Nanotechnology. Allotropes of Carbon

Nanotechnology

- In 1959 the Nobel Prize winning physicist Richard Feynman gave a groundbreaking talk about the physical possibility of making, manipulating and visualizing things on a small scale and arranging atoms “the way we want”. Feynman challenged scientists to develop a new field where devices and machines could be built from tens or hundreds of atoms. This field is now called nanotechnology, which has been described as “the science of the very small with big potential”.

Definition of Nanotechnology

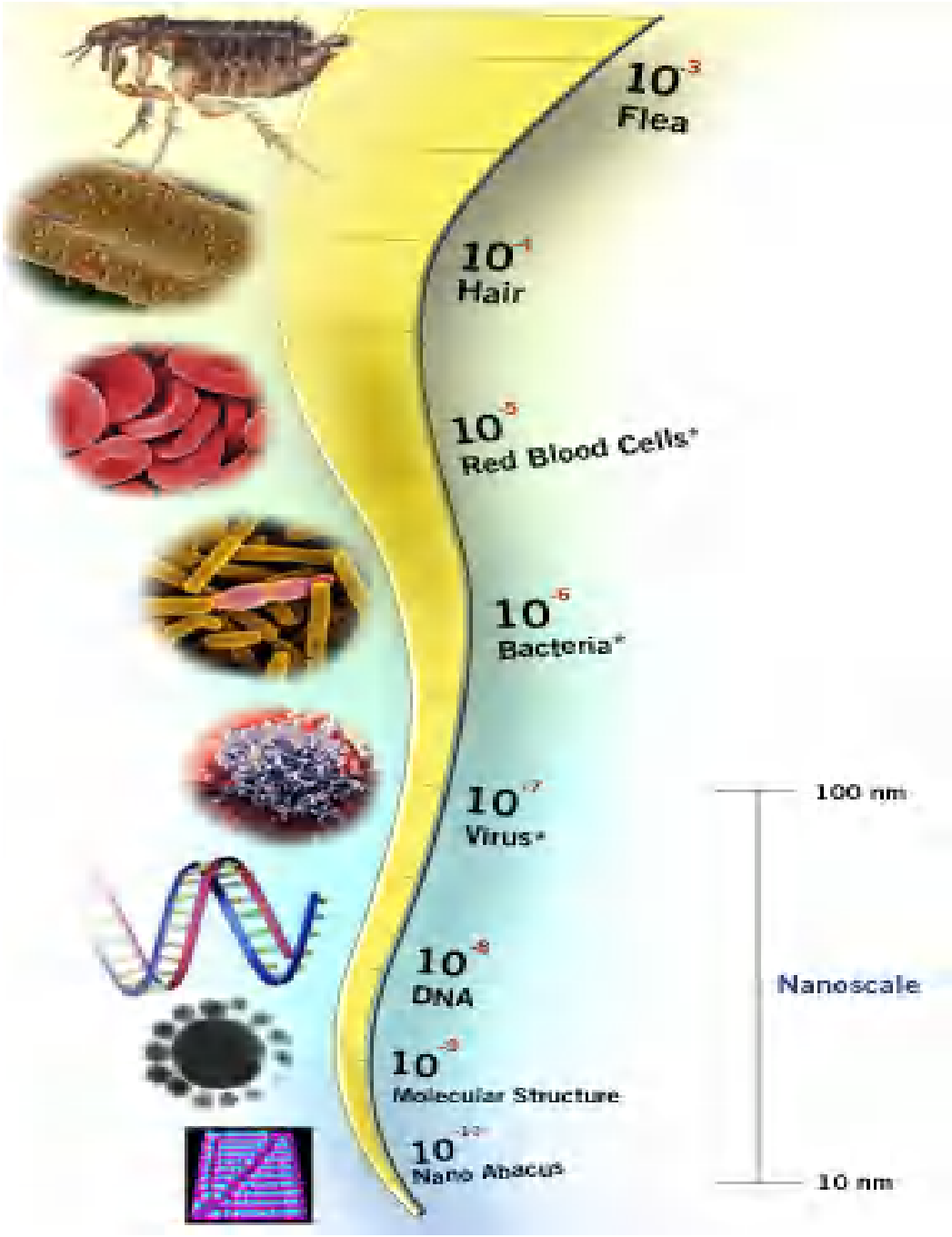
- Nanotechnology is defined as the research and technology development in the 1 – 100 nm range. Nanotechnology creates and uses structures that have novel properties because of their small size. It builds on the ability to control or manipulate matter on the atomic scale.

Prefix	Measurement	Scientific Notation
Kilo-	1000 m	1×10^{3} m
Hecta-	100 m	1×10^{2} m
Deka-	10 m	1×10^{1} m
BASE	1 m	1×10^{0} m
Deci-	0.1m	1×10^{-1}m
Centi-	0.01 m	1×10^{-2} m
Milli-	0.001m	1×10^{-3} m
Micro-	0.000001 m	1×10^{-6} m
Nano-	0.000000001 m	1×10^{-9} m
Pico-	0.000000000001 m	1×10^{-12} m
Femto-	0.000000000000001 m	1×10^{-15} m

Table-1 SI Units of Measurements [1]

Some examples of nanoscale are:

- A sheet of paper is about 100 000 nanometres thick.
- A human hair measures roughly 50 000 to 100 000 nanometres across.
- Your fingernails grow one nanometres every second.
- A single blink of an eye is about one-billionth of a year (a nano year).
- A single water molecule is about 1/4th of a nanometres across.
- 10 hydrogen atoms lined up next to one another spans 1 nanometre.
- A cell membrane is about 9 nanometres thick.
- A virus is approximately 70 nanometres wide.
- A strand of human DNA is 2,5 nanometres in diameter.
- A single gold atom is about a third of a nanometre in a diameter.



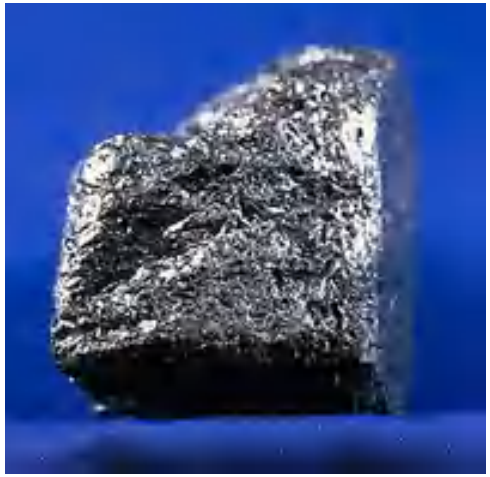
Carbon

- **Carbon** (from Latin: *carbo* "coal") is the chemical element with symbol **C** and atomic number 6. As a member of IV “A” group on the periodic table, it is nonmetallic and tetravalent—making four electrons available to form covalent chemical bonds.

- All carbon allotropes are solids under normal conditions with graphite being the most thermodynamically stable form. They are chemically resistant and require high temperature to react even with oxygen.

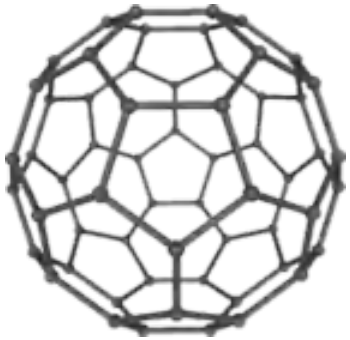
The three allotropes of carbon

- Graphite



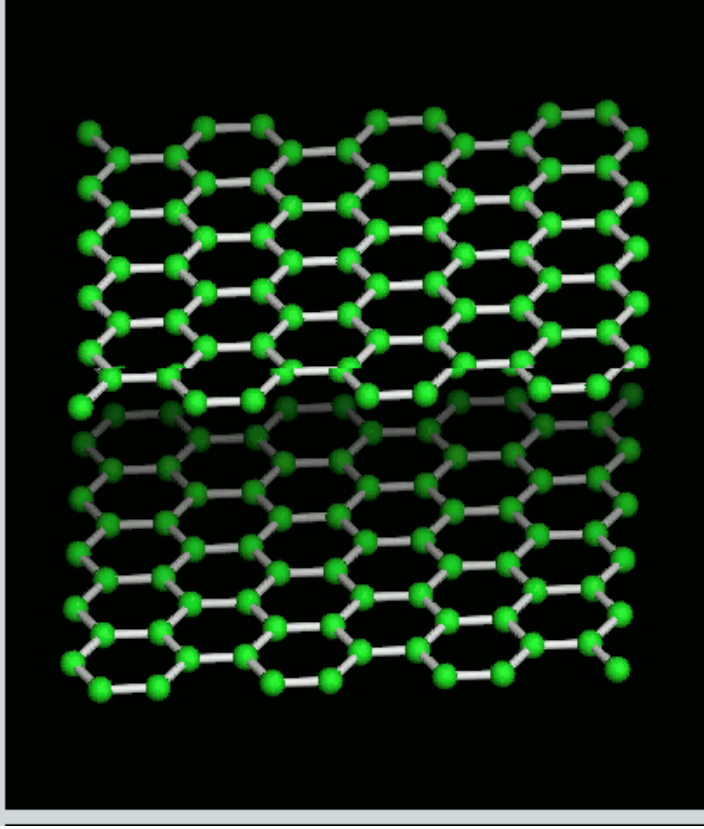
- Diamond

- Fullerene

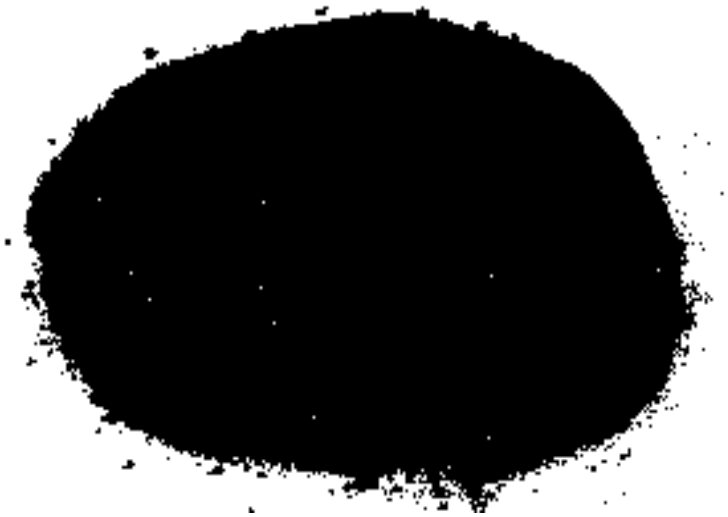


Graphite

- The mineral **graphite** is an allotrope of carbon. It was named by Abraham Gottlob Werner in 1789. Unlike diamond (another carbon allotrope), graphite is an electrical conductor, a semimetal. It is useful in such applications as arc lamp electrodes.



- Graphite is the most stable form of carbon under standard conditions. Therefore, it is used in thermochemistry as the standard state for defining the heat of formation of carbon compounds.



- Graphite may be considered the highest grade of coal, just above anthracite and alternatively called meta-anthracite, although it is not normally used as fuel because it is difficult to ignite.

Diamond

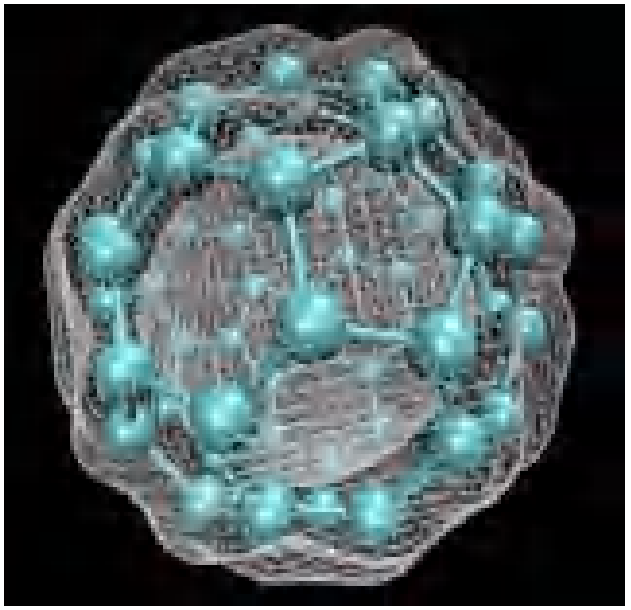
- **Diamond** is a allotrope of carbon, where the carbon atoms are arranged in a diamond lattice.

- Diamond is a material with superlative physical qualities, most of which originate from the strong covalent bonding between its atoms. In particular, diamond has the highest hardness and thermal conductivity of any bulk material.

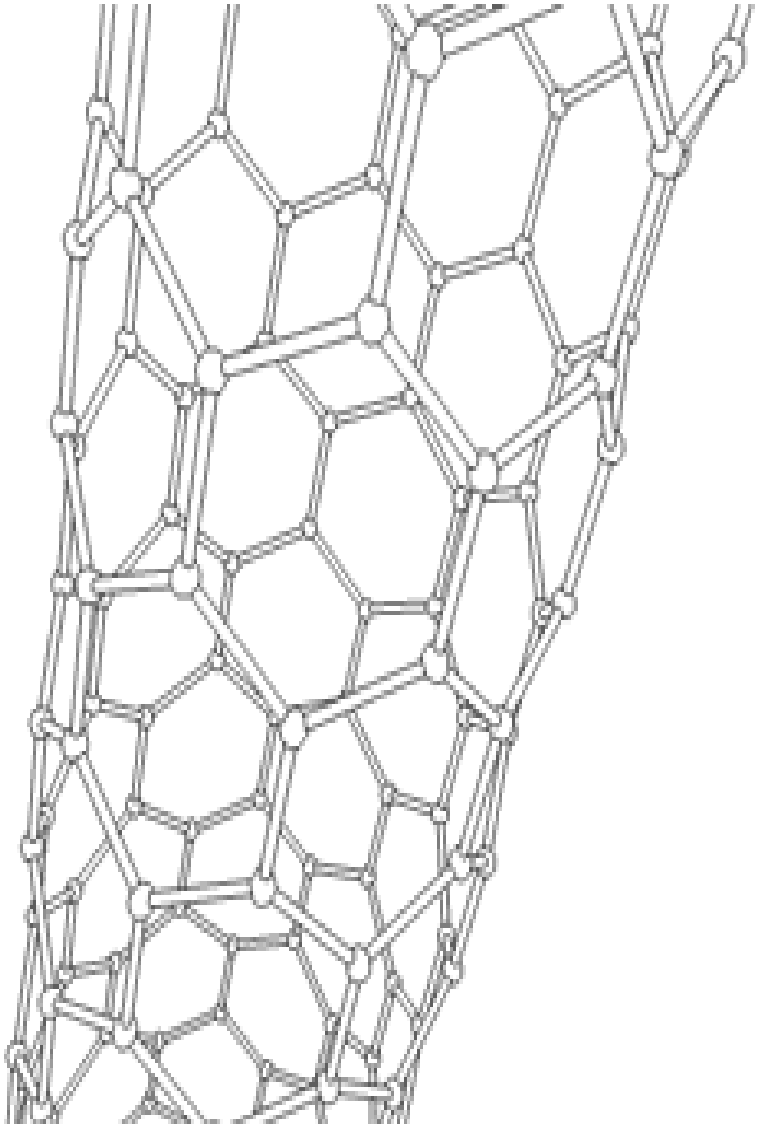
- Those properties determine the major industrial application of diamond in cutting and polishing tools and the scientific applications in diamond knives and diamond anvil cells.

Fullerene

- A **fullerene** is any molecule composed entirely of carbon, in the form of a hollow sphere, ellipsoid or tube. Spherical fullerenes are also called **buckyballs**, and they resemble the balls used in football (soccer).



- Cylindrical ones are called carbon nanotubes or buckytubes. Fullerenes are similar in structure to graphite, which is composed of stacked graphene sheets of linked hexagonal rings; but they may also contain pentagonal (or sometimes heptagonal) rings.



Question 1

- Which two of the following have a great similarity in common in atomic structure; salt, diamond, coal, gold, and silver?
- Diamond and coal.

Question 2

- How can such different looking materials have this much similarity?
- Because they are allotropes of the same element: carbon. Allotropes are different structural modifications of an element. They have different physical properties, but the same chemical properties.

Question 3

- Do you know about other famous allotropes in the nature?
- Oxygen gas – Ozone
- White phosphorus – Red phosphorus
- C (diamond) – C (graphite) and Fullerenes

Question 4

- You probably know about bowling ball, disco ball, and tennis ball. Likewise, have you heard about buckyball? What is a buckyball?
- Buckyball is a spherical fullerene molecule with the formula C_{60}. It has a cage-like ring structure which resembles a classical soccer ball, with 20 hexagons and 12 pentagons, with a carbon atom at each vertex of each polygon and a bond along each polygon edge.

Question 5

- Other than buckyball (C_{60}), what kind of Fullerene molecules can you name?
- Carbon nanotubes, carbon megatubes.
- **C_{70}, C_{540}** and etc

- Watch the animation on the website; The Scale of the Universe 2 http://htwins.net/scale2/

Question 6

- To what scale is C_{60} molecules (buckyballs) equivalent? (Answer according to the previous animation named “The Scale of the Universe 2”) Emphasize the size of nanometers.
- Alpha Helix, Cs atom, X-ray wavelength and buckyball are nearly at the same size.

- Now we divide the class into 4 groups.
- Each group has to do a different activity:

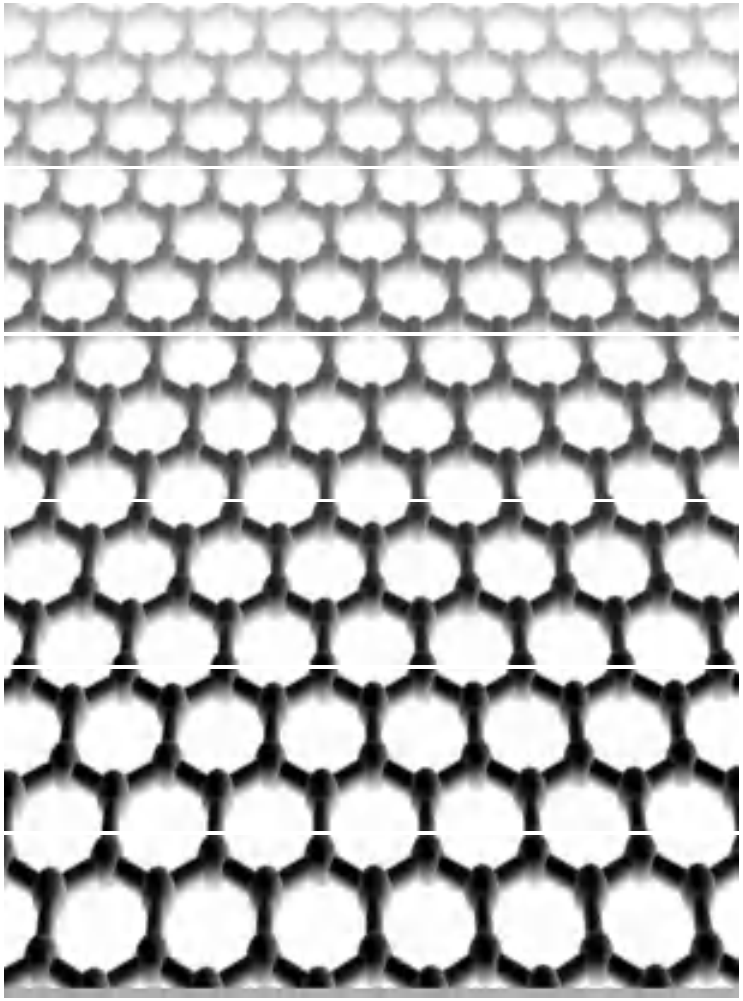
- Group 1 – activity 1(graphite);

- Group 2 – activity 2(diamond);

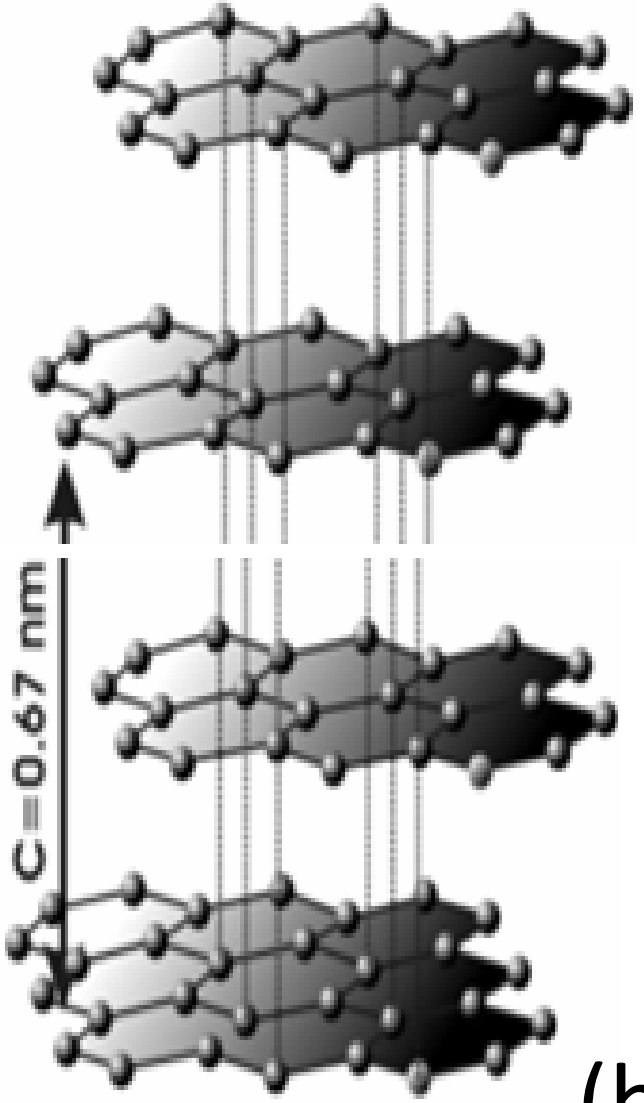
- Group 3 – activity 3(buckyball);

- Group 4 – activity 4(nanotubes).

Activity 1: (a) Graphene, (b) Graphite



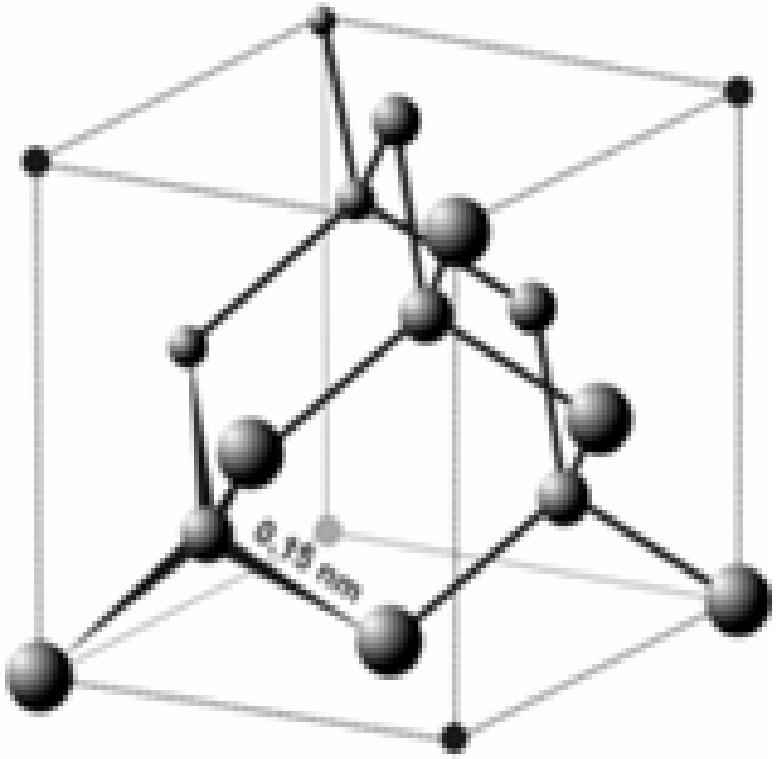
(a)



(b)

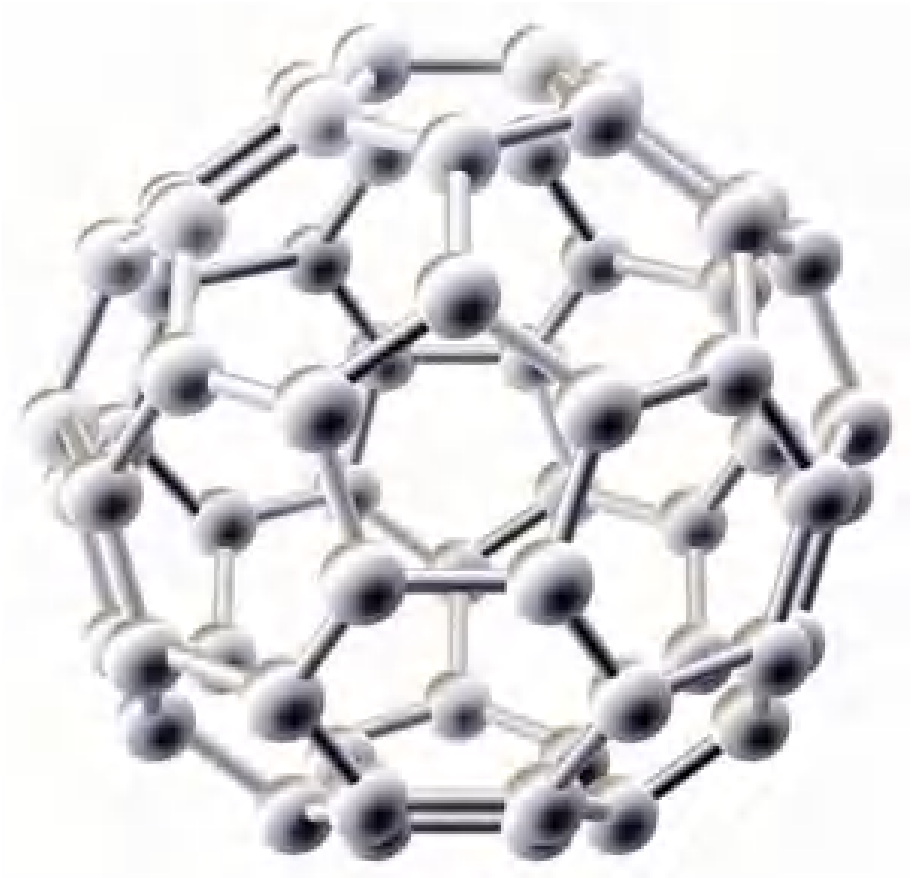
Activity 2: Dimond(2) and crystal structure of dimond(3).

(2)

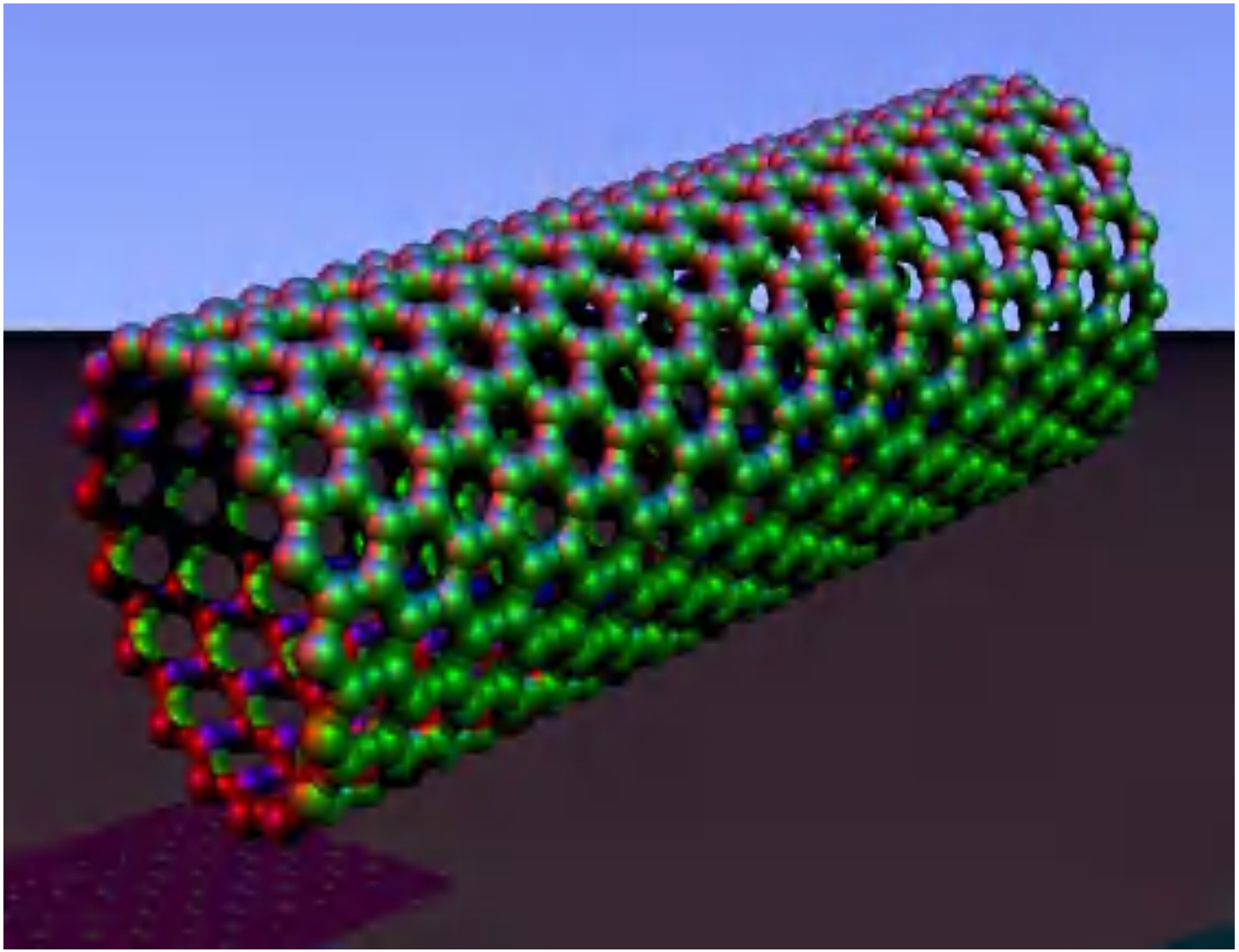


(3)

Activity 3: Buckyball C_{60}



Activity 4:Carbon nanotubes



Question 7

- Crumple up another carton paper to be the same size as Buckyball you have built. Press both of them and compare the differences (figure 1). What can you say for this comparison? Which of them is stronger? Why?

Figure 1: Buckyball and Crumple up another carton paper.

- Bucykball is more durable than crumpled paper.
- Spherical structures distribute the forces applied in equal pieces on their surfaces.

Question 8

- What kind of bonding is there in between the carbon atoms of fullerene?
- Covalent bonding.

Question 9

- Carbon nanotubes are the strongest and lightweight material yet discovered. What can be the application areas of carbon nanotubes?
- Buildings
- Batteries
- Solar panels
- Space vehicles

Question 10

- We know that fullerenes show superconducting properties. Which research areas are related to super-conductivity?
- Magnetic-levitation
- Super conducting magnets especially for transport such as trains
- Biomagnetism
- Electric generators made with superconducting wire
- Energy storage to enhance power stability
- "Petaflop" computers

Question 11

- Why do you think Fullerenes dissolve in toluene, but not in water?
- Water is a polar solvent, but fullerenes are nonpolar substances. That's why they can only be dissolved in nonpolar solvents.

Quiz

- **A. Write (T) True or (F) False for the statements below. (5 minutes)**
- ( ) 1- Graphite is a conductor and can be used as the material in the electrodes of an electric arc lamp.
- ( ) 2- Allotropes have different physical properties and the same chemical properties.
- ( ) 3- The atoms forming allotropes have the same kind of bonding in between, but in different manners.
- ( ) 4- Diamond is a hollow cluster of 60 carbon atoms shaped like a soccer ball.

- **B. Fill in the blanks with an appropriate expression.(5 minutes)**
- 1- Buckyball is a ……molecule with the formula C_{60}.
- 2- ……. are different structural modifications of an element.
- 3- …….. is the hardest natural mineral.

- I hope that by the end of this presentation you understand better nanotechnology, the allotropes of carbon and their application!

Thank you for the attention!!!

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