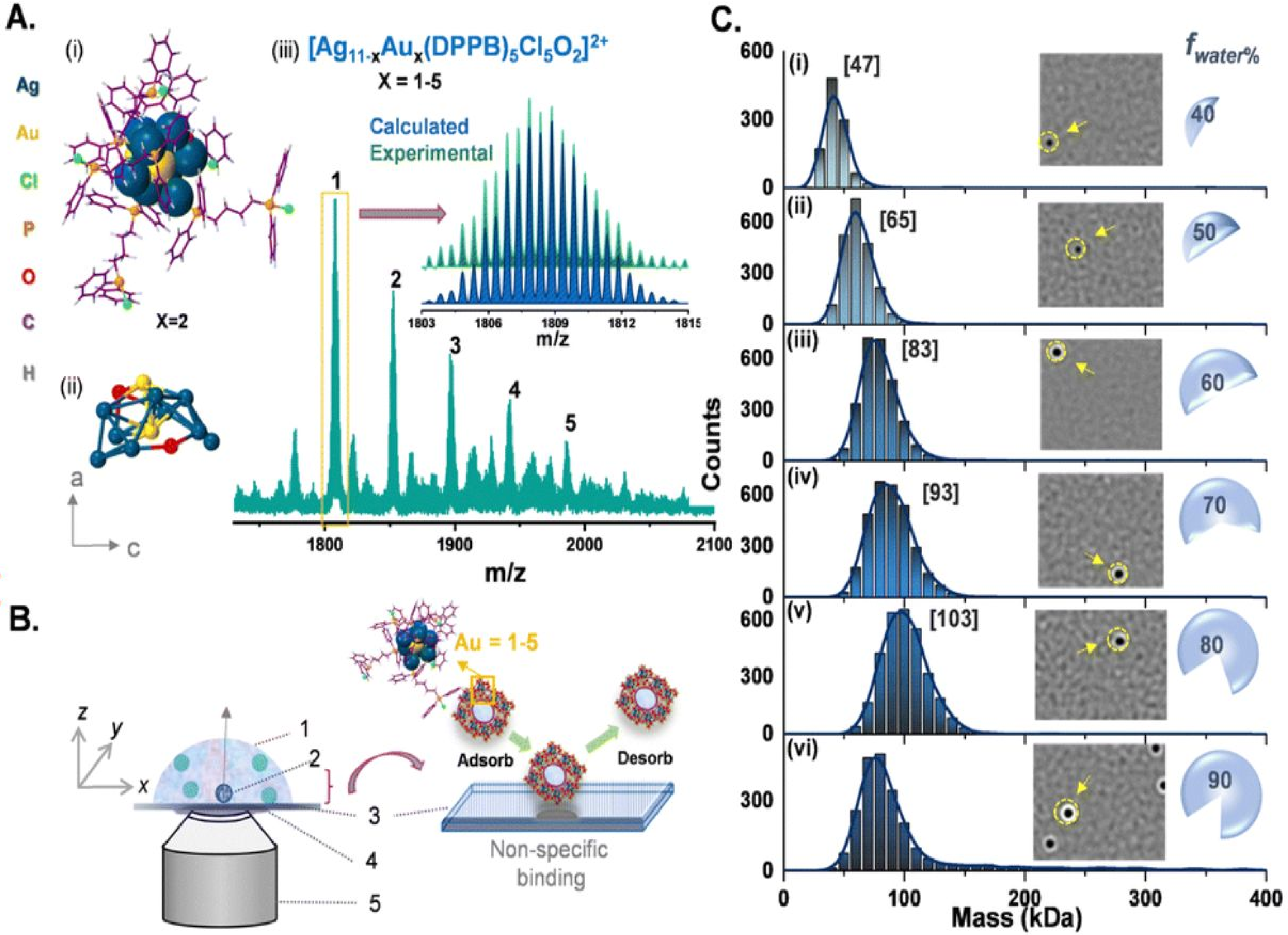
(b)



B. S. Sooraj, et. al. J. Phys. Chem. Lett. (2025) (DOI: 10.1021/acs.jpclett.5c0107

Mass Photometry

Mass Range: 30 kDa to 5 MD
a

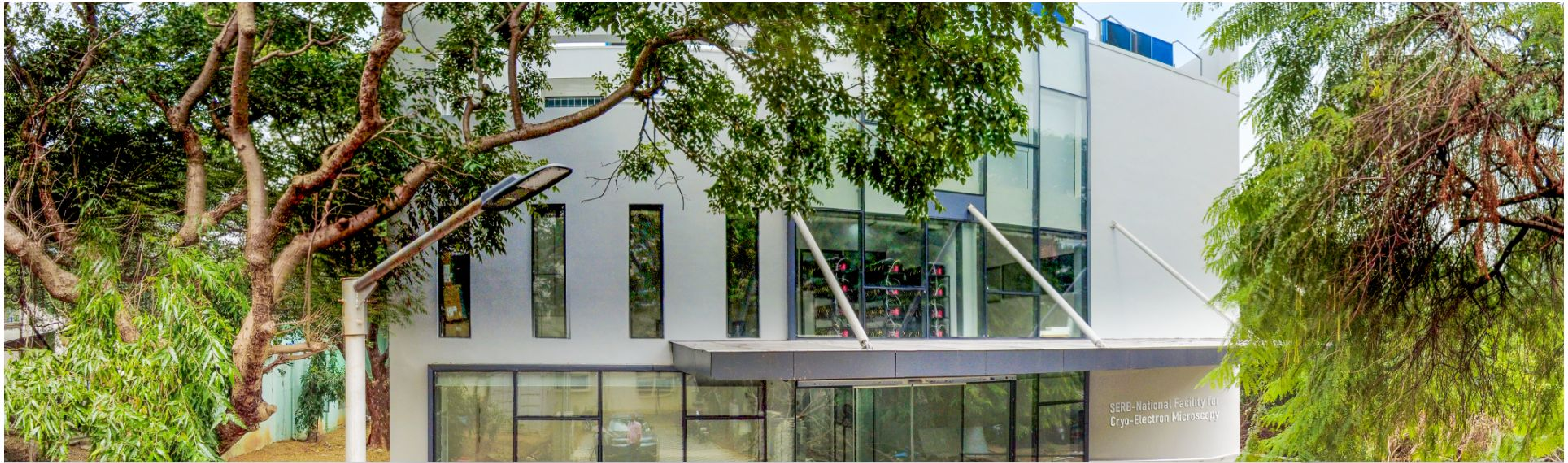


J. Roy, et. al., *Chem. Commun.*, 2024,60, 6655-6658

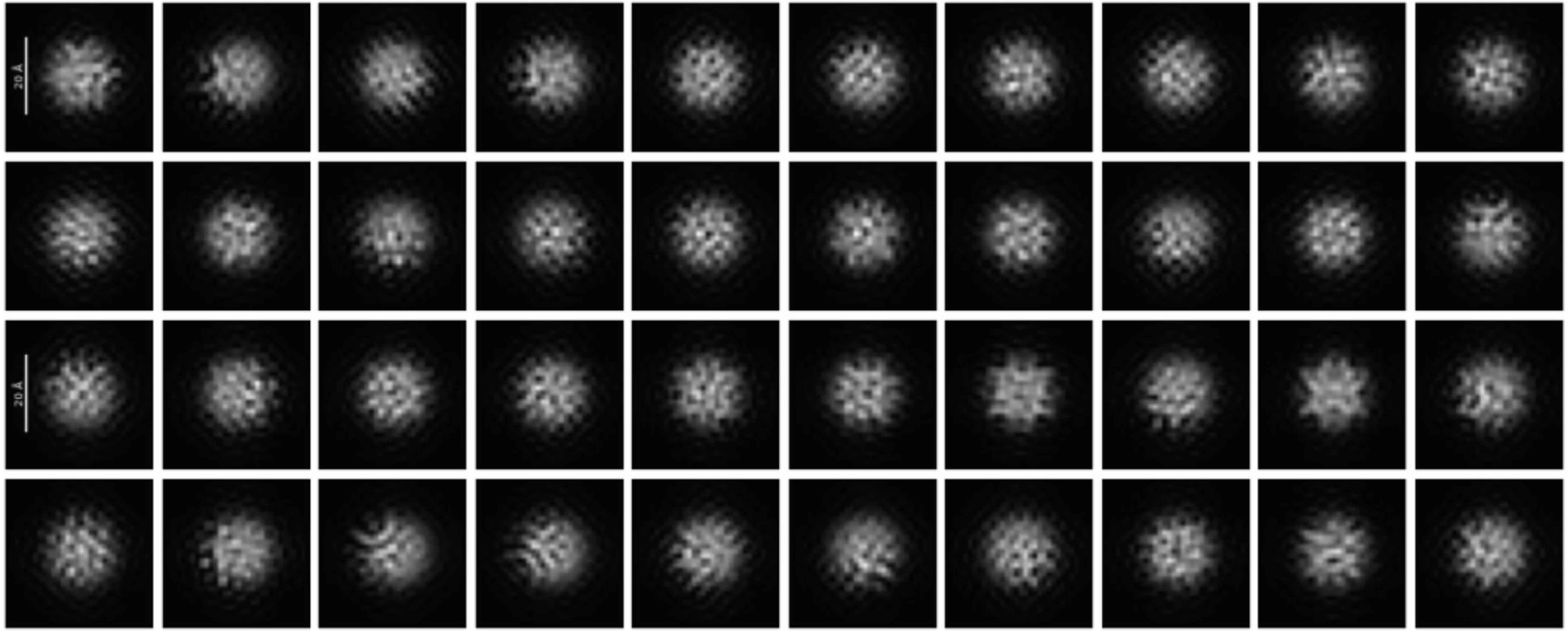
[redacted]

Structural Transitions and Micro-ED

Harshita Nagar, Anirban Som,... Chem. Comm. 2025


SERB-National Facility for
Cryo-Electron Microscopy


thermoscientific
ThermoFisher
SCIENTIFIC



B. S. Sooraj, et. al. Unpublished

How is the research no
w?

Mexico
Universidad Nacional Autónoma de México (UNAM)
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Imperial College London
Swansea University
University of Birmingham
University of Cambridge
University of Manchester
University of Nottingham
University of Oxford
University of Warwick
Greenland
University of Greenland
Switzerland
EPFL
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United Arab Emirates
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CENTRAL UNIVERSITY OF PUNJAB
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JADAVPUR university
IIT INDORE
CSIR- Institute of Minerals and Materials Technology
IIT Kanpur
Brazil
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LNNano / CNPEM (National Nanotechnology Laboratory)
Universidade Federal de Pelotas (UF Pelotas)
Universidade Federal do ABC (UFABC)
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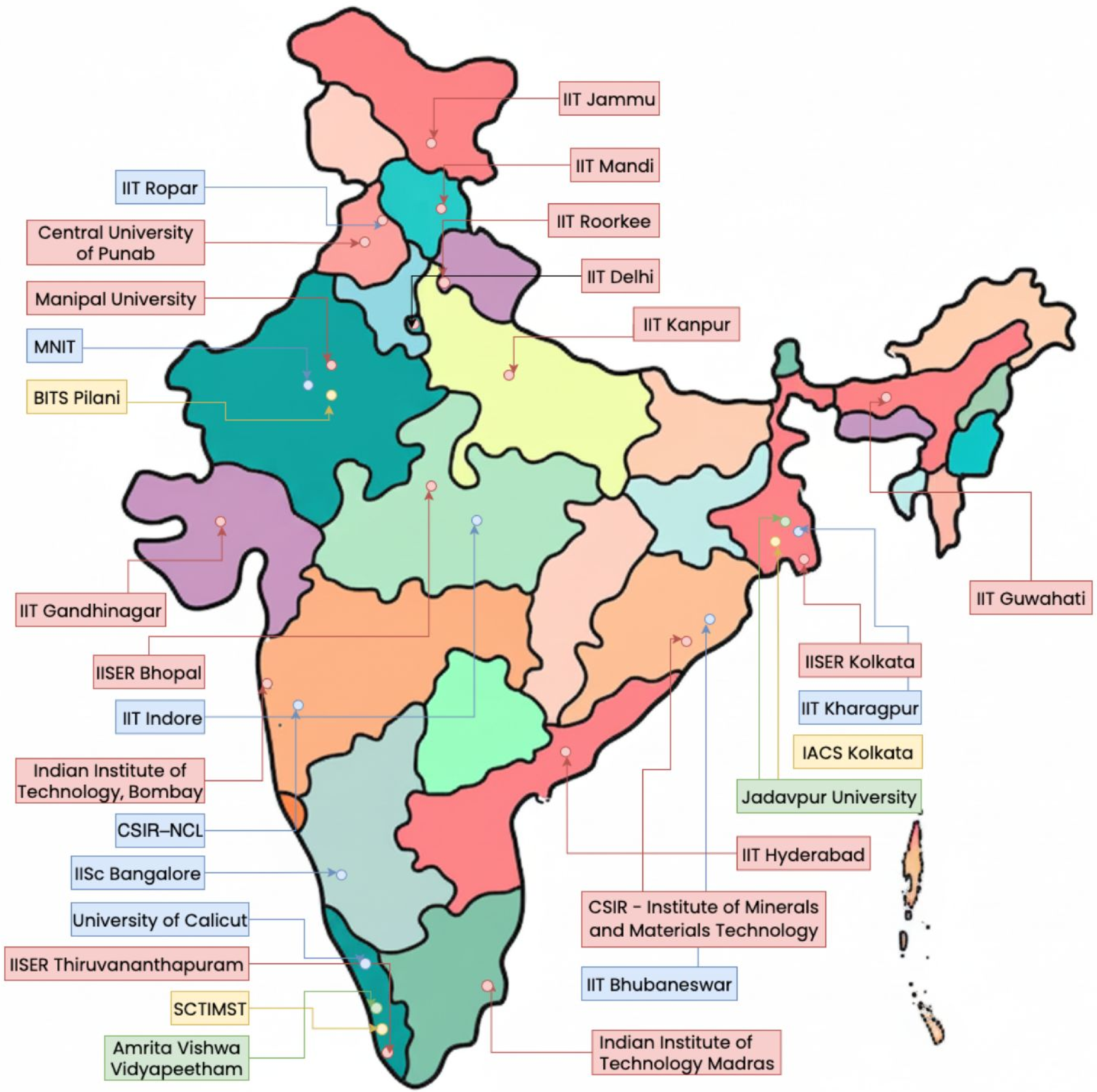
New Zealand
University of Canterbury
MacDiarmid Institute (for Advanced Materials & Nanotechnology)
The University of Auckland


IIT Jammu
IIT Mandi
IIT Ropar
Central University of Punab
IIT Roorkee
IIT Delhi
Manipal University
IIT Kanpur
MNIT
BITS Pilani
IIT Gandhinagar
IIT Guwahati
IISER Bhopal
IISER Kolkata
IIT Indore
IIT Kharagpur
IACS Kolkata
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CSIR–NCL
IIT Hyderabad
IISc Bangalore
CSIR - Institute of Minerals and Materials Technology
University of Calicut
IISER Thiruvananthapuram
IIT Bhubaneswar
SCTIMST
Indian Institute of Technology Madras
Amrita Vishwa Vidyapeetham

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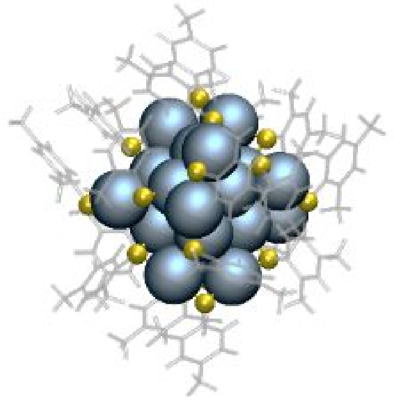
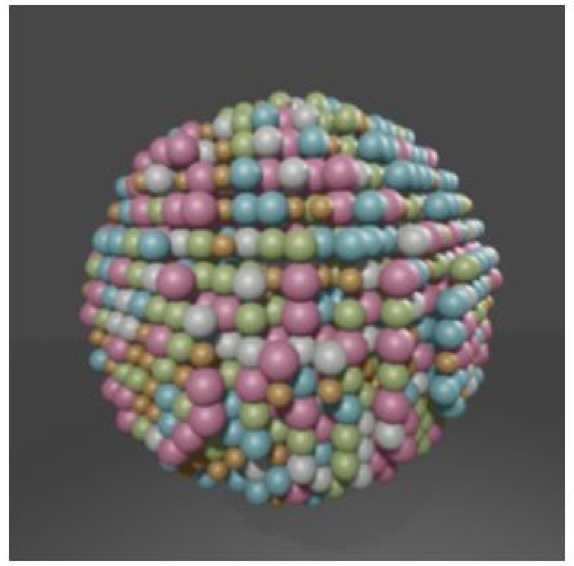
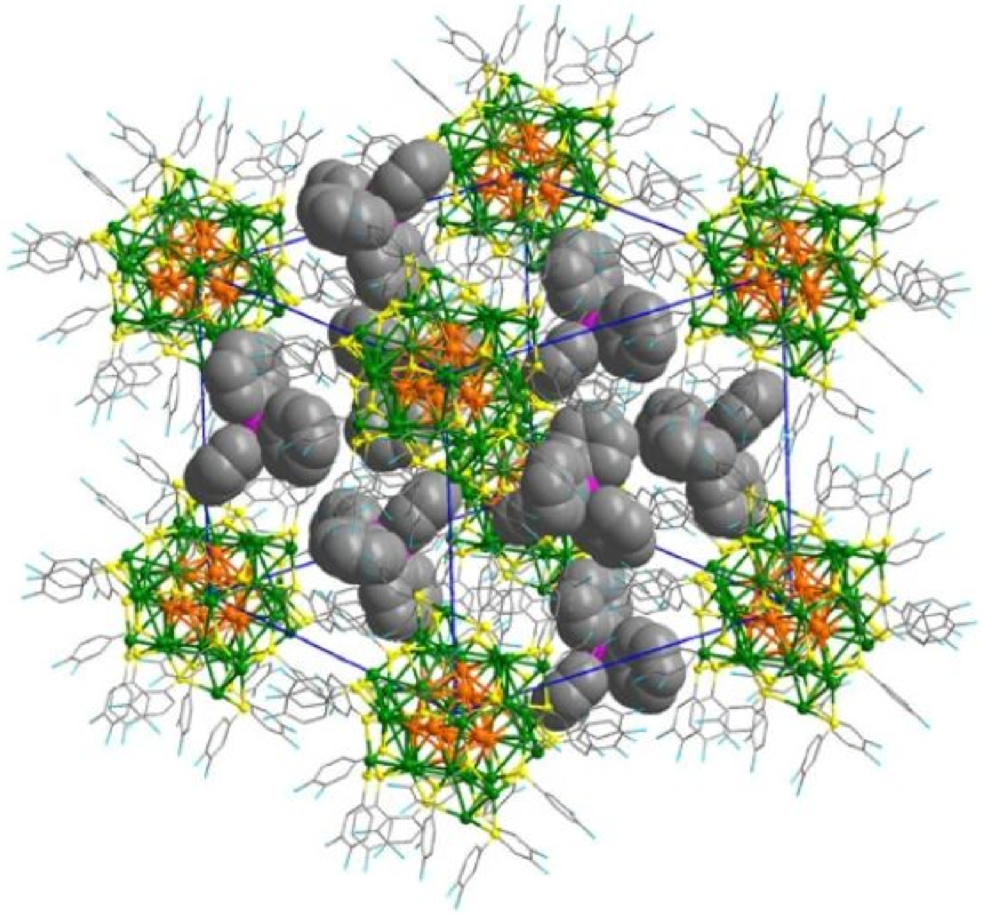
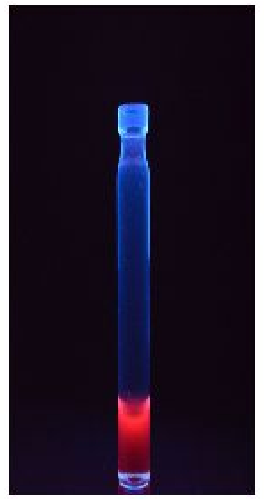
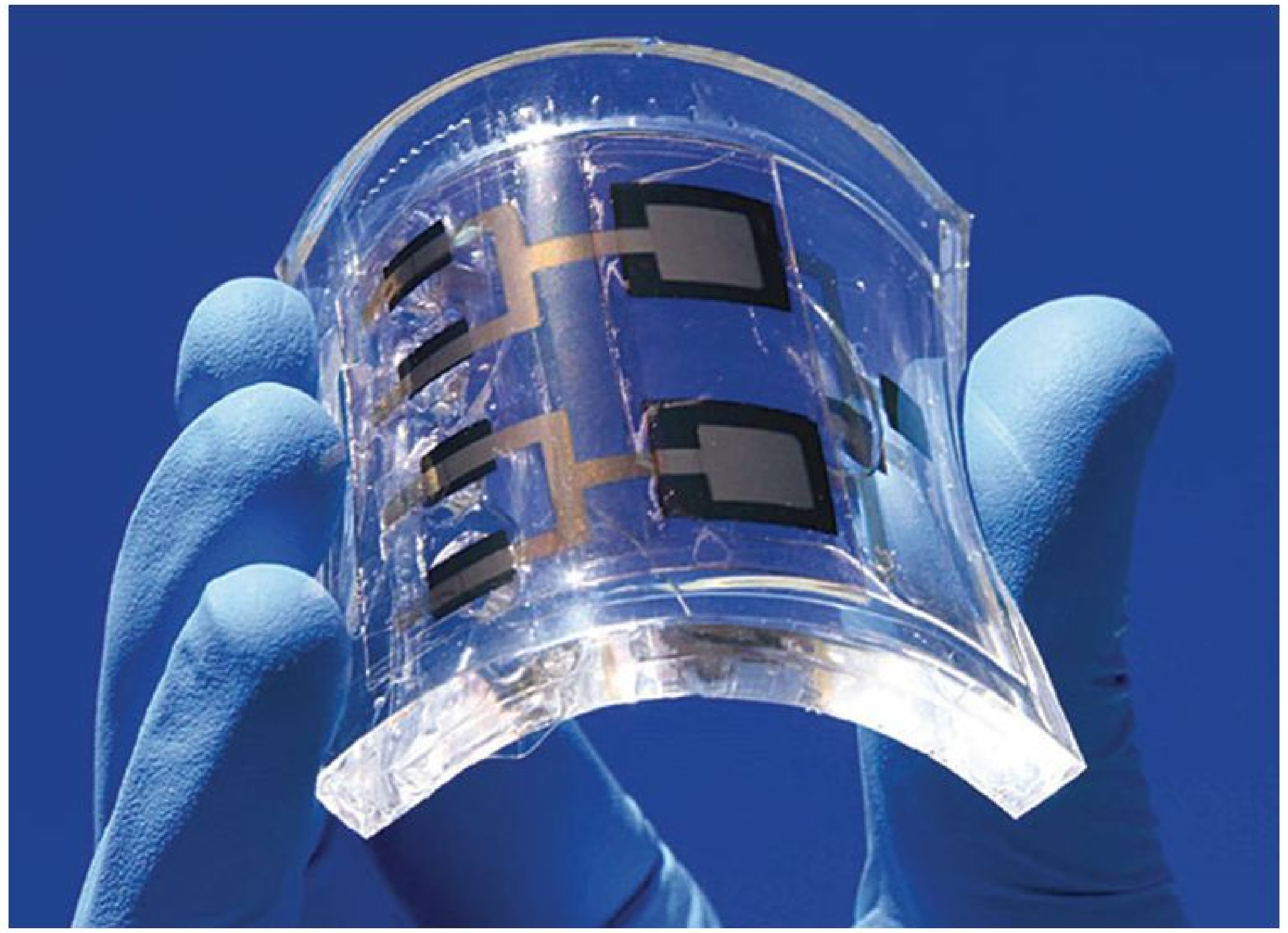




Chasing the ‘Cluster’ D
reams

Challenge 1. We do not know enou gh

Structures – we have over 400, yet…

Protein protected clusters?

Why certain clusters form?

Why certain ligands are essential for some clust ers?

Physical properties

Phase diagram

many others

Is there a liquid phase for clusters?

How do they behave under stimuli?

N. Sandhyarani, Thalappil Pradeep, J. Chakrabarti and Mohammad Yousuf, Phys. Rev. B., 62 (2000) R739-R742.

Co-crystals

Ag40 and Ag46 with the same shell

M. Bodiuzzaman, et. al. *Angew. Chem. Int. Ed.* **2018**

Challenge 2. We do not make enough

How do I test an idea?

How do I expand to other disciplines?

Will there be interest in industry?

Materials availabili ty

nature

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nature > letters > article

Letter | Published: 07 July 1972

Electrochemical Photolysis of Water at a Semiconductor Electrode

AKIRA FUJISHIMA & KENICHI HONDA

Nature **238**, 37–38 (1972) | Cite this article

Abstract

ALTHOUGH the possibility of water photolysis has been investigated by many workers, a useful method has only now been developed. Because water is transparent to visible light it cannot be decomposed directly, but only by radiation with wavelengths shorter than 190 nm (ref. 1).

Sections | References

Abstract

References

Author information

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About this article

CLEAN AIR WITH PHOTOCATALYSIS

Akira Fujishima

Former President of Tokyo University of Science
Director, Photocatalysis International Research Center, TUS

Challenge 3. We do not know deep enough

Do we have a model for cluster formation?

Can we write a balanced chemical equation?

How clusters grow?

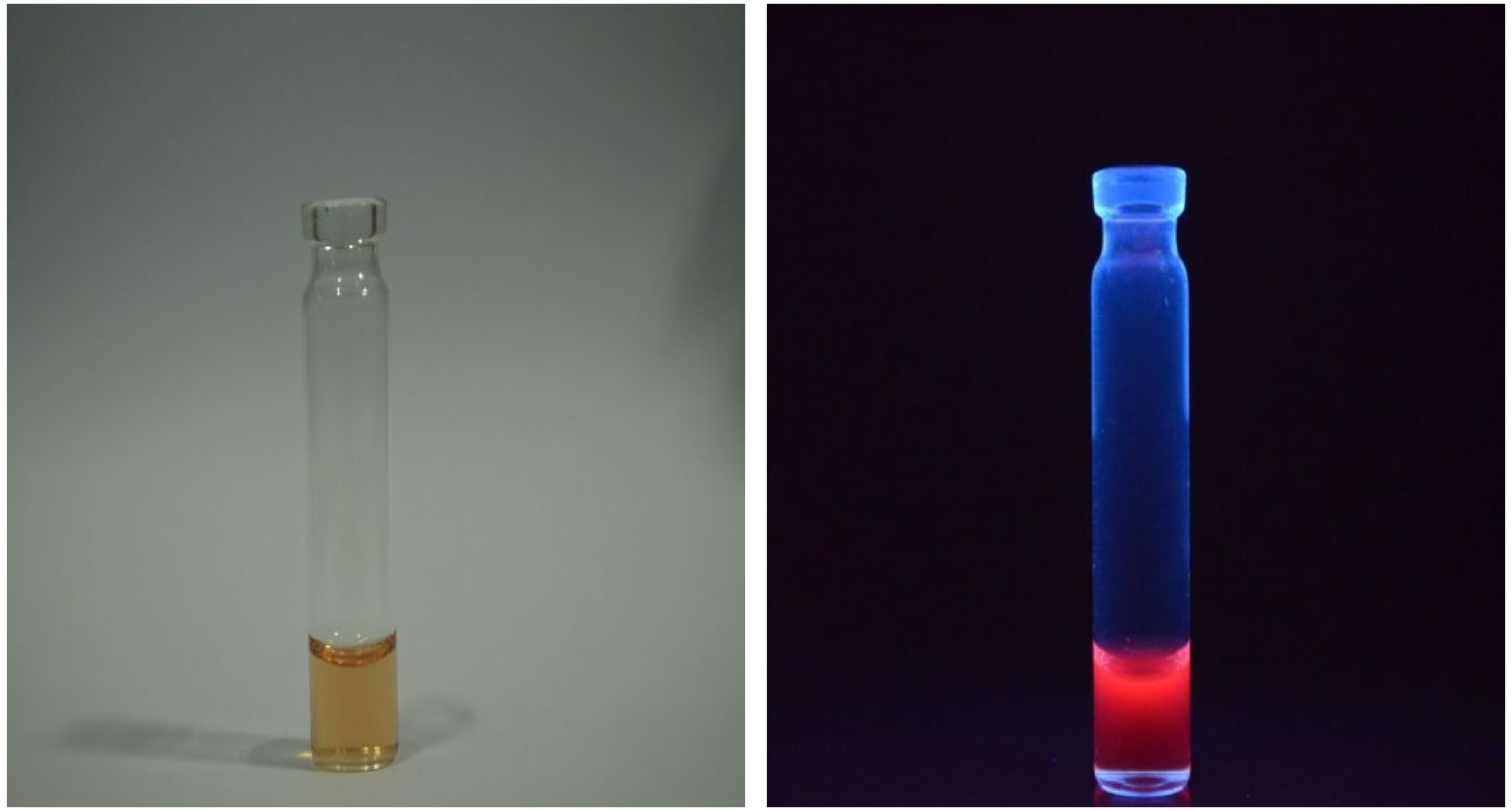
How clusters react?

How do ligands/atoms exchange

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l) \qquad \Delta H^\circ = -286\text{kJ}$$

From a textbook

Molecular reaction
s



Reactions on clusters

Reactions between cluste
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Dynamic
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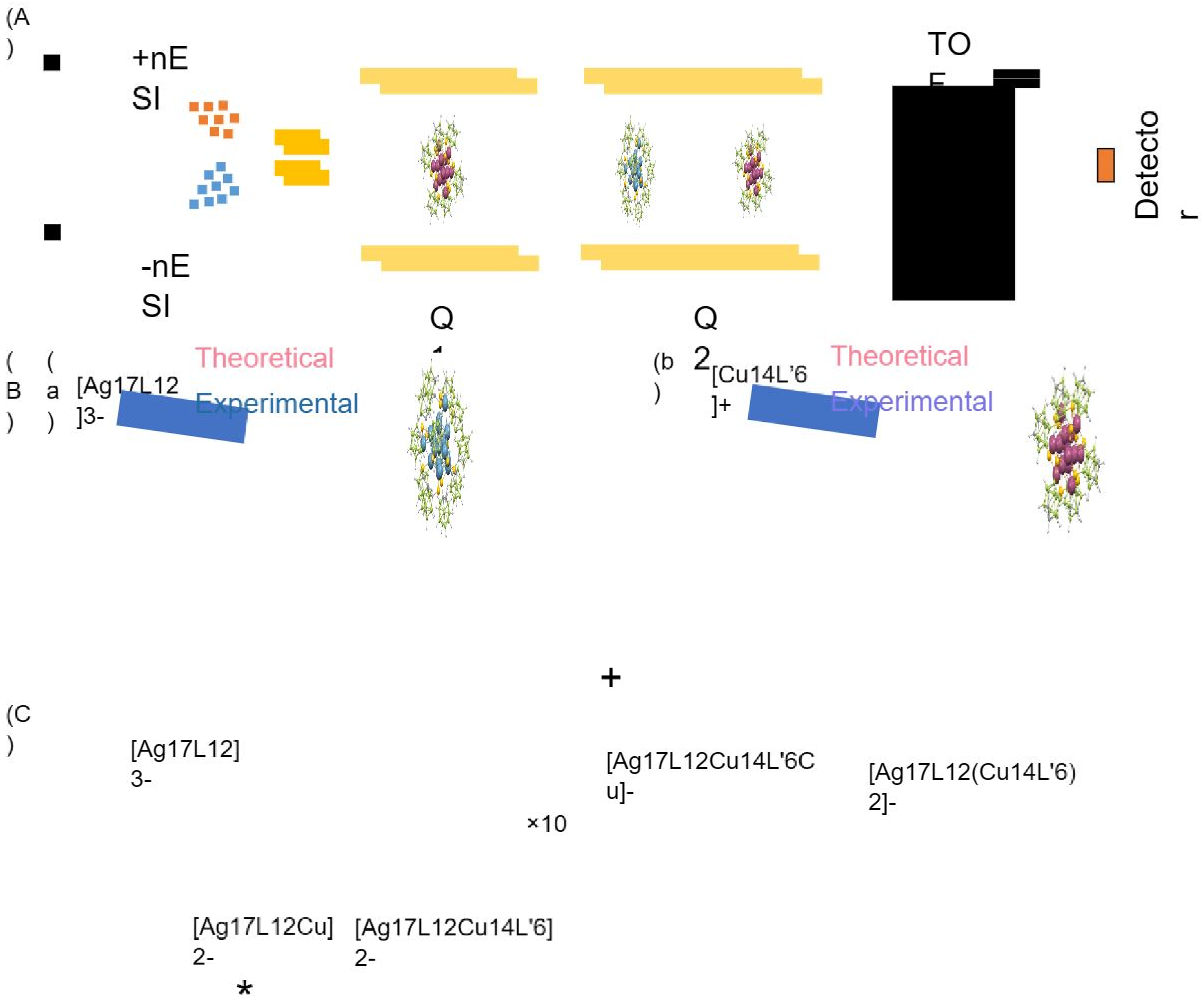
Mechanis m

Coulombic adducts

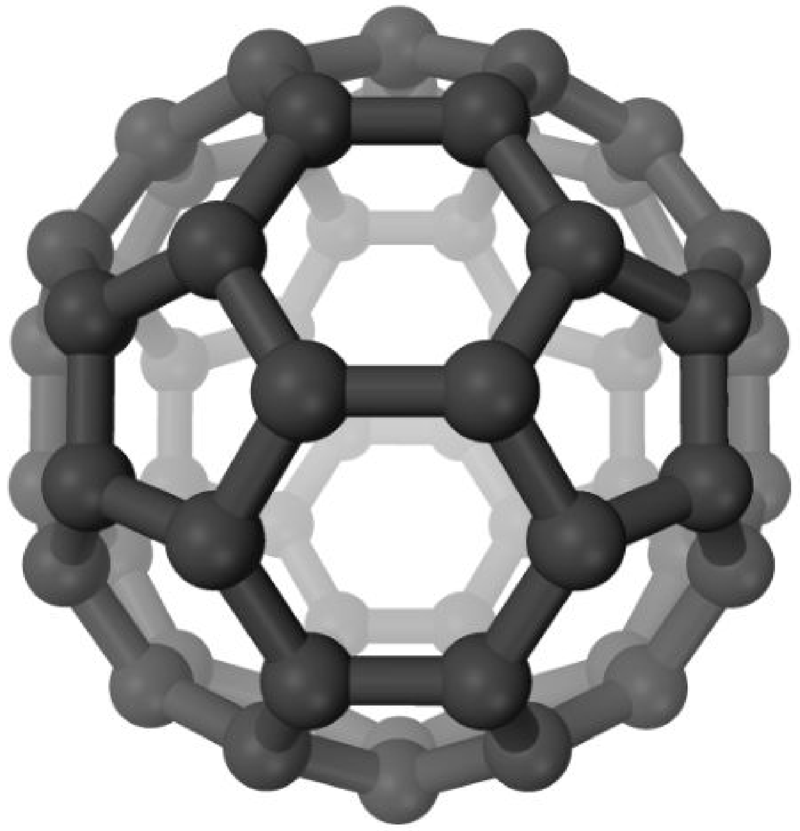


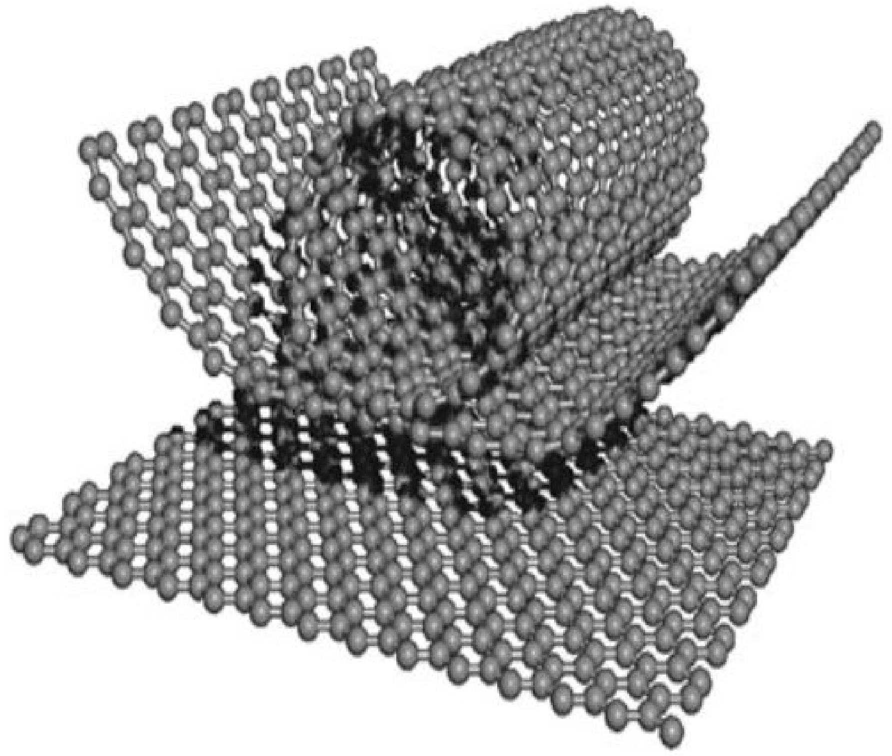
(A) Schematic representation of gas phase ion-ion reaction of atomically precise nanoclusters in an MS trap cell. Atomically precise nanoclusters (B) (a) [Ag17(o1-CBT)12]3- and (b) [Cu14(o9,12-CBDT)6]+ forming (C) Columbic adducts.

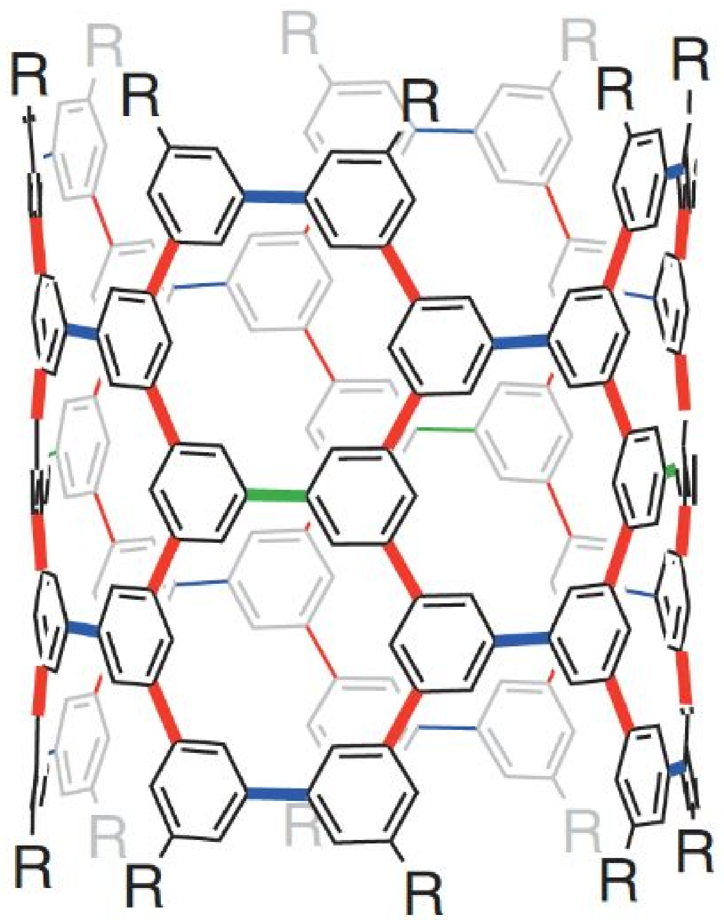
With Scott McLuckey and De-en Jiang

Phenine nanotube (pNT)

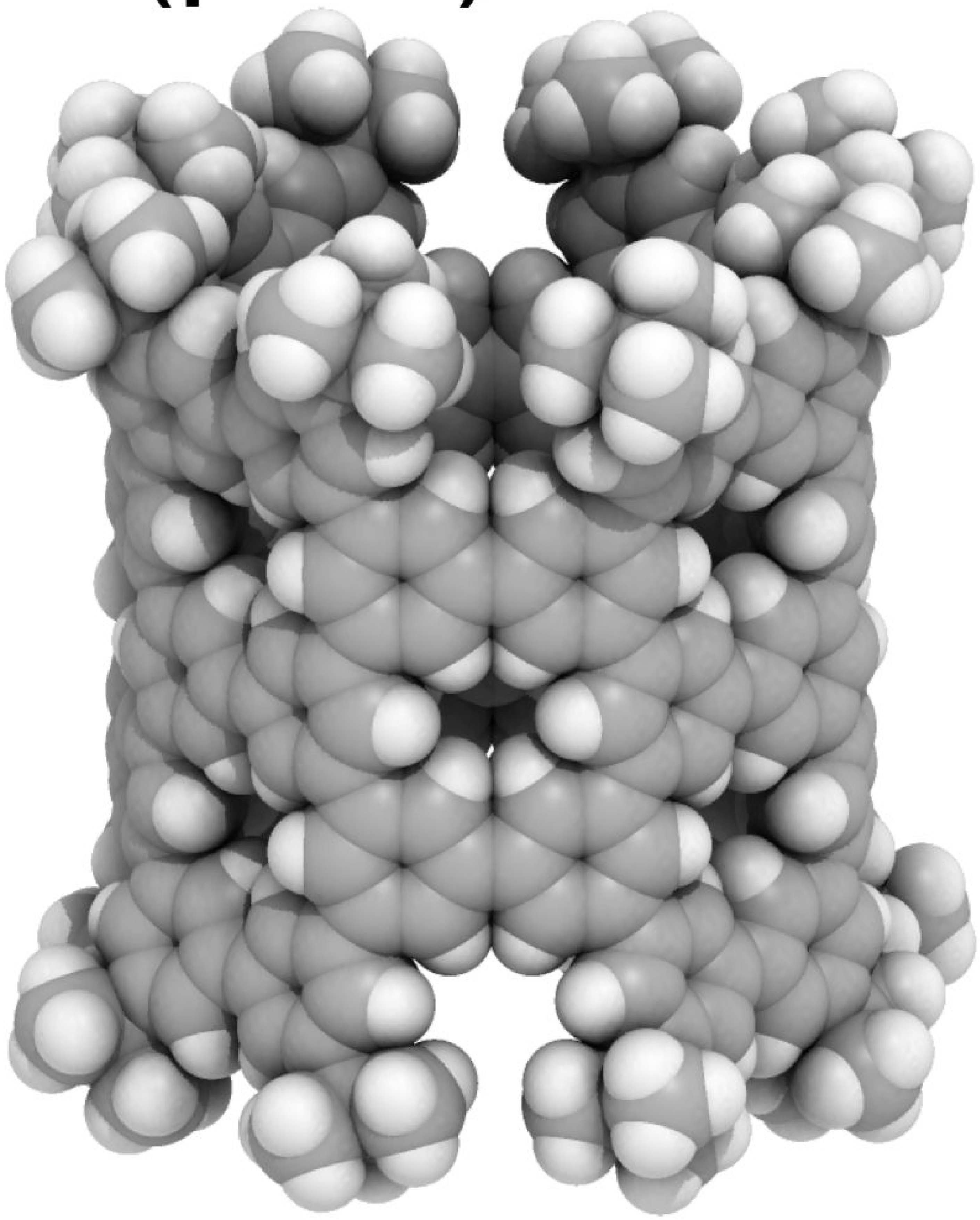
Precision is at another lev
el







— Yamamoto coupling
— Suzuki-Miyaura coupling
— Bäurle/Yamago/Isobe coupli
ng



H. Isobe *et al.* *Science* **2019**, *363*, 1

Single particle
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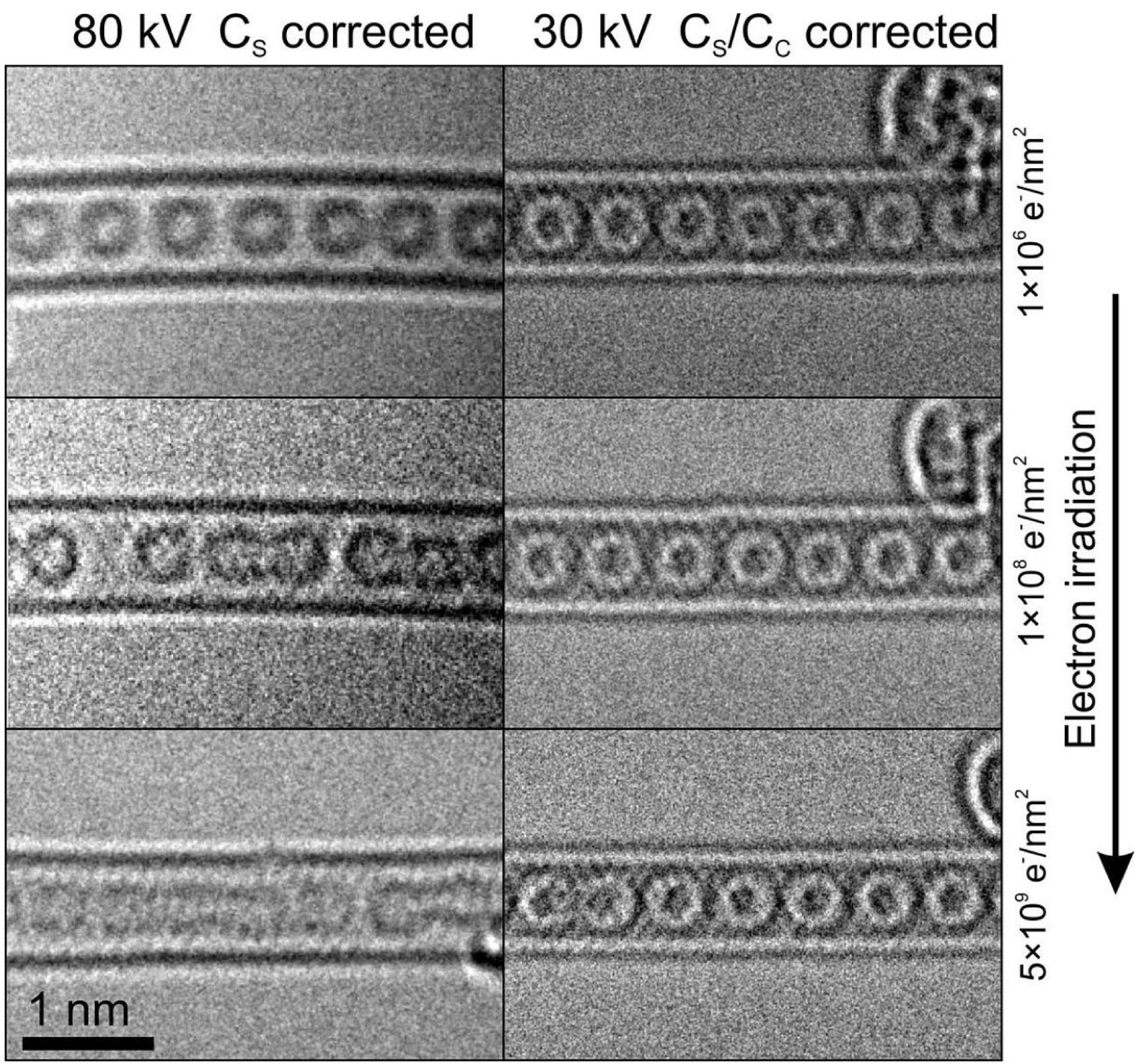


Fig. 1: Effect of electron irradiation of C60 molecules (fullerene) at different electron energies. At 30 kV the molecul es do not undergo any structural changes. However, at 80 kV the C60 start to polymerize, first forming dimers and subsequently another tube within the original tube.

https://www.uni-ulm.de/en/einrichtungen/hrem/forschung/forschungsfelder/carbon-nanotubes/

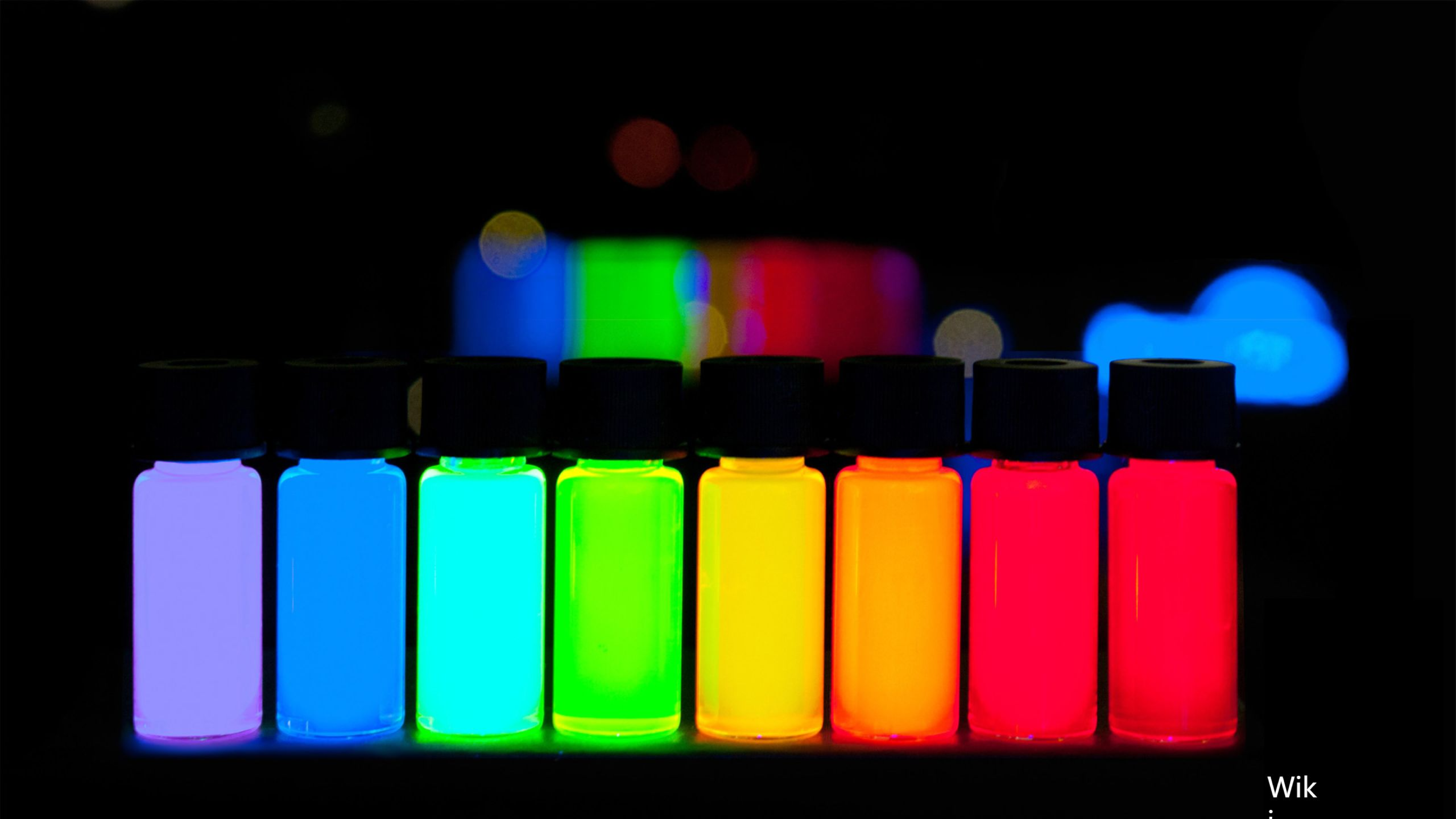
Atomic precision does not en
d

4. How to comprehend this molecular world?

Nomenclature – we still don’t have a unified scheme

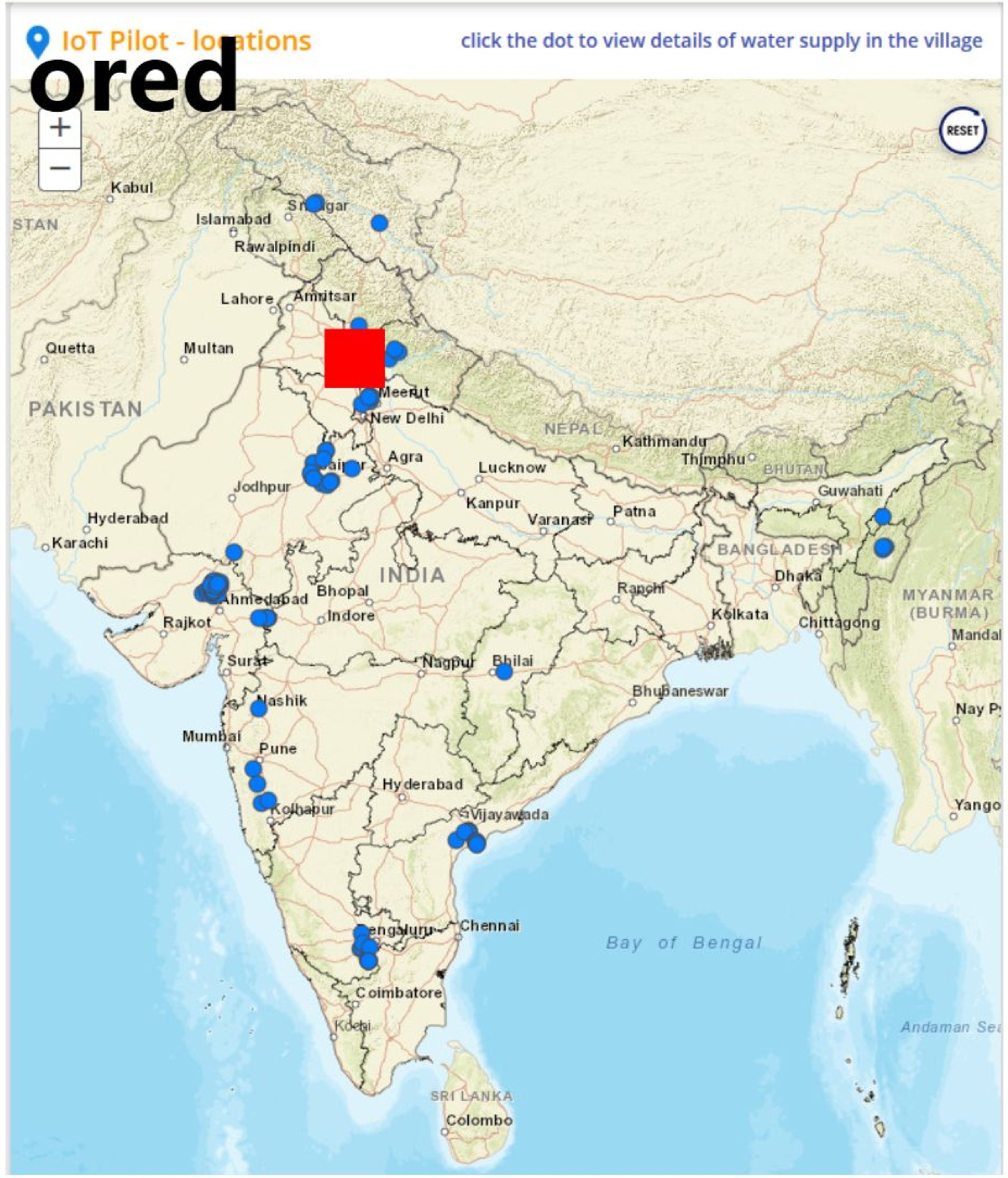
5. What for ?

Devices, quantum, catalysis, energy, CO_2 conversion, biology ,....



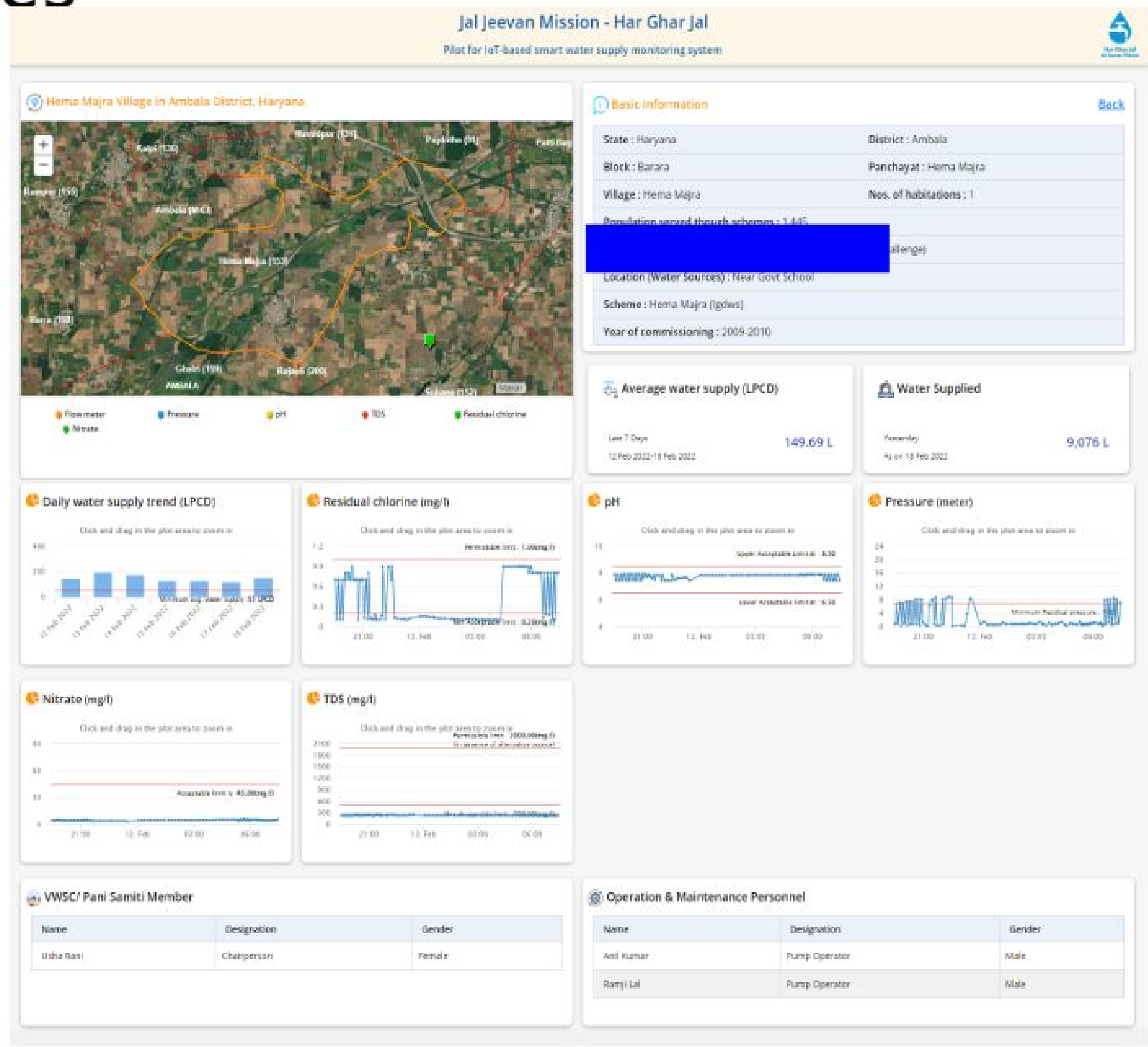
Wik

India’s water is being monitored



IITM/IISc

Installations made by four companies



New catalysi
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Catalysis

Vivek Yada
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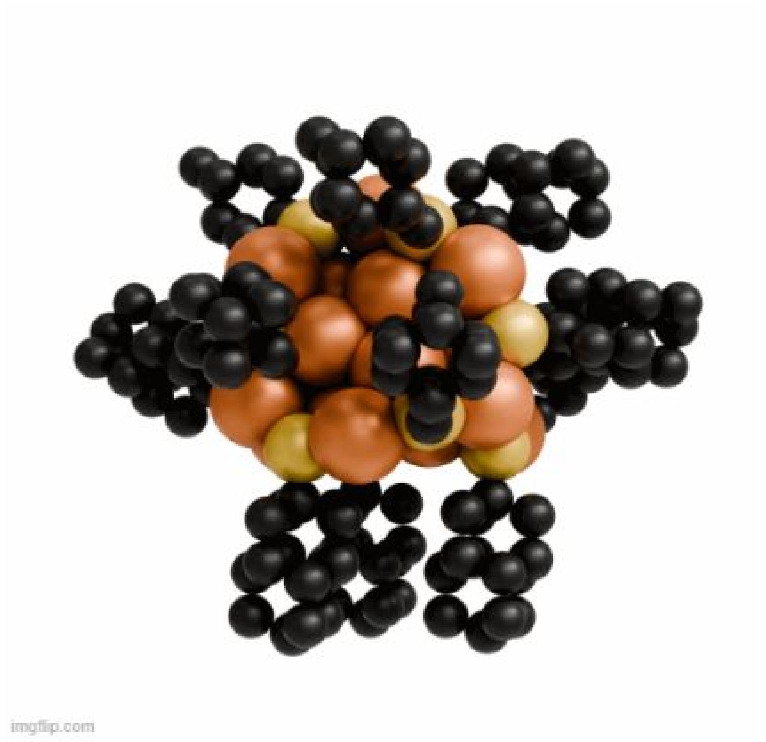
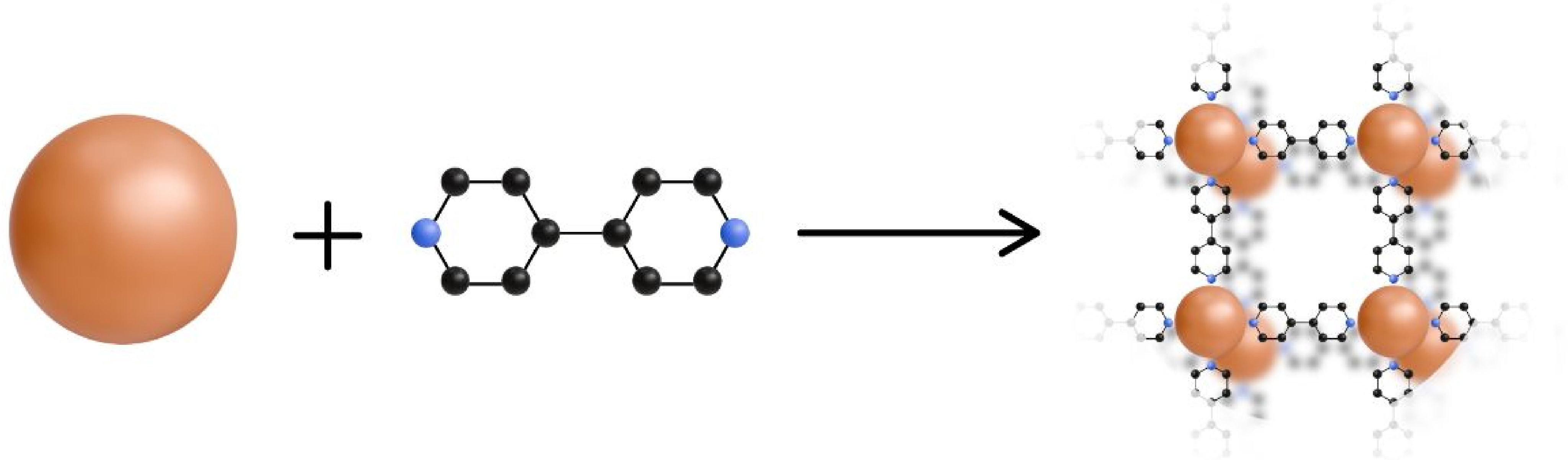
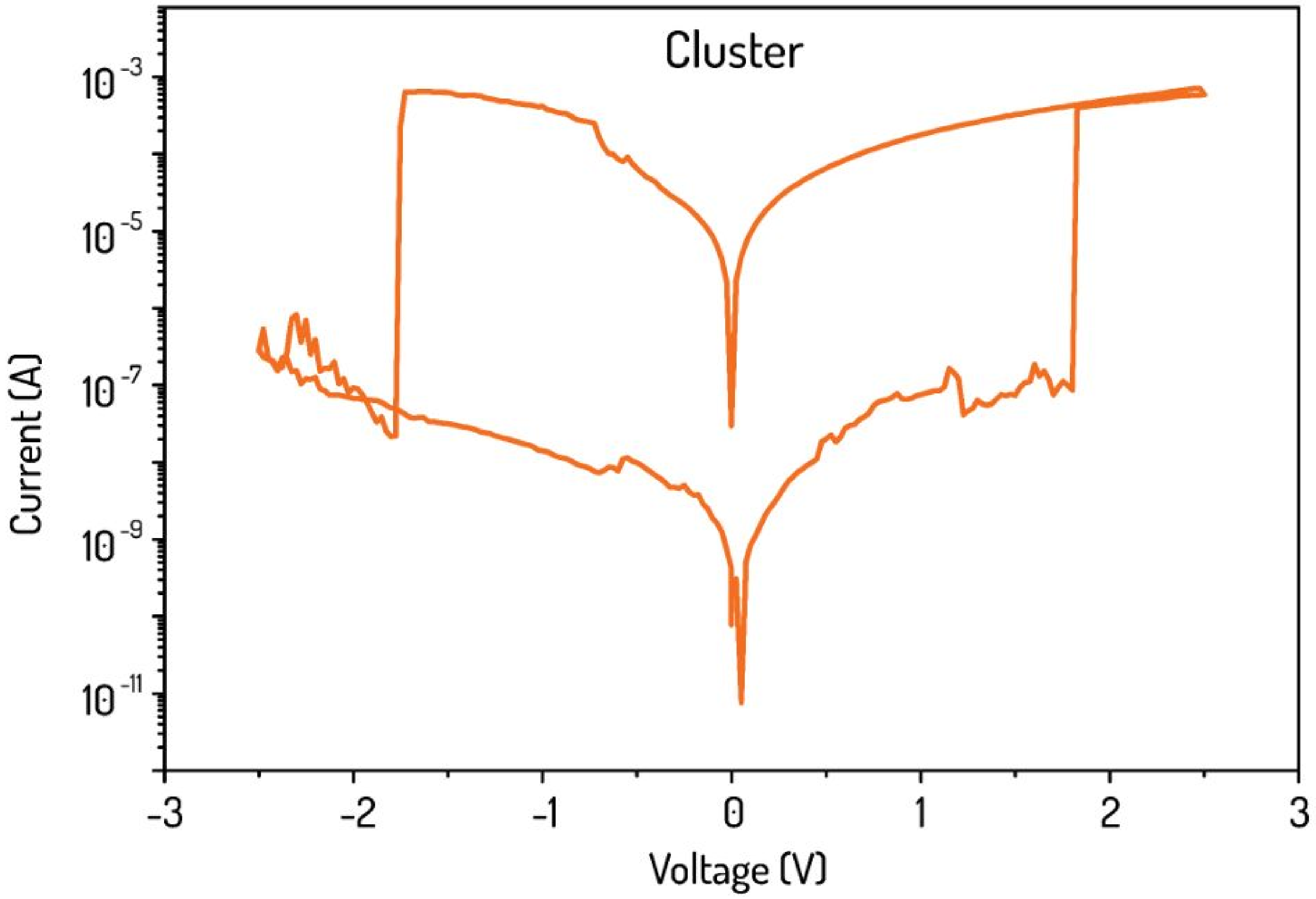
Molecular Memory Devic

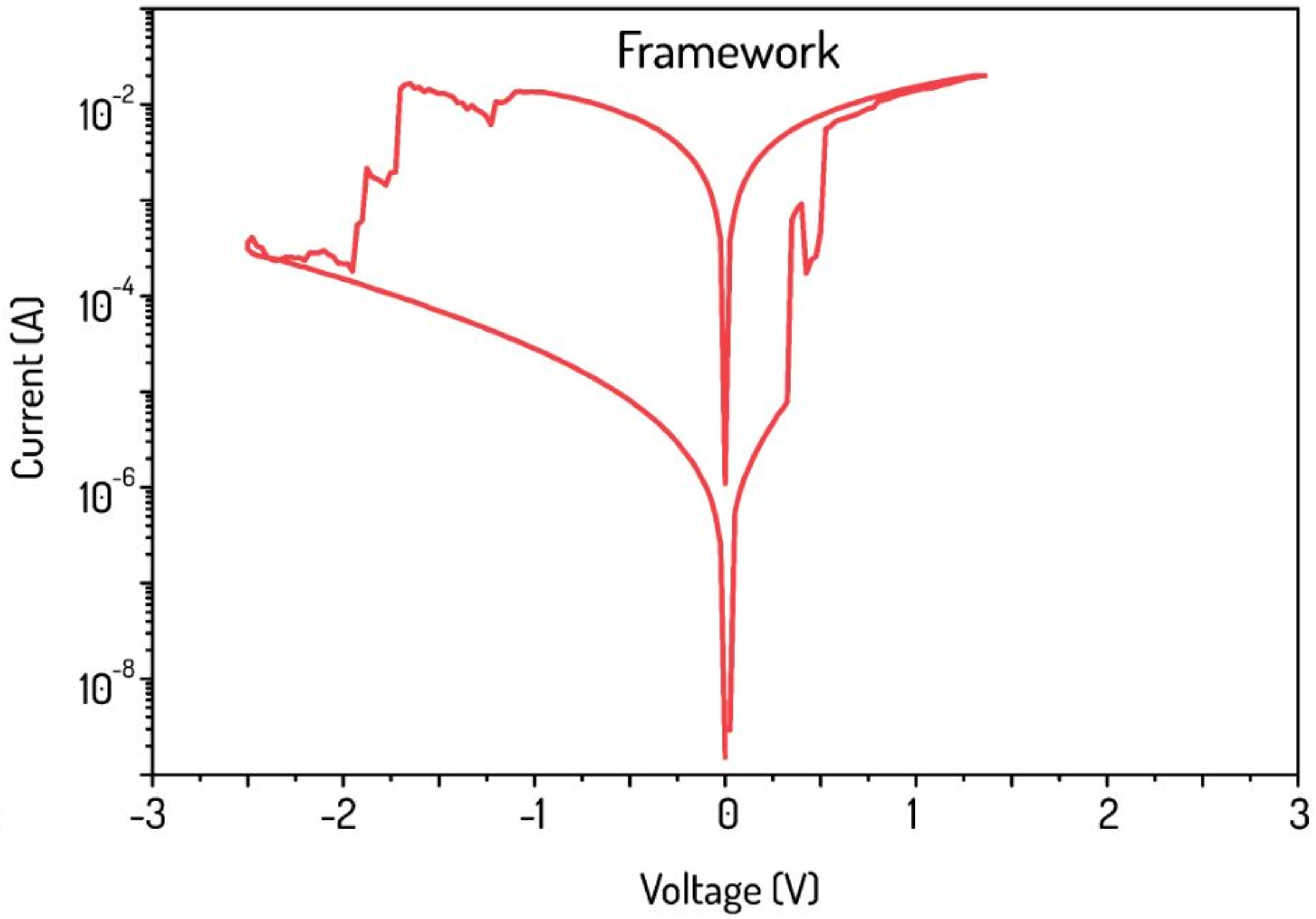


- Silve
  r
- Sulphur
- Carbon

[Ag23(S-Dia)



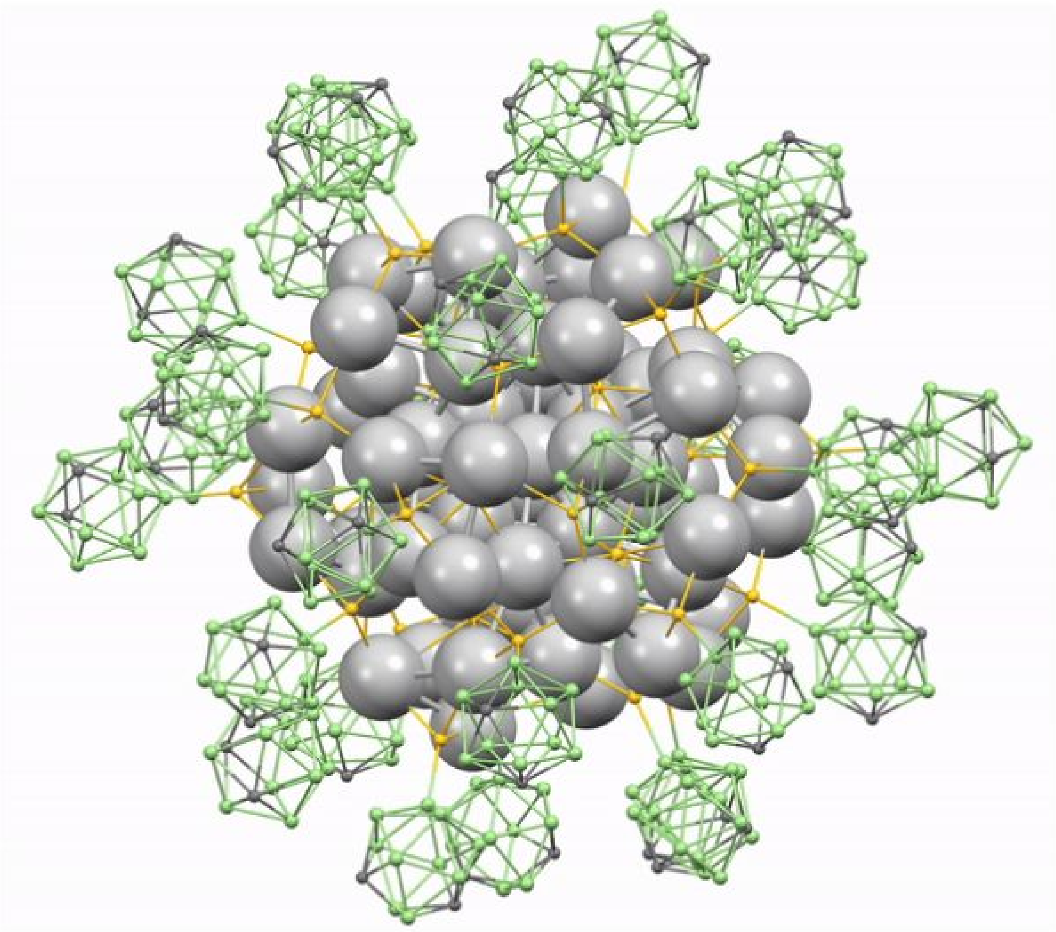




Details will be shown by Amoghavarsha

Summary

- Atomically precise clusters are a category of new materials
- They are molecules – properties, nomenclature,…
- Clusters are thermally stable up to 400°C.
- They exhibit useful applications
- Atomic precision across the periodic table
- An era cluster-based materials is being born



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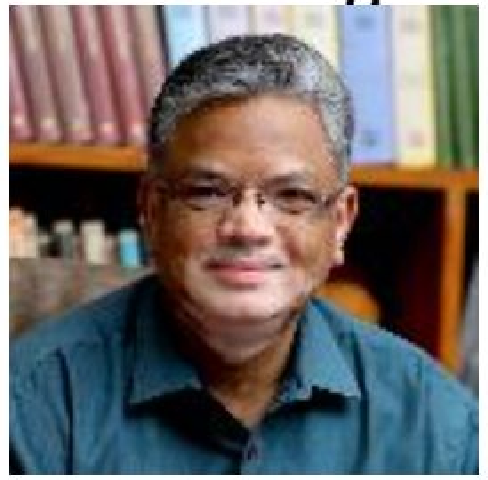


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