Small is Beautiful

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Most of the images in this presentation are taken from various internet sources

Which is the smallest object that you have *seen* so far?

Which is the smallest object that

you have *seen* so far?

Macroscopic : visible to the naked eye

Which is the smallest object that you *know*?

Which is the smallest object that you *know*?

Microscopic : Not visible to the naked eye

https://www.youtube.com/watch?v=BT7be4tIfBQ

That is a fantacy!!

That is a fantacy!!

Here is a REAL example of miniaturization

256 MB = 256 x 10^6 Bytes

16 GB = 16 x 10^9 Bytes

a byte is a unit of computer memory

It is miniaturized (reduced in size) with enhanced capacity

Miniaturization: Reduce the size without changing the properrty!

1971: Intel Transistor count 2,300 with area 12 sq. mm
2016: Intel Transistor count 7,200,000,000 within area of 456 sq. mm

In last 45 years size of a transistor has reduced drastically

https://en.wikipedia.org/wiki/Transistor_count

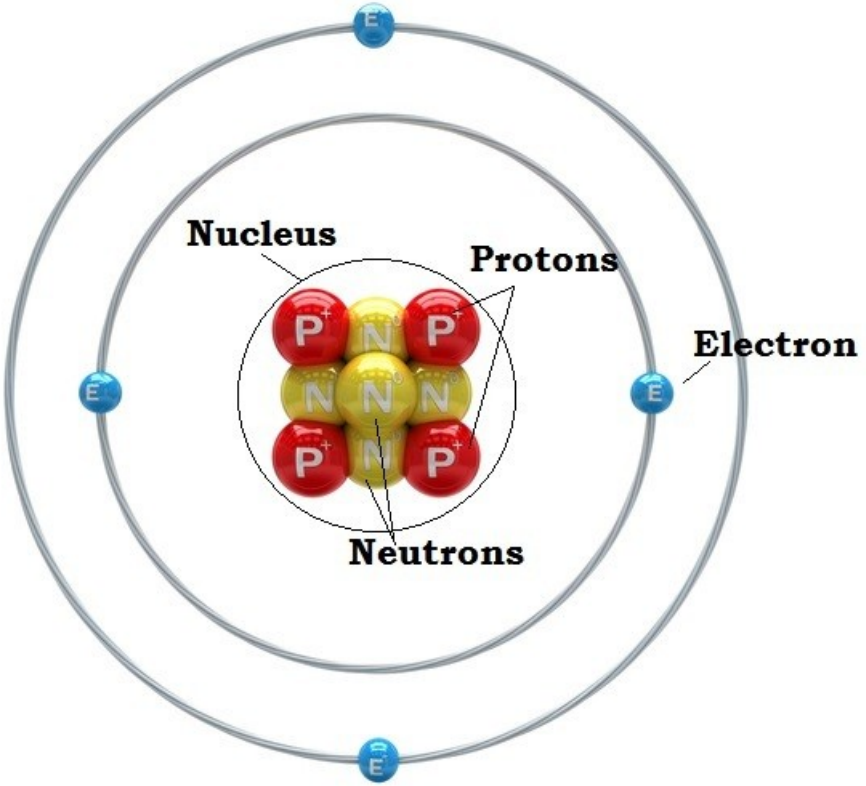
Reduce the size without changing the property!

There is limit to this miniaturization!!

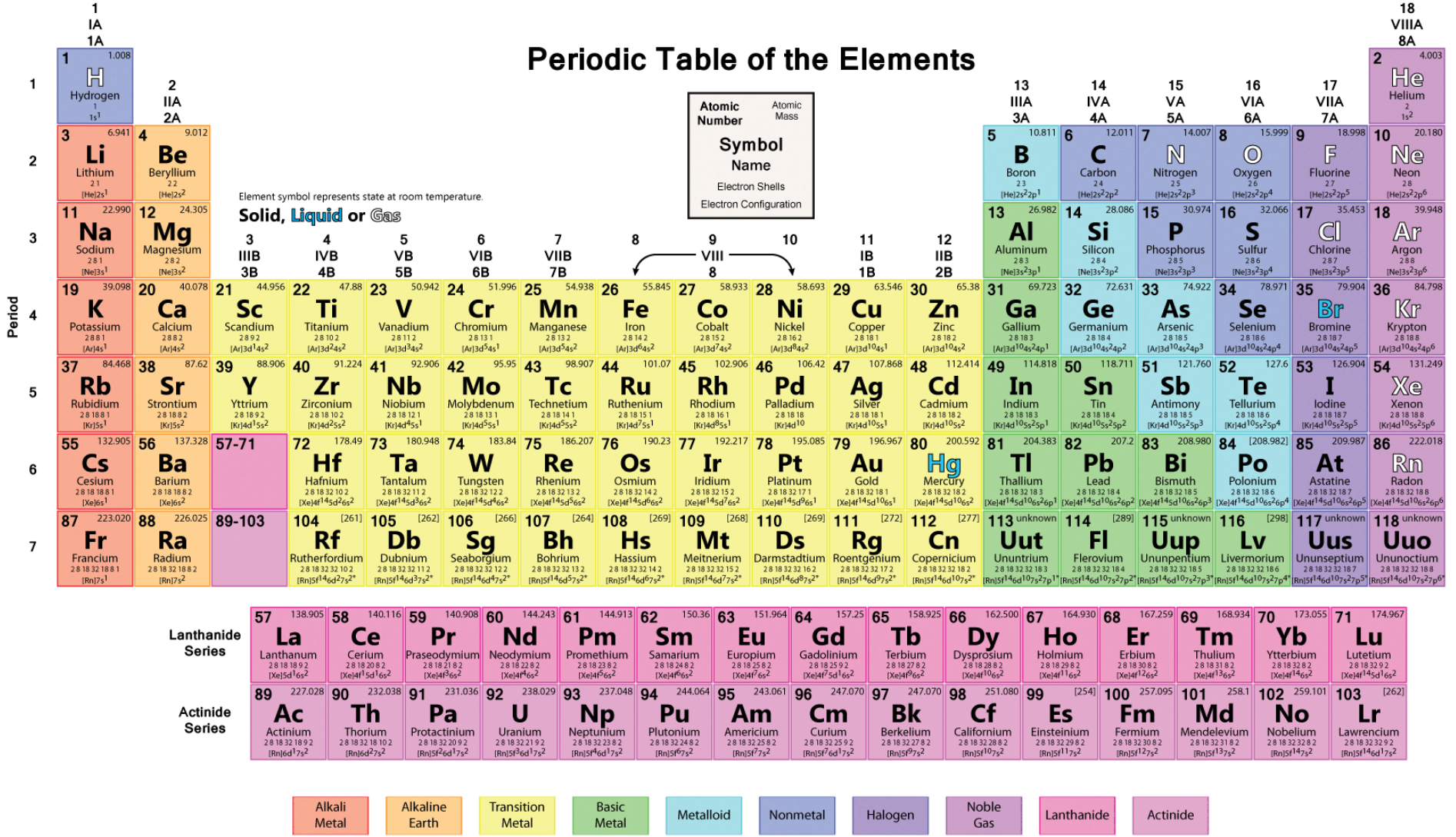
Why?

What is *everything* made up of?

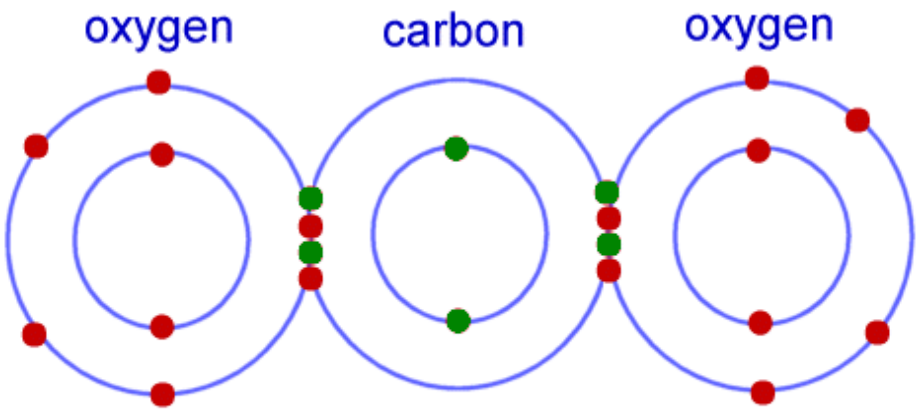
Inside an atom



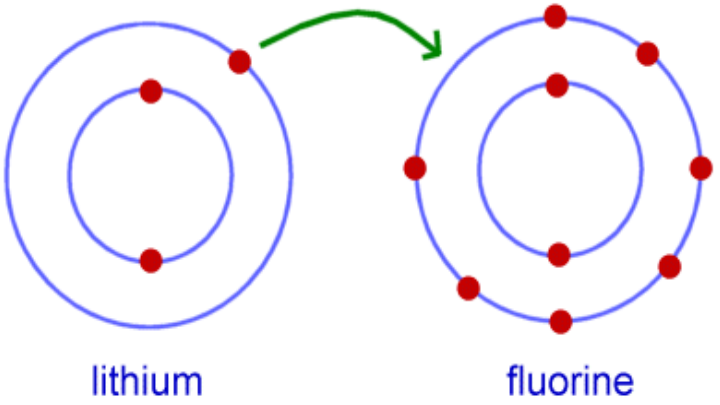
Periodic Table of the Elements



How the bonds are formed?



carbon dioxide



lithium fluoride

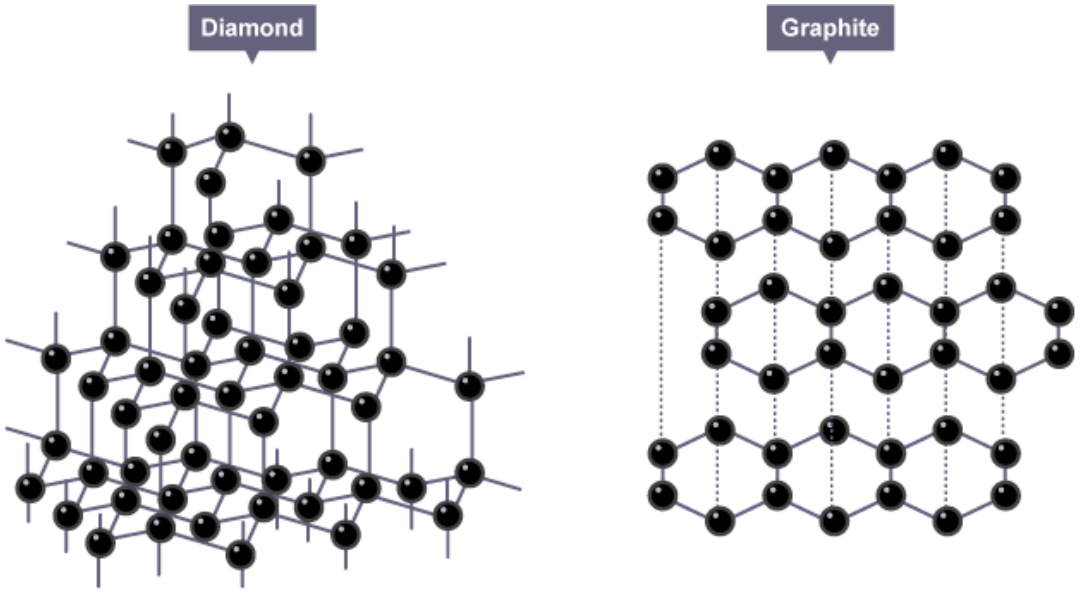
Electrons are shared
equally or unequally

Metals and Non-metals

Metals : electrons shared by all the atoms
non-directional bonds

Non-metals: electrons are shared within
small group of atoms
Directional bonds

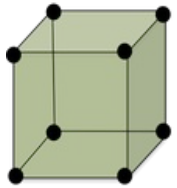
Carbon

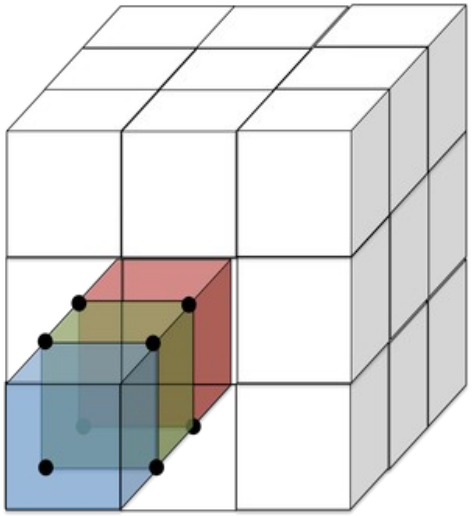


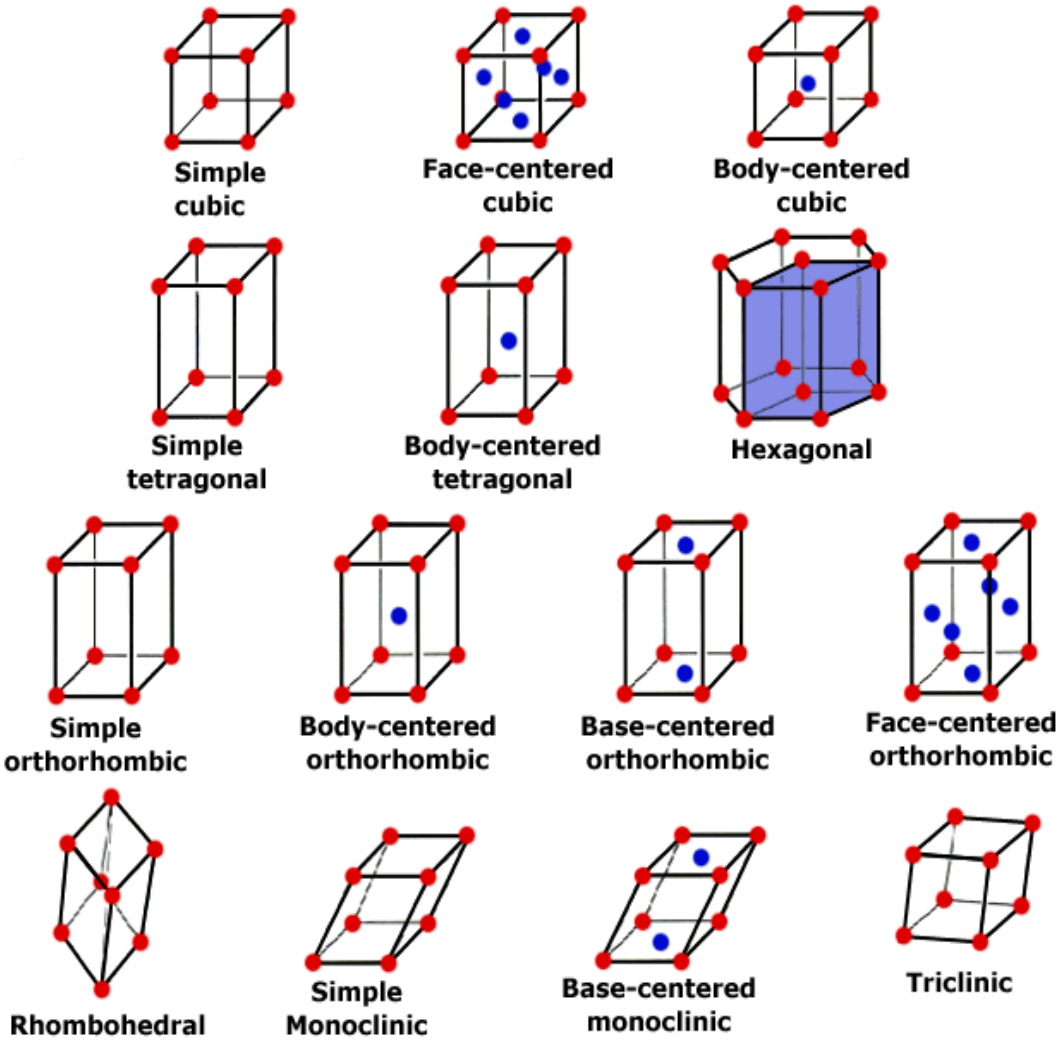
Same element: Different structure: different bonding

drastically different properties!!

How atoms are arranged in a bulk?







What happens as the size reduces?

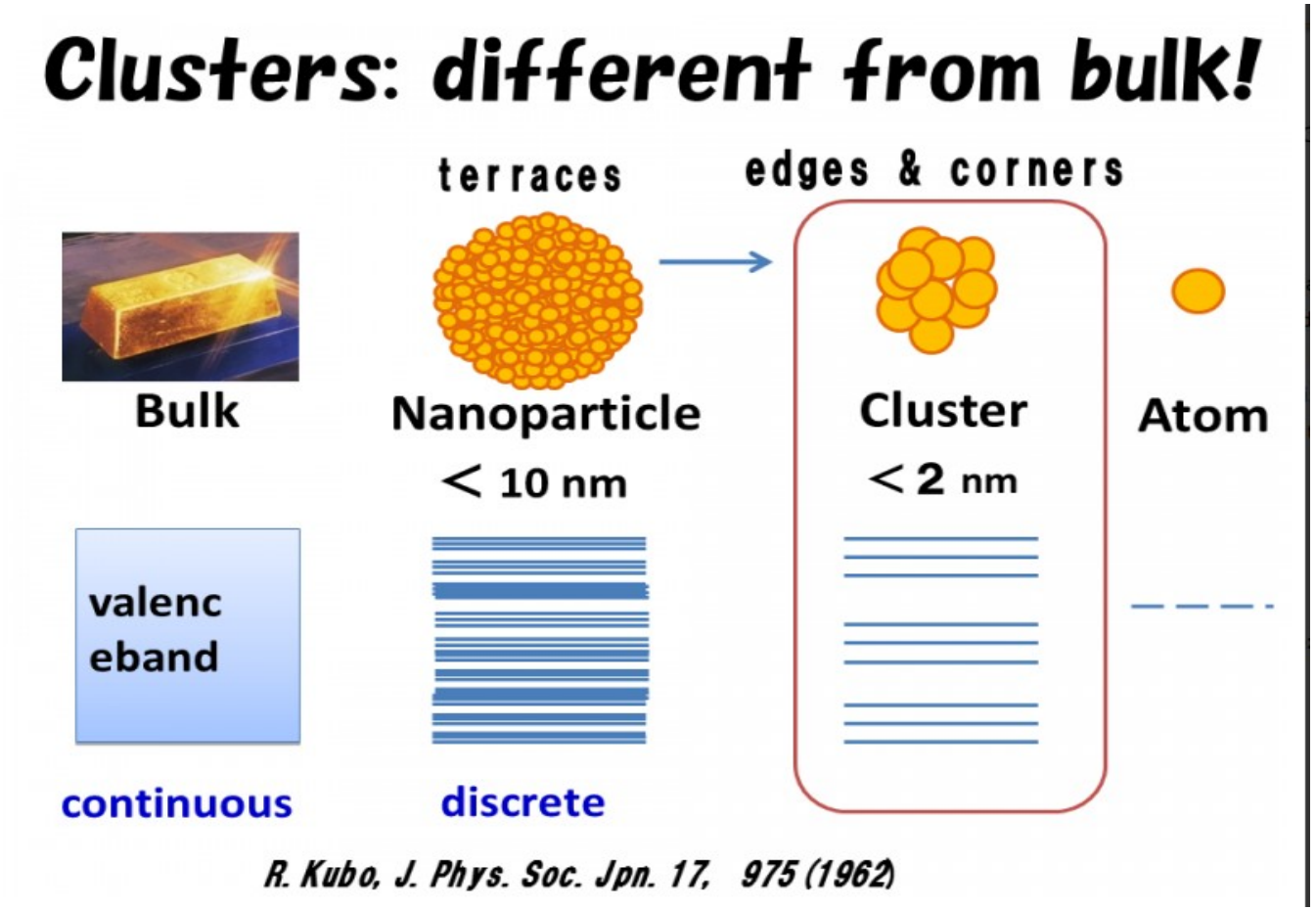
Atoms are no more organized in a periodic fashion

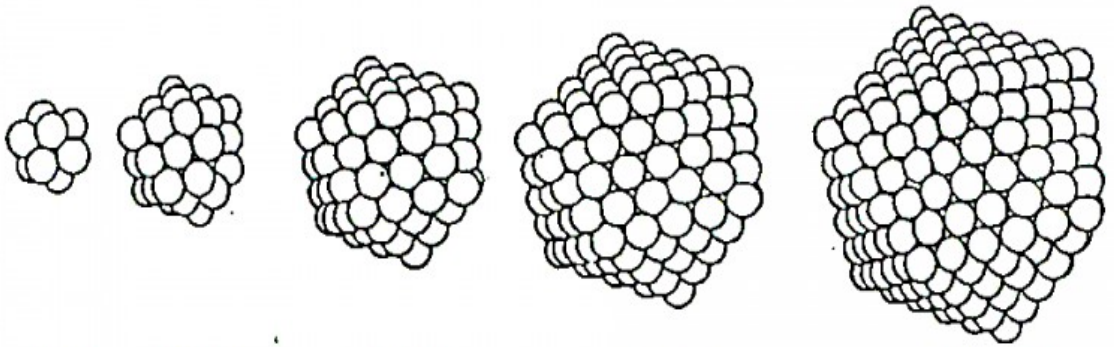
the crystal structure collapses
and this is the limit of miniaturization.

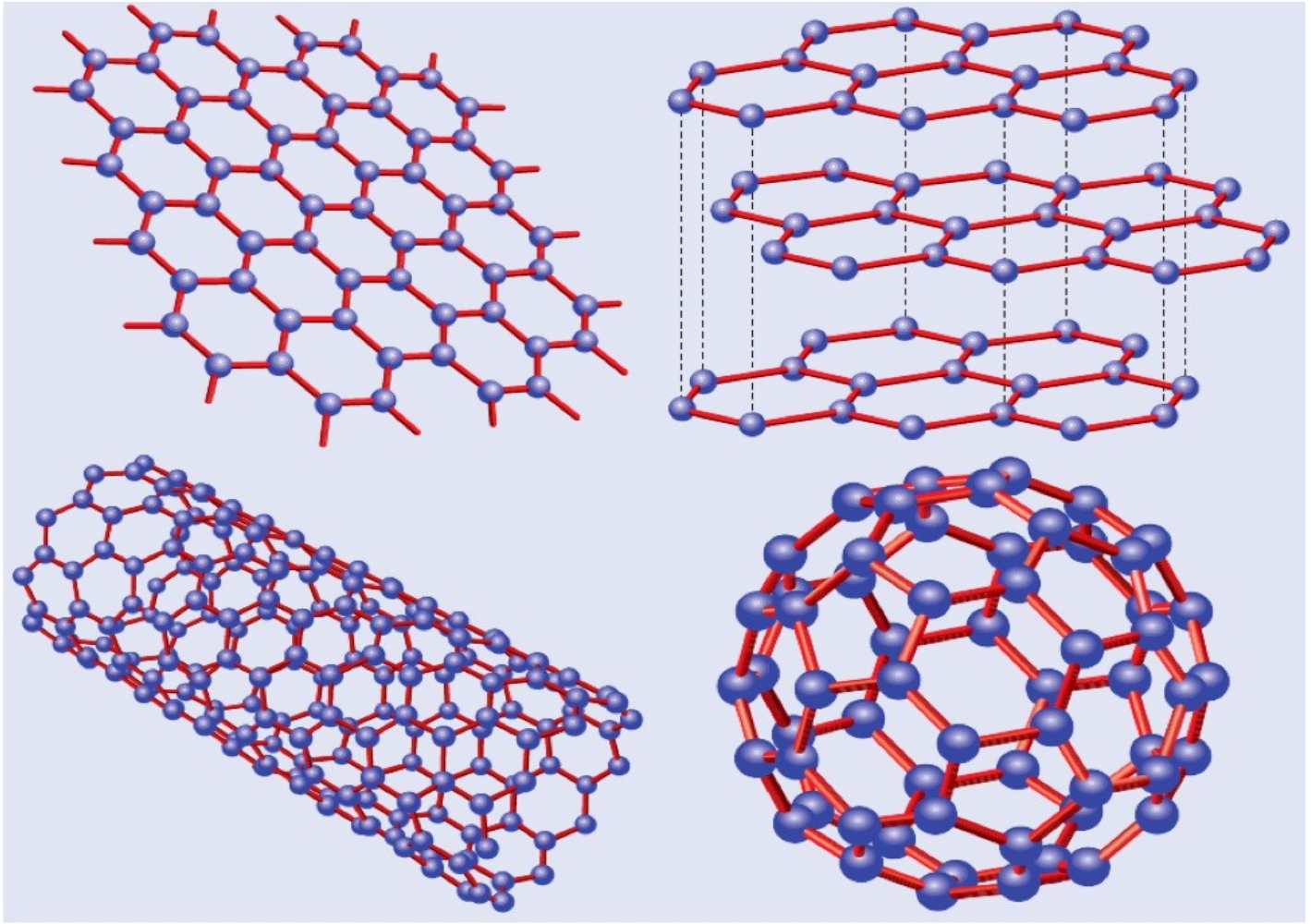
Miniaturization is possible in scalable regime

Where the surface atoms form a very small fraction of total number of atoms

A non-scalable regime



1.1	1.6	2.2	2.7	3.3	nm
Outer diameter					
					
13	55	147	309	561	
92	76	63	52	45	surf.%
0	55	41	29	21	edge%
92	22	8	4	2	corner%

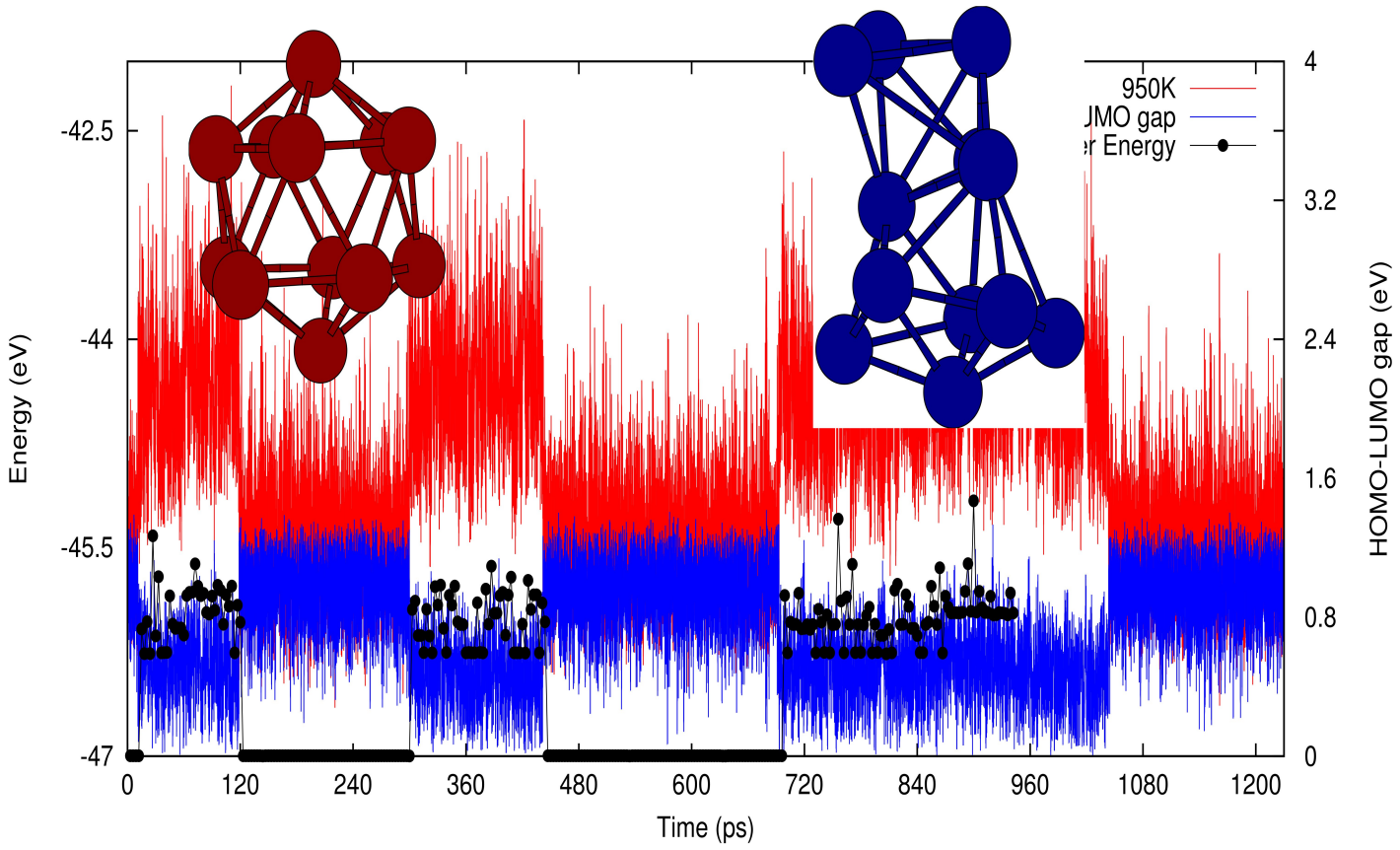


This is successful example of research field drivien by theory and computation

Computers as a tool

- Understanding
- Predicting
- Designing
- Control

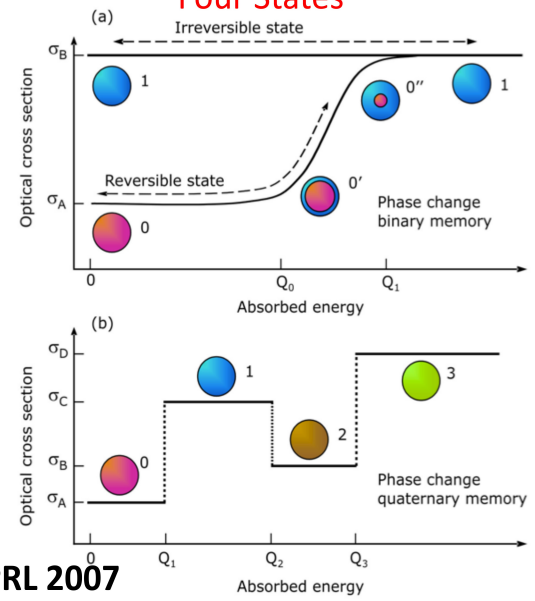
Two states: Cage and Non-Cage



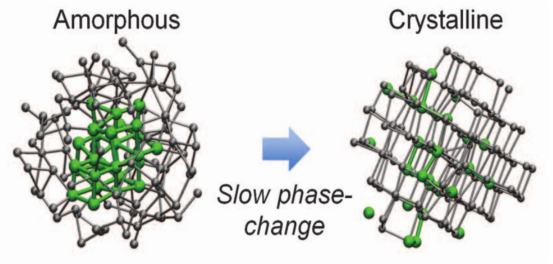
Nano Cages OR Nano Switches?

A.Susan and K.Joshi, to be published

Four States

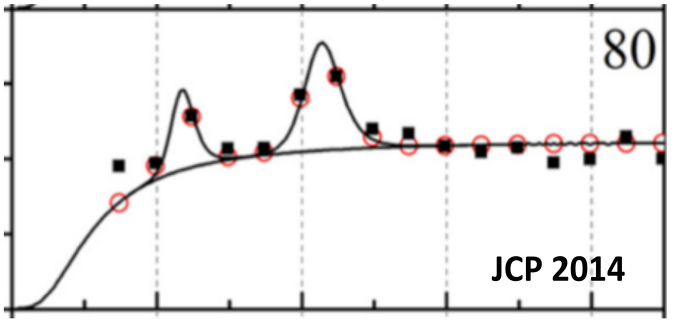


PRL 2007

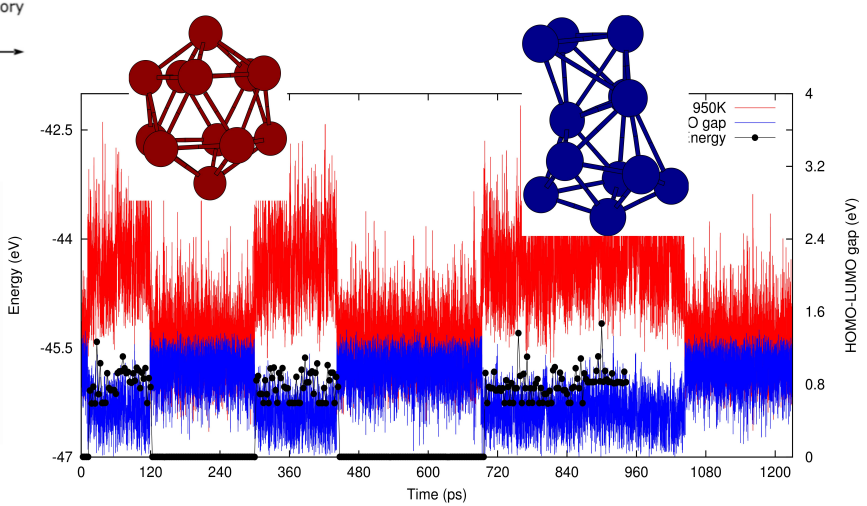


Science 2012

Three States ??



Two states: Cage and Non-Cage



Clusters as catalyst

Inhomogeneous charge distribution
in homogeneous clusters

Thank you