Assignment 1_21: TOPICS IN NANOSCIENCES

MAX. MARKS: …….

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1. Mention two currently available commercial products that have nanoparticles and write the names of the nanoparticles. (2)
2. Define the following terms: Quantum Dot, Quantum Wire, and Quantum Well of a given material. (3)
3. What happen to the melting temperature of gold nanoparticles when their size decreases? (1)
4. What is an artificial atom? Why is it called so? (2)
5. In the band theory of solids, there are an infinite number of bands. If, at T = 0 K, the uppermost band to contain electrons is partially filled, and the gap between that band and the next lowest band is 0.8 eV, is the material a metal, an insulator, or a semiconductor? (2)
6. In the band theory of solids, if, at T = 0 K, the uppermost band to have electrons is completely filled, and the gap between that band and the next lowest band is 8 eV, is the material a metal, an insulator or a semiconductor? What if the gap is 0.8 eV? (2+2)
7. What is Stokes Shift in the context of fluorescence spectrum? (2)
8. Indicate whether each statement is true or false: (3)

   (a) The band gap of a semiconductor decreases as the particle size decreases in the ~1–10-nm range.

   (b) The light that is emitted from a semiconductor, upon external stimulation, becomes longer in wavelength as the particle size of the semiconductor decreases.

   (c) If you want a semiconductor that emits blue light, you could either use a material that has a band gap corresponding to the energy of a blue photon or you could use a material that has a smaller band gap but make an appropriately sized nanoparticle of the same material.
9. Explain how QDs may be better suited compared to organic dyes for the fluorescence emission based multiplex detection. (2)
10. Under high-intensity illumination conditions, QDs are better suited as the fluorescent probes than the organic fluoroprobes. Why? (2)
11. GaP has a band gap of 2.26 eV. If GaP is illuminated with ultraviolet light, it emits light equal to the band gap energy. (a) What color is the emitted light? (b) Would appropriately sized GaP quantum dots be able to emit blue light? (c) What about red light? (2+1+1)
12. Which statement correctly describes a difference between graphene and graphite? (1)

    (a) Graphene is a molecule, but graphite is not.

    (b) Graphene is a single sheet of carbon atoms and graphite contains many, and larger, sheets of carbon atoms.

(c) Graphene is an insulator, but graphite is a metal.

(d) Graphite is pure carbon, but graphene is not.

(e) The carbons are sp^2 hybridized in graphite but sp^3 hybridized in graphene.

13. What evidence supports the notion that buckyballs are actual molecules and not extended materials? (1)

(a) Buckyballs are made of carbon.

(b) Buckyballs have a well-defined atomic structure and molecular weight.

(c) Buckyballs have a well-defined melting point.

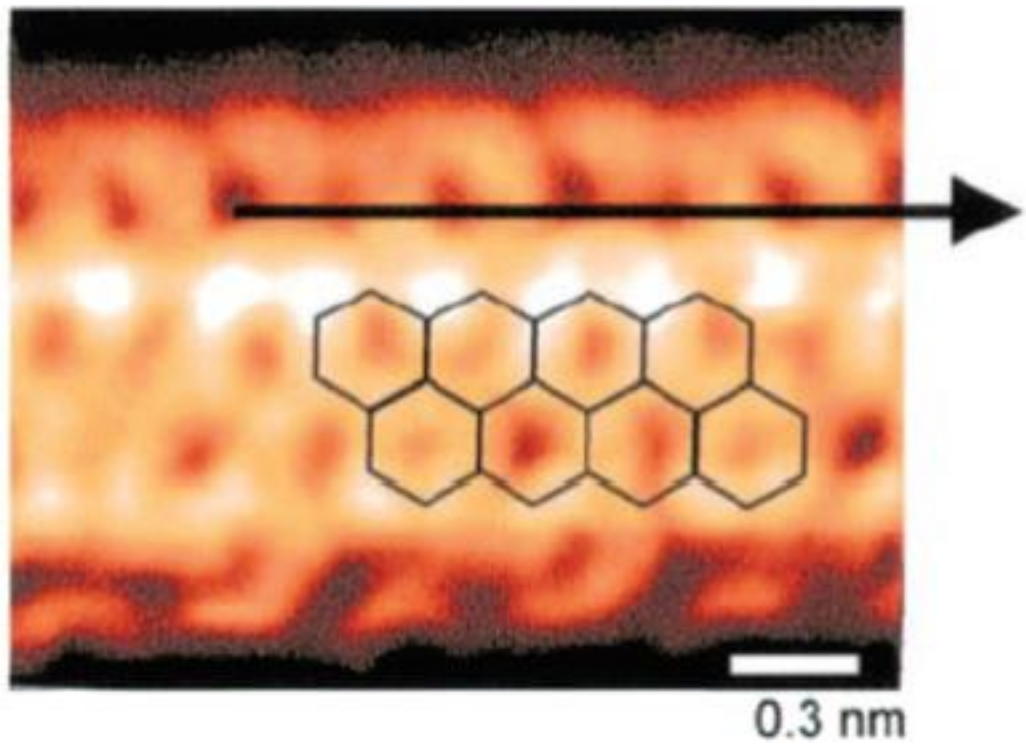
(d) Buckyballs are semiconductors.

(e) More than one of the previous choices.

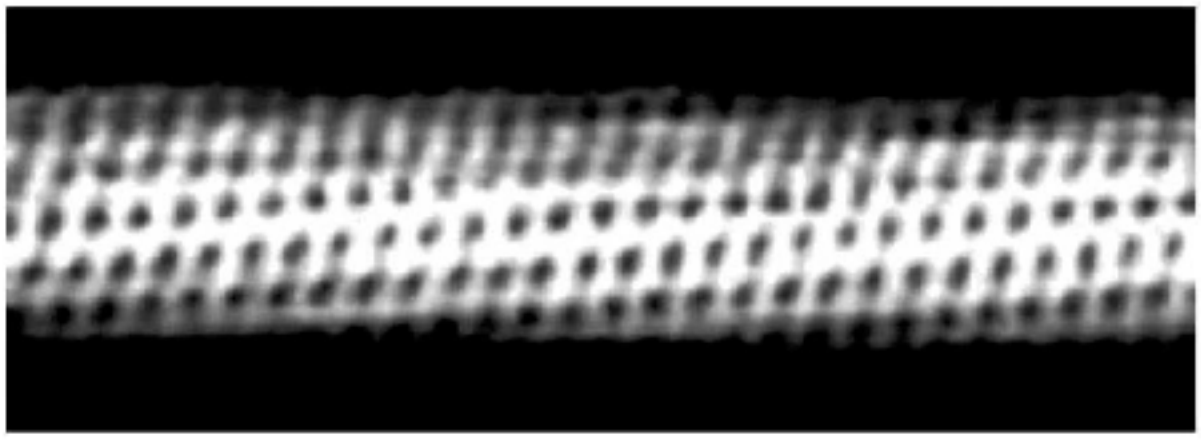
14. You wish to track the motions of two proteins within a cell. To protein A you attach a quantum dot that emits yellow light, and to protein B, a quantum dot of the same substance that emits blue light. Which quantum dot is larger? Explain. (3)

15. The following Figures show atomically resolved STM images of CNTs. The arrow is in the direction of the tube axis. Determine whether the CNT is a zigzag, armchair or chiral type in each case. (1.5+1.5)

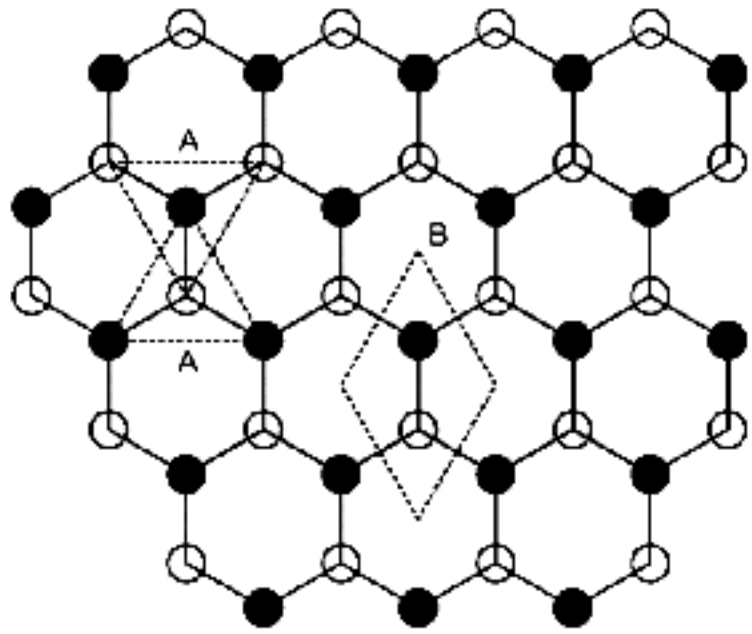
(i)



(ii)



16. The structure of graphene consists of carbon atoms located at the corners of Hexagons. The structure can also be looked at as consisting of two interpenetrating triangular lattices (shown as A). Show that this kind of structure of the graphene also gives 2 atoms per unit cell. (2)



17. In the following, the chiral vectors of some CNTs are given:

(i) $c = 9\ a_1$ (ii) $c = 9\ a_2$ (iii) $c = 9a_1 + 9a_2$ (iv) $c = 10a_1 + 10a_2$ (v) $c = 10a_1 + 9a_2$ and (vi) $c = 9a_1 + 7a_2$

(a) What is the type of nanotube (zig-zag, arm-chair, chiral) formed in each case? (6)

(b) Arrange these tubes in the order of increasing diameter. (6)

18. Vectors along the circumference of some nanotubes are: $6a_1 + 6a_2$; $5a_1$; $5a_1 + 5a_2$; $6a_1 + 3a_2$; $11a_1 + 7a_2$

    (a) Write the type of nanotube in each case. (5)

    (b) Which of these tubes is metallic and which is semiconducting? Why? (5)

19. (a) What are the C – C – C bond angles in diamond? (b) What are they in graphite (in one sheet)? (1+1)
20. Look up the diameter of a silicon atom, in pm. The latest semiconductor chips have fabricated lines as small as 14 nm. How many silicon atoms does this correspond to? (2)