Objects of Nanochemistry and Unique Properties of Nanoparticles

Lecture-presentation on “Basics of Nanochemistry and Nanotechnology”

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Purpose of lecture –presentation:

Study of objects of Nanochemistry and their properties

Plan of lecture –presentation:

1. Objects of Nanochemistry
2. Classification of Nanochemistry Objects
3. Properties of Some Nanoparticles

1. Objects of Nanochemistry

Basic Objects if Nanochemical Investigations

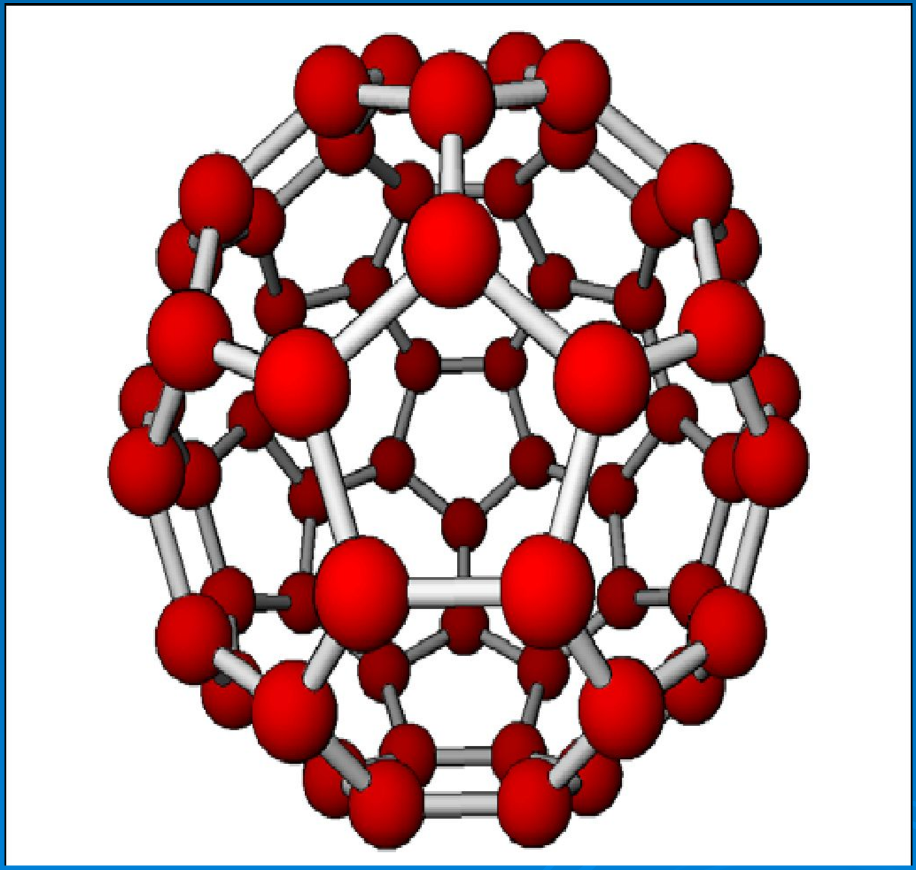
Nanoparticles	Nanosystems*
Fullerenes	Crystals, Solutions
Nanotubes	Aggregates, Solutions
Protein Molecules	Solutions, Crystals
Polymeric Molecules	Soles, Gels
Inorganic Nanocrystals	Aerosols, Colloidal Solutions
Micelles	Colloidal Solutions
Nanoblocks	Solids
Longmire-Blojett Films	Subjects with Films on Surface
Clusters in Gases	Aerosols
Nanoparticles in Substances' Layers	Nanostructured Films

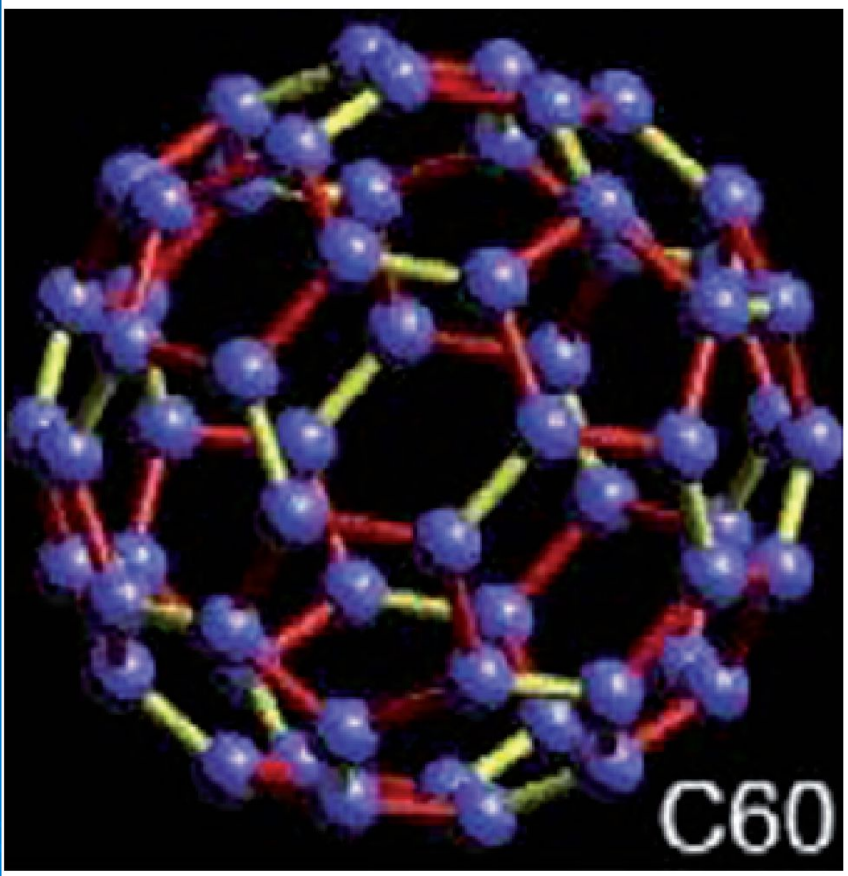
1. Objects of Nanochemistry

Fullerenes or Buckyballs - pure carbon, cage-like molecules composed of at least 20 atoms of carbon. The word ‘fullerene’ is derived from the word “Buckminsterfullerene,” which refers specifically to the C60 molecule and is named after Richard Buckminster Fuller, an architect who described and made famous the geodesic dome. C60 and C70 are the most common and easy to produce fullerenes.

1. Objects of Nanochemistry

Fullerene C60 molecule





1. Objects of Nanochemistry

For C70 molecule it was suggested the structure with ellipsoidal form of symmetry D5h. Polyedric clusters of carbon were named fullerenes and the most used molecule C60 — buckminsterfullerene, after American architect Buckminster Fuller.

1. Objects of Nanochemistry

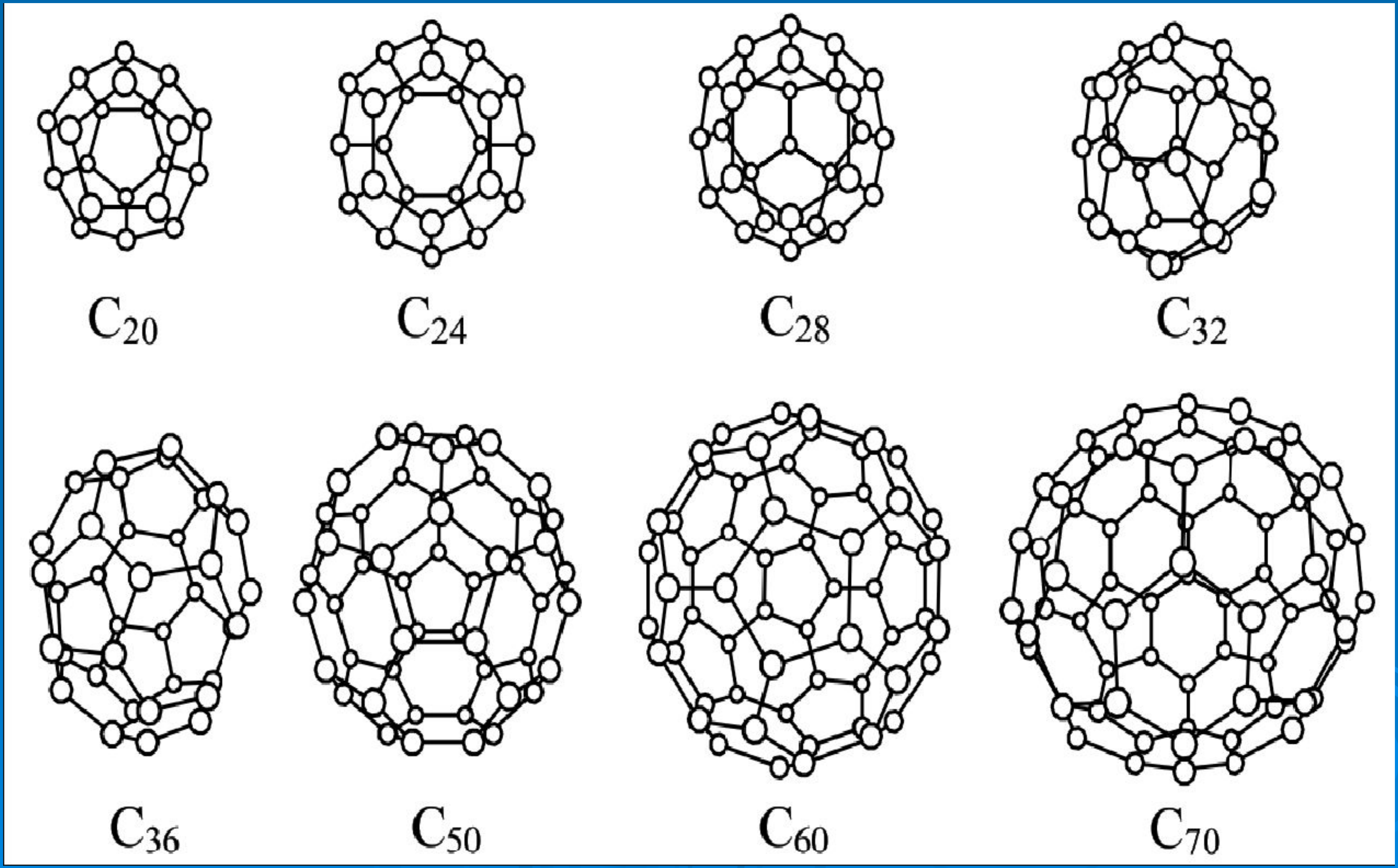
In fullerenes molecules carbon atoms are situated in the tops of regular six and fife cornered structures which compose the surface of sphere or ellipsoid. The most symmetric and studied representative of fullerenes – fullerene C60, in which carbon atoms form multifaced structure consisting of 20 six cornered and 12 five cornered structures and looks like football ball.

1. Objects of Nanochemistry

The next widely used is fullerene C70, which differs from fullerene C60 by insert of belt of 10 carbon atoms in equatorial area of C60, as the result, C70 molecule looks like the ball for rugby.

1. Objects of Nanochemistry

Fullerenes C20 – C70 family

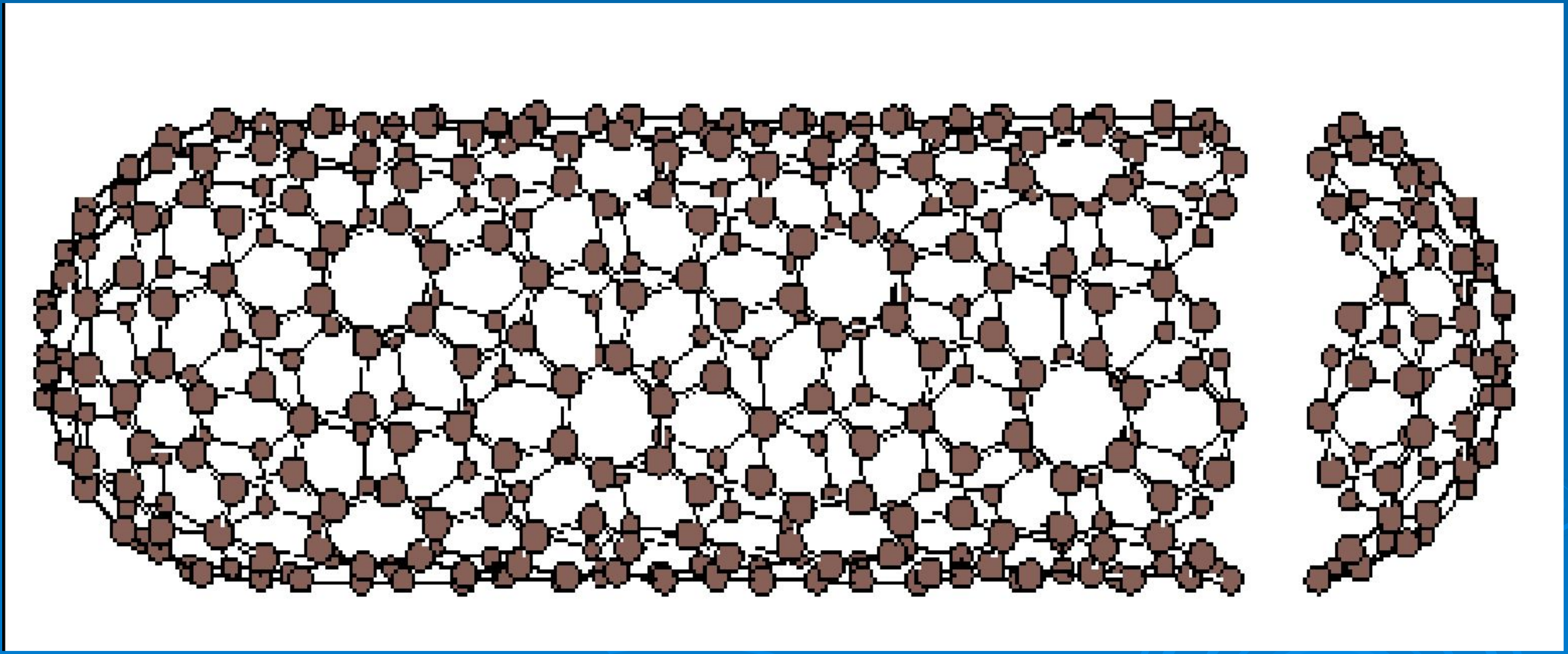


1. Objects of Nanochemistry

Carbon Nanotubes - carbon based tubular structures with dimensions in nanometer regime which consist from one or several hexagonal graphite tubes (graphenes) and end with semispherical head.

1. Objects of Nanochemistry

Ideal model of one layered carbon nanotube



1. Objects of Nanochemistry

Nanotubes are mostly classified according to the type of rolling of graphite plane which is characterized by two numbers n and m that determine the division of rolling direction to the vectors of graphite grid translation.

According to the values of parameters (n, m) there are:

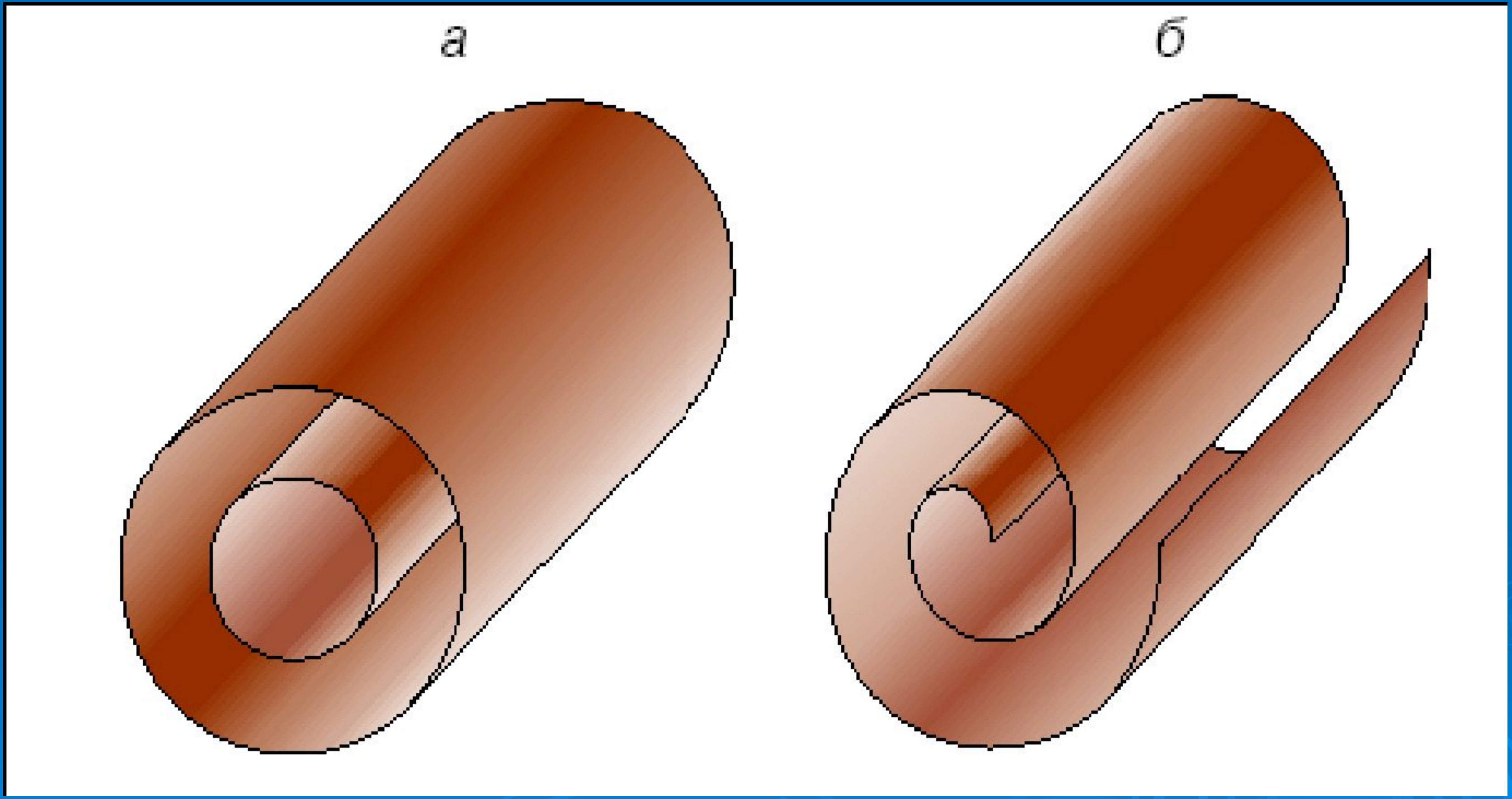
1) «armchair» $n=m$

2) zigzag $m=0$ or $n=0$

3) spiral (hiral) nanotubes $m \neq n$

1. Objects of Nanochemistry

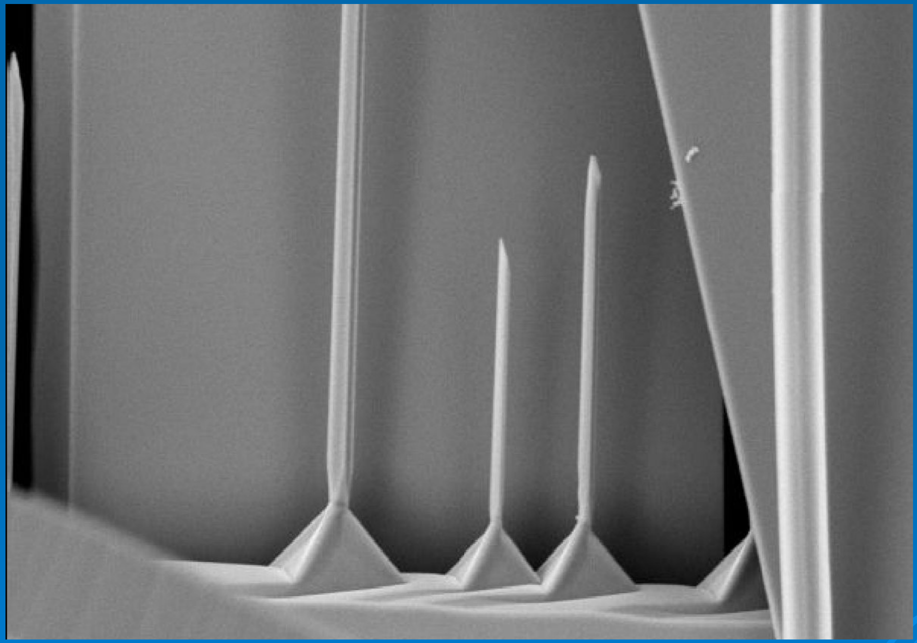
Models of cross cut of multilayered nanotubes: a – russian dolls (“matreshka”); б - roll



1. Objects of Nanochemistry

Inorganic Nanocrystals

Whiskers – (hair, mustache, inorganic fibers) – thread typed crystals with diameter from 1 to 10 mkm and length / width ratio >1000



Whiskers: thread typed crystals of SnO_2,

1. Objects of Nanochemistry

Manganites – compounds with the effect of colossal magnetic resistance (CMR).

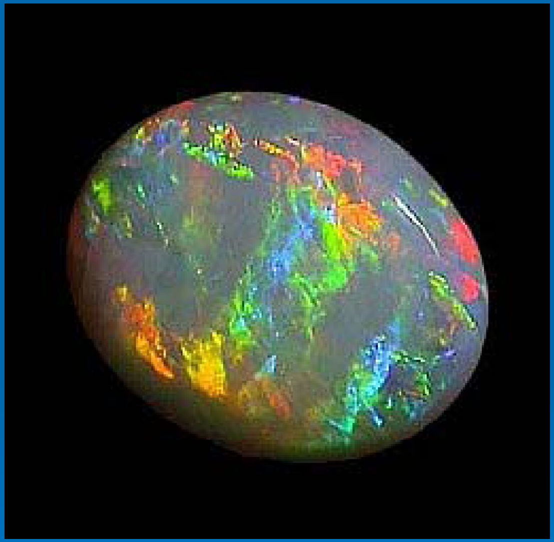
Beginning with the 20-th of the XX century it was known that electrons that form electric current in electric chain have their own magnetic moment, spin. But this was not used in practice. With the beginning of new century new field of science – magneto electronics (spintronics) – appeared.

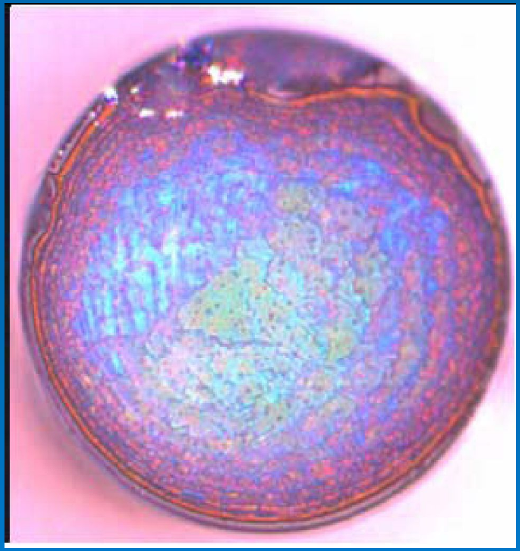
1. Objects of Nanochemistry

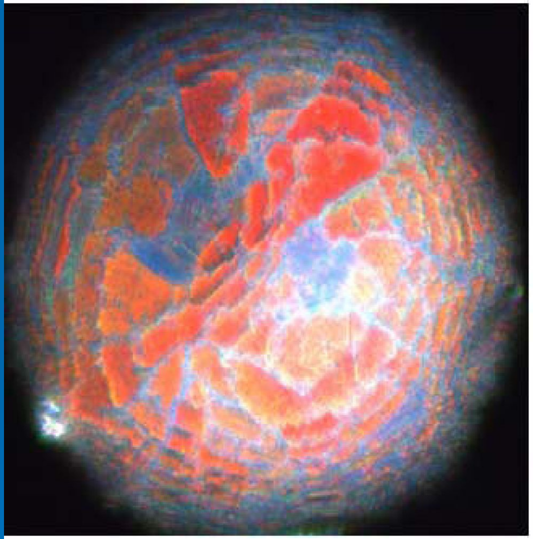
Effect of CMR was found out in manganites family with general formula $Ln_{1-x}A_xMnO_3$ (Ln – rare earth element, A – alkali or alkali earth element) and structure of perovskite. The basic mechanism of charge transfer for this class of materials is mechanism of double change $Mn^{3+} - O - Mn^{4+}$. There were also found other families of materials with CMR effect: $La_{1-x}A_xCoO_3$, halcogenides based on chromium, pyro chlorine family $Tl_2Mn_2O_7$ etc.

1. Objects of Nanochemistry

Photonic crystal – material with structure characterized by periodic change of refraction index in spatial dimensions.







Photonic crystals: a – opal – natural photonic crystal; б, в – micro photographs of one mode (125 microns in diameter) optic fiber's cross-sections

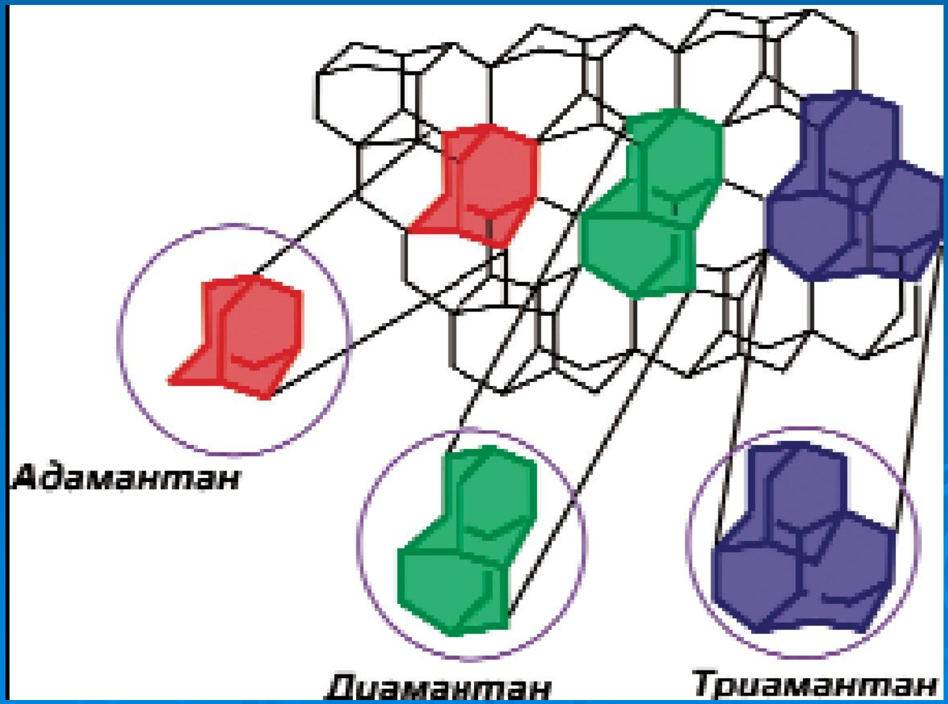
1. Objects of Nanochemistry

Bio ceramics – structural material compatible with biological objects, which is used in practical medicine for making prosthesis and implants

1. Objects of Nanochemistry

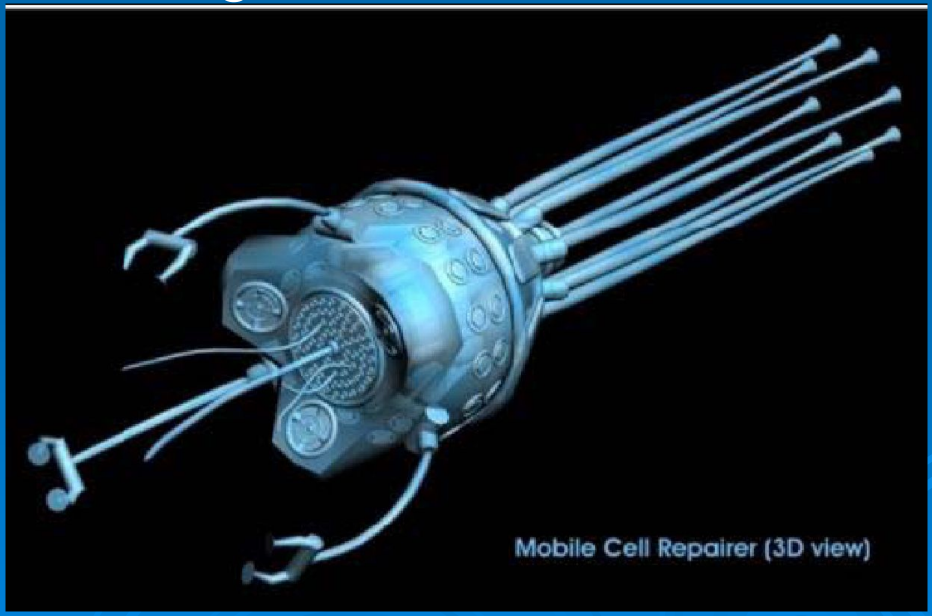
Diamondoids - nanometer-sized structures derived from the diamond crystal structure.

As nanotechnologies developed the idea of existence of diamondoids - smallest bricks from which crystal of macroscopic diamond consists. Such elemental bricks-molecules were named *adamantane* ($C_{10}H_{16}$), *diadamantane* ($C_{14}H_{20}$) and *triadamantane* ($C_{18}H_{24}$)



1. Objects of Nanochemistry

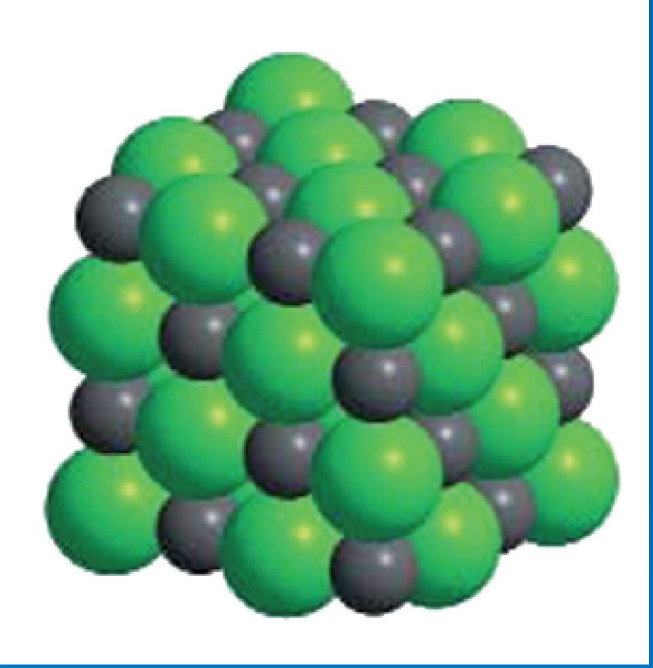
In 1957 diamondoids were found in crude oil. Due to characteristics similar to those of diamond diamondoids are widely used in different fields of life: microelectronics, nanoelectronics, medicine (pic. 2.9), machine building, metals treatment, engines building, aviation and automobiles building.



Medical nanorobot made from diamondoids

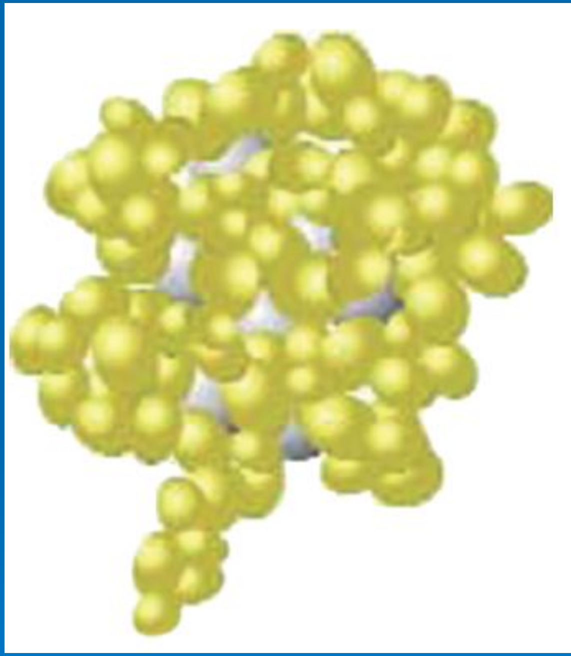
1. Objects of Nanochemistry

Clusters



NaCl cluster – ionic cluster

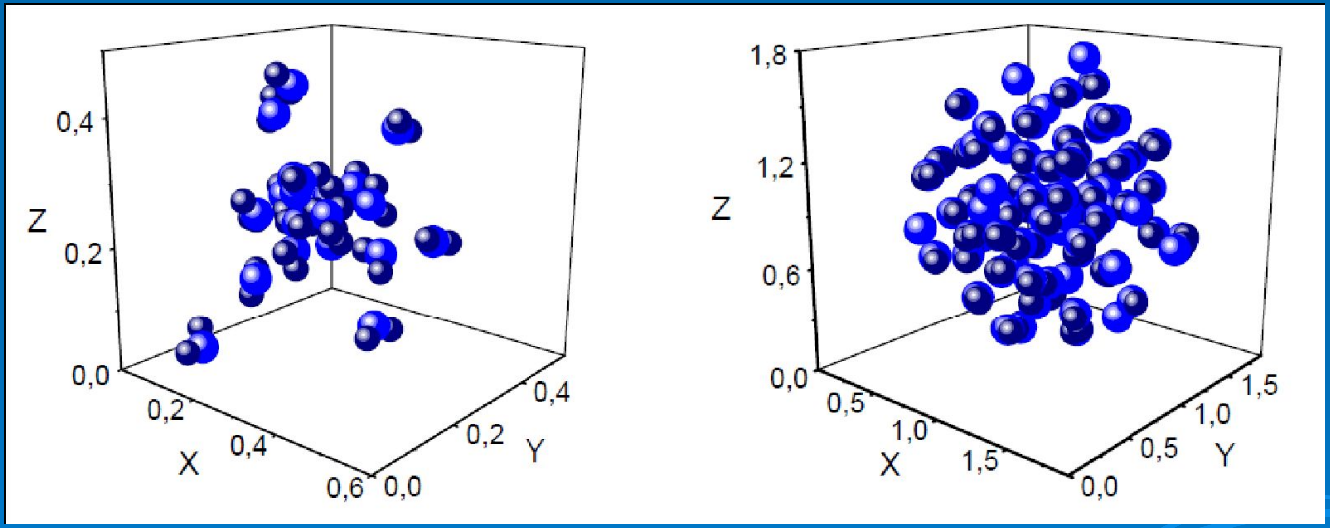
Fractal cluster



Molecular cluster of ferredoxine

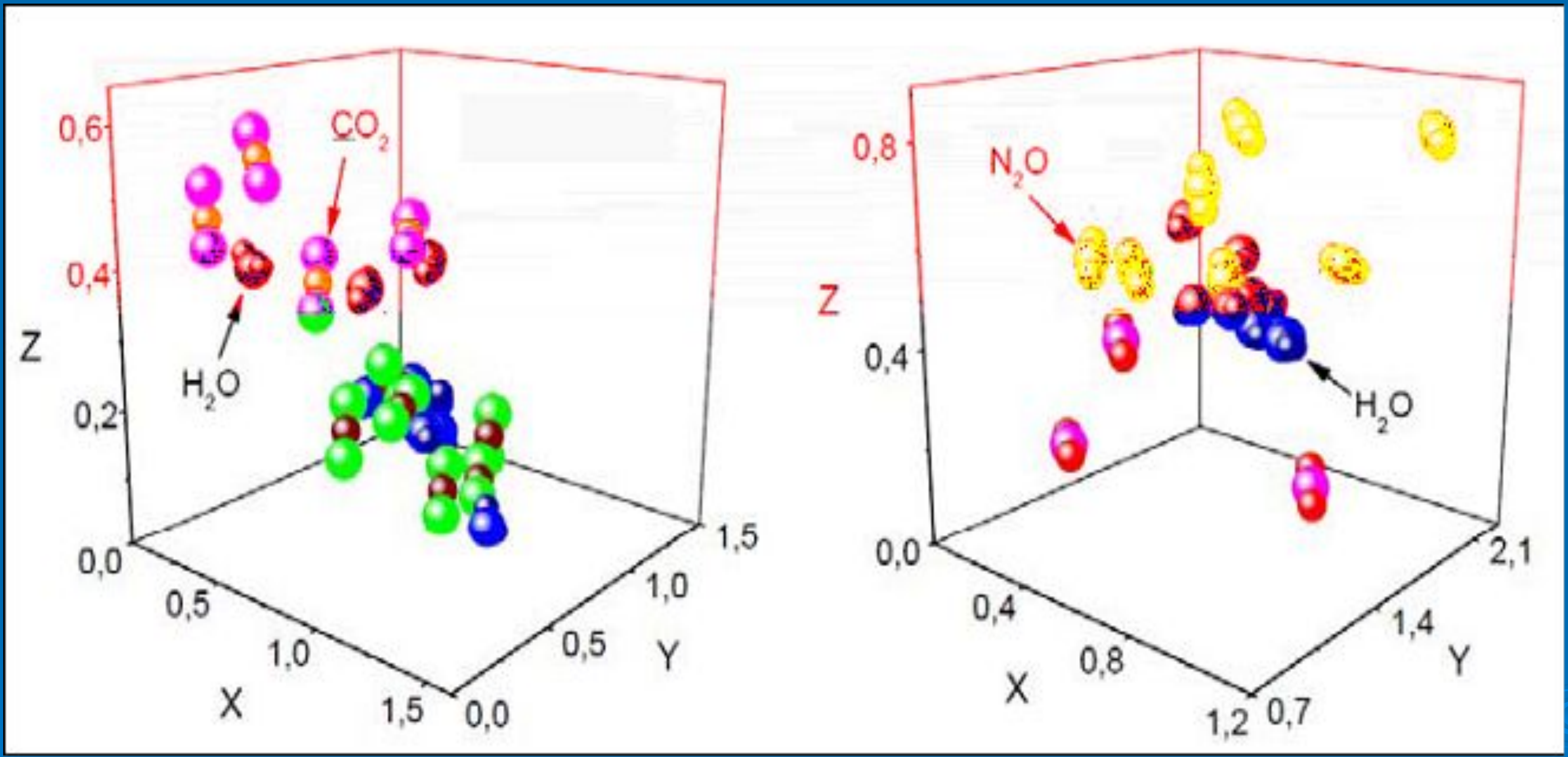
1. Objects of Nanochemistry

Clusters in gases. In the present rate of global Earth temperature gross and rate of greenhouse gases concentration increase exceed more than for one order characteristics of all earlier warming periods. Clusterization of water vapor in atmosphere is the factor that influences the heat balance of Earth atmosphere.



Configurations of clusters: a – (H2O)20 и б – (H2O)90, corresponding to 20ps. Coordinates are shown in nm.

1. Objects of Nanochemistry



Configurations of clusters: a – (CO2)10(H2O)10, б – (N2O)10(H2O)10, corresponding to 20ps. Coordinates are shown in nm.

2. Classification of Nanochemistry Objects

Objects of Nanochemistry

Phase	Single atoms	Clusters	Nanoparticles	Compact substance
Diameter, nm	0.1 – 0.3	0.3 – 10	10 – 100	over 100
Number of atoms	1 – 10	$10 - 10^6$	$10^6 - 10^9$	over 10^9

The United Classification of Nanochemistry Objects

Characteristics of Object	Number of Measurements **less than** 100nm	Number of Measurements **more than** 100nm	Examples
All three sizes (length, width and thickness) are less than 100nm	3 – dimensional object	0 – dimensional object	**Quantum dots**, fullerenes, colloidal solutions, microemulsions
Transversal sizes are less than 100nm while length is significant	2 – dimensional object	1 – dimensional object	**Quantum threads (wires)**, nanotubes, nanofibers, nanocapillaries and nanopores
Only one size (thickness) is less than 100nm while length and width are significant	1 – dimensional object	2 – dimensional object	**Quantum pits**, nanofilms and nanolayers
All three sizes (length, width and thickness) are more than 100nm	0 – dimensional object	3 – dimensional object	Ordinal macro bodies

2. Classification of Nanochemistry Objects

Quantum dot (QD) – three-dimensional potential pit for quantum particle, limiting movements of the last in three directions, it has sizes about the length of de-Broil wave of quantum particle.

Physically QD can be realized on form of double heterostructure in which narrow zoned semiconductor is placed in the matrix of wide zoned semiconductor as small inclusion. In this case three-dimensional quantum pit (or quantum dot) forms for the charge carriers in the area of narrow zoned semiconductor.

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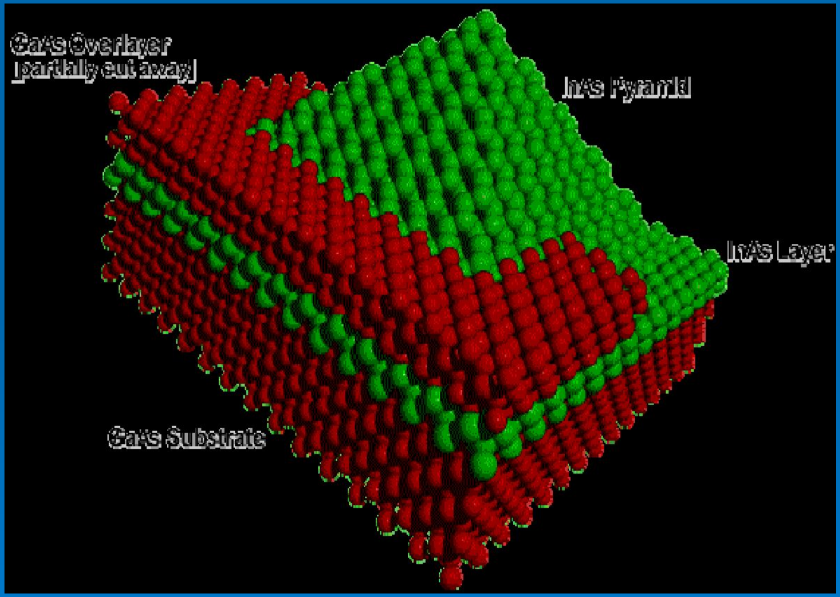
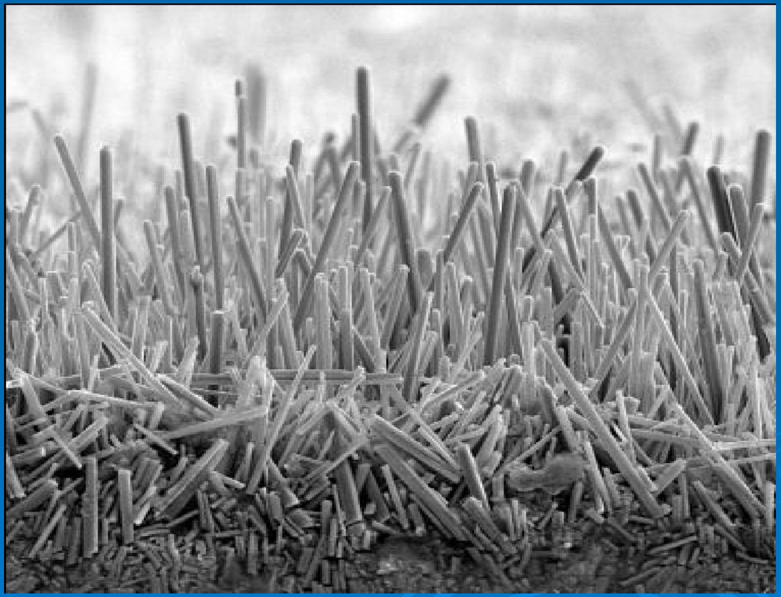




Quantum dot

Quantum threads (manganite whiskers)

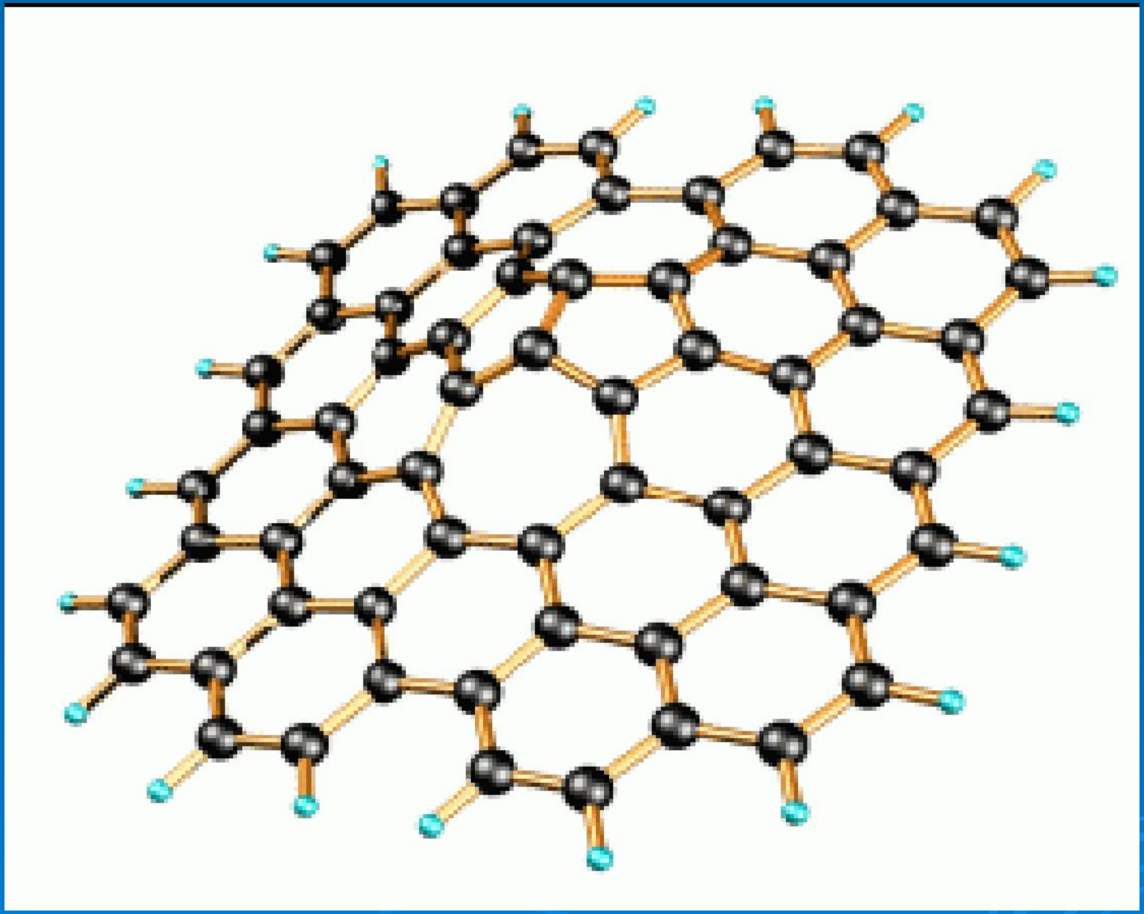
2. Classification of Nanochemistry Objects

Quantum thread (wire) — two-dimensional potential pit for quantum particle which sizes in two dimensional directions ~ the length of de-Broil wave of quantum particle. Particularity of quantum particle’s movement in the direction normal to the quantum wire’s axis is that the set of allowed values of energy of movements in mentioned directions is discreet.

2. Classification of Nanochemistry Objects

Quantum (pit) hole – one dimensional potential hole for quantum particle with sizes proportional to de-Broil wave length of quantum particle. Characteristic feature of quantum particle’s movement is that the set of allowed energies is discreet.

2. Classification of Nanochemistry Objects



Graphen (nanothin)

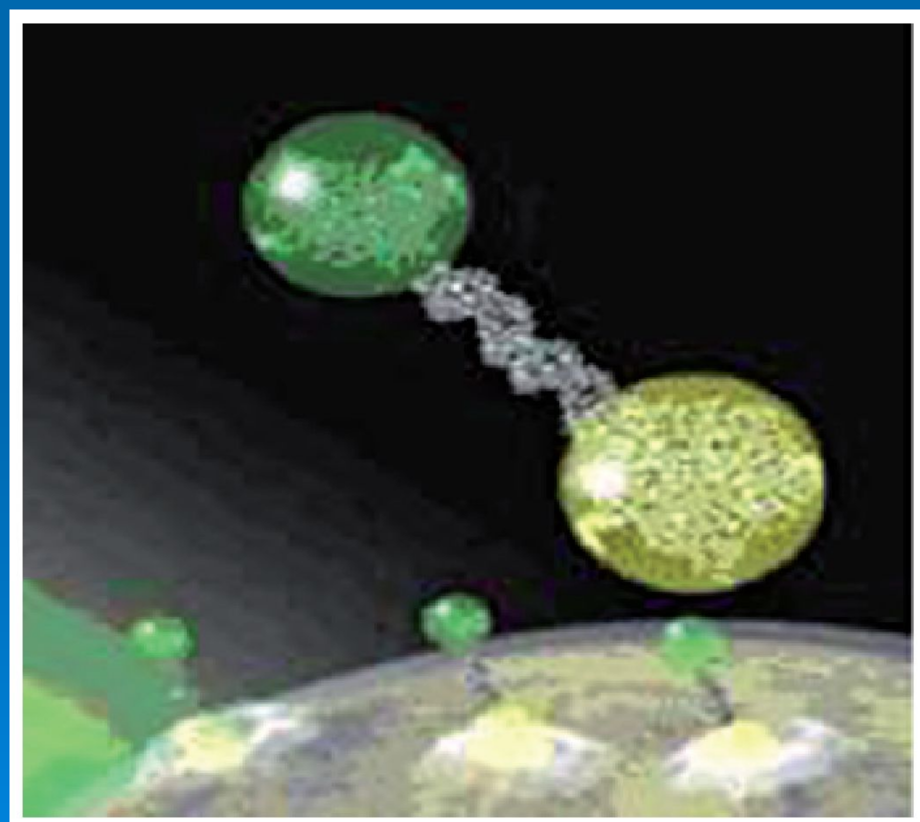
3. Properties of Some Nanoparticles

The unique properties of these various types of intentionally produced nanomaterials give them novel electrical, catalytic, magnetic, mechanical, thermal, or imaging features that are highly desirable for applications in commercial, medical, military, and environmental sectors. These materials may also find their way into more complex nanostructures and systems.

3. Properties of Some Nanoparticles

Zinc oxide:

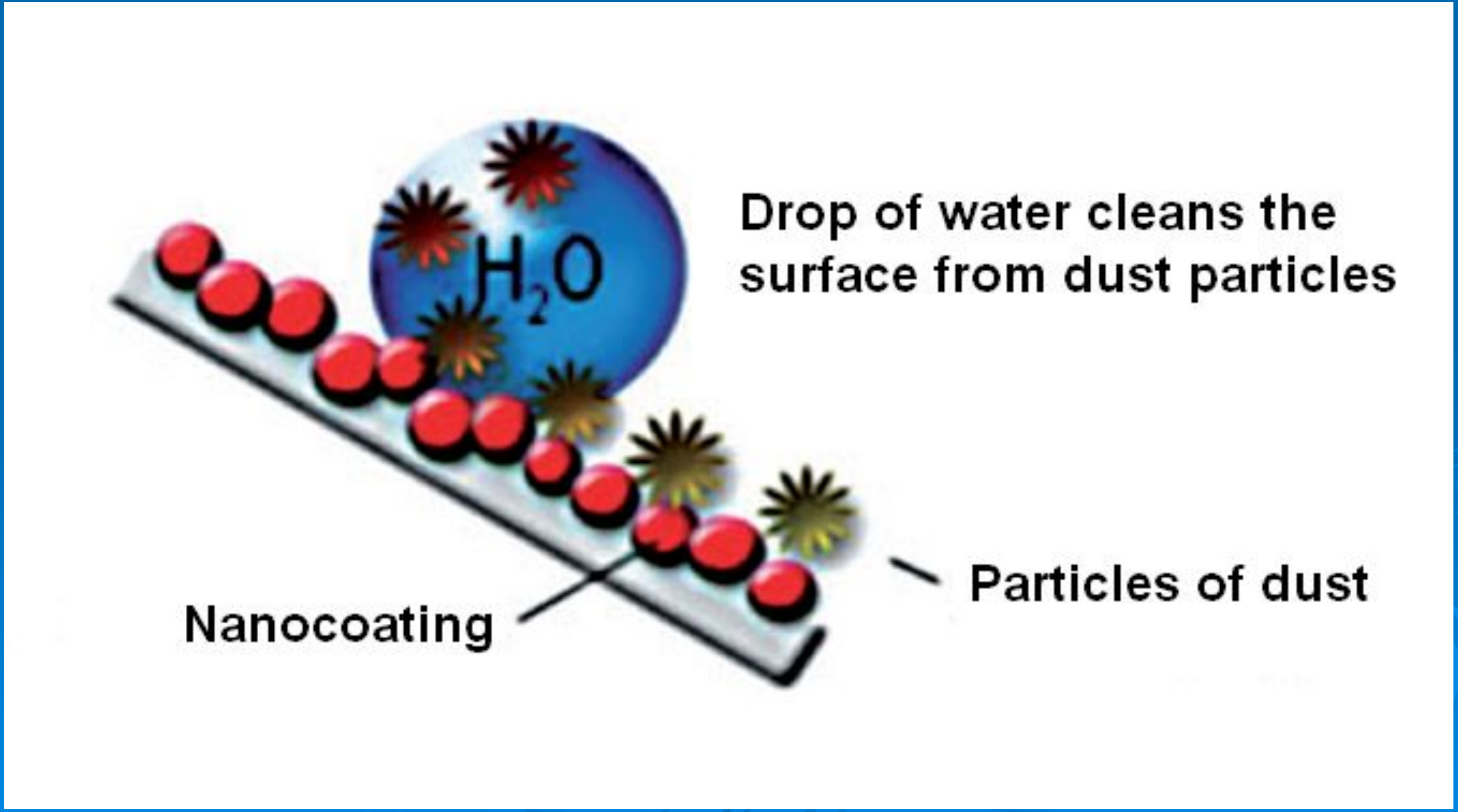
- Ability to adsorb wide spectrum of electromagnetic rays (UV, IR, microwaves, radio waves).



3. Properties of Some Nanoparticles

Silica dioxide:

- Coating from silica dioxide nanoparticles defends the surface from dust and moisture.



3. Properties of Some Nanoparticles

Silver nanoparticles' properties:

- Phenomenal bactericide and antivirus activity (silver nanoparticles are thousand times effective then silver ions);
- Silver nanoparticles act very selectively – they affect only for viruses, cells are not destroyed;
- High electric conductivity.

Check Yourself

1. List the basic objects of nanochemical investigations.
2. Give the definition of fullerenes (buckyballs) and name the most widely used ones.
3. Give the definition of carbon nanotubes and name their properties.
4. How are nanotubes classified?
5. What is called whiskers?
6. What are the properties of manganites?
7. What are the properties of photonic crystals?
8. List the applications of bioceramics.
9. Give the definition of diamondoids and name their properties.
10. Give the definition of clusters and name their properties.
11. What is quantum dot? What are its properties?
12. What is quantum wire? What are its properties?
13. What is quantum pit? What are its properties?

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