Topics in Nanosciences
Assignment - 1

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Q1) * Tyres and other rubber products:
Nanomaterials like CARBON BLACK are often used to strengthen the rubber in tyres

* Medical devices and antibacterial agents
Silver nanoparticles are used as antibacterials for dressing wounds & is capable of killing a broad range of microbes.

* Paints & coatings
Nanoscale Titanium Dioxide and Silicon Dioxide are used in commercial paint products.

Q2) * Quantum Dots:
These are man-made nanocrystals that can transport electrons. These electrons present in the DOT occupy discrete energy levels. Basically, if all the three dimentions of the nanostructure are at nanoscale, then it is called a QUANTUM DOT.

* Quantum WIRE:
If TWO Dimensions of the 3D nanostructure are at nanoscale, then it is called a Quantum Wire.

* Quantum Well:
If only ONE dimension of the 3D nanostructure is at NANOscale, then it is called a Quantum Well.

quantum Dot → 3D.

Hence, quantum wires are 2D nanostructures (because only two dimensions are at nanoscale).
IIIly, quantum well is 1D nanostructure.

Q3) The melting temperature of Gold DECREASES when particle dimensions are reduced to the nanoscale range. Generally, Au melts at 1064°C, but for nanoparticles, it comes down to 430°C.

Q4) As we saw in q3, if all three dimensions of nanostructure are at nanoscale, it's called Quantum Dot. These 'Dots' produce a rarefied structure that resembles $\boxed{\text{discrete electronic states}}$ found in single atoms. They are too sparse to create continuous valence and conduction bands.

∴ Electrons occupy discrete ~~energies~~ energy levels and quantum dots are called "artificial atoms".

Q5) This material is a METAL. It's given that the uppermost level of the electron is partially filled, which means that electrons can move freely, and CONDUCTION is possible.

Also, band gap given is 0.8eV, which is very less. Metals generally have very small band gaps or none, since their valence and conduction bands overlap. Hence, this material is metal.

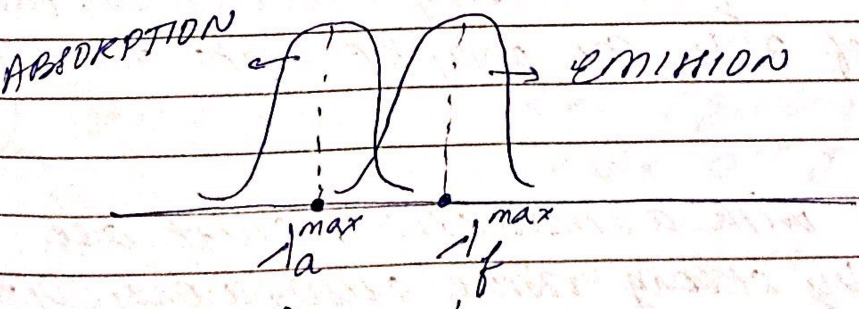
*

Q6) given that uppermost band is completely filled, which implies conduction isn't possible.
The Band Gap is 8eV, and typically, insulators have band gaps > 4eV. So this material is an $\boxed{\text{INSULATOR}}$. (large energy reqd. to send $\bar{e}$ to conduction band)

* If band gap is only 0.8eV, then the material is a $\boxed{\text{SEMI-CONDUCTOR}}$. semiconductors generally have band gaps < 4eV and electrons can easily be sent to the conduction bands with very little energy!

Q7) * In fluorescence Spectroscopy, the Stokes Shift is the difference between the spectral position of the maximum of the first absorption band and the maximum of the fluorescence emission.

* Expressing this in wavelength,
Stokes Shift ∋ $\Delta\lambda = \lambda_f^{max} - \lambda_a^{max}$



The diff. between the two is $\Delta\lambda$, which is the Stokes Shift.

Q8) FALSE!
(a) ~~[illegible]~~. As particle size decreases, band gap INCREASES

(b) FALSE!
As particle size decreases, band gap increases and hence, the wavelength decreases.

(c) TRUE! A nanoparticle with smaller band gap can be made smaller to increase the band gap! Hence, even if band gap is less, we can make a correctly-sized nanoparticle to ↑ the band gap.

∴ (a) False (b) False and (c) True.

Q9) * For quantum dots (QD's), a single light source can be used to excite multiple colours of fluorescence emission, causing a LARGE Stokes shift and improving sensitivity. Whereas, the Stokes shift of QD's can only be upto 300-400 nm.

* Organic dyes with a small Stokes shift are often buried by strong tissue autofluorescence. But QD signals, due to their large Stokes spectral shift, are clearly recognizable above the background.

* QD signals are ALSO more stable against photobleaching.

Q10) * Quantum Dots (QD's) are better suited as fluorescent probes due to
(1) optical tunability
(2) multi-colour emission
(3) Better photostability position.

* Under high-intensity illumination conditions, they have greater sensitivity and spatial resolution, as compared to organic fluoroprobes.

* Also, QD's with organic capping are even better, since they have a core crystal with an inorganic capping with outer organic group, which help during QD conjugation.
For instance, ZnS capped CdS is 20 times brighter than rhodamine (an organic dye) and is also 100 times more stable to photo-bleaching.

Hence, we prefer QD's to organic fluoroprobes.

Q11) Band gap = 2.26 eV (given)
$= 2.26 \times 1.6 \times 10^{-19}$ J.

$\therefore h\nu = \frac{hc}{\lambda} = 2.26 \times 1.6 \times 10^{-19}$

$\Rightarrow \lambda = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{2.26 \times 1.6 \times 10^{-19}}$

$\simeq$ 549 nm $\rightarrow$ This corresponds to λ of GREEN LIGHT

(b) We have seen earlier in q8 that for semiconductor QD's, as size decreases, the band gap increases.

∴ YES, appropriately size QD's would be capable of emitting blue light. It would require a larger band gap, so we can reduce the size of QD accordingly.

(c) Yes; using the same logic as above, we can use larger QD's to emit RED light (which have smaller band gap).

The above answer is assuming that we have GaP quantum dots. If NOT, then red light wouldn't be possible because E(red) < E(green).

But blue would be possible, since E(blue) > E(green) so we can excite it using photons of larger energy.

Q12) (B) correctly describes the difference b/w graphene and graphite.

Graphene - single sheet of C atoms.

Graphite - many larger sheets of C atoms.

Q13) The most supportive evidence is (B) Buckyballs have a well-defined atomic structure and molecular weight.

Hence, they're actual molecules and NOT extended materials.

Q14) We know that, smaller the QD, higher the band gap, and smaller the wavelength.
Blue has shorter wavelength (λ) as compared to yellow. Hence, its corresponding QD would be smaller than yellow. ∴ A is larger.

Hence, Protein (A) (yellow) QD will be LARGER than Protein B.

Q15)
(i) The CNT here is ARM-CHAIR type.
This is because the axis is HORIZONTAL.
Hence, armchair.

(ii) The CNT given is CHIRAL type. This is because the hexagons are arranged along a helix on the tube surface.

Q16) * In this interpretation of the graphene structure, we can see that each of the 6 atoms in hexagonal unit cell are shared by 3 unit cells.

* Hence, the unit cell has $6/3 = 2$ atoms per unit cell.

PTO

Q17)

(a) Types of Nanotubes formed:

(i) $c = 9a_1$ Zig Zag.

(ii) $c = 9a_2$ Zig Zag.

(iii) $c = 9a_1 + 9a_2$ ARM-CHAIR.

(iv) $c = 10a_1 + 10a_2$ ARM-CHAIR.

(v) $c = 10a_1 + 9a_2$ Chiral

(vi) $c = 9a_1 + 7a_2$ Chiral.

(b) Diameter of nanotube $= \dfrac{\sqrt{3}\, a_{c-c} \sqrt{n^2 + mn + m^2}}{\pi}$

$\therefore$ Diameter $\propto \sqrt{n^2 + mn + m^2}$

We compute $\sqrt{n^2+mn+m^2}$ for each case

(i) 9 (iv) $10\sqrt{3} \simeq 17.32$

(ii) 9 (v) $\sqrt{271} \simeq 16.46$

(iii) $9\sqrt{3}$ (vi) $\sqrt{193} \simeq 13.89$

$\simeq 15.58$

$\therefore$ Order of $\uparrow$ Diameter.

(i) = (ii) < (vi) < (iii) < (v) < (iv).

Q18)

(a) $6a_1 + 6a_2$: ARM-CHAIR (m, m)

$5a_1$: Zig-Zag. $(m, 0)$

$5a_1 + 5a_2$: ARM-CHAIR. (m, m)

$6a_1 + 3a_2$: Chiral (m, n)

$11a_1 + 7a_2$: Chiral (m, n)

(b) CNT's which have $n = m$ are ~~metl~~ metallic.
If $n - m = 3j$ (j is a non-zero int)
then it's "nearly metallic"
else
a semi-conductor with large band gap.

$\therefore$ $6a_1 + 6a_2$: metallic ($n = m$)
$5a_1$: semi-conductor, large gap.
$5a_1 + 5a_2$: metallic ($n = m$)
$6a_1 + 3a_2$: Nearly metallic ($6 - 3 = 3j$
$= 3 * 1$)
$11a_1 + 7a_2$: $11 - 7 = 4 \neq 3j$.
Hence, semi conductor with large gap!

"Nearly metallic" $\rightarrow$ means semiconductor with tiny band gap.

Q13) (a) In Diamond, carbon atoms exist in sp^3 bonded structure which is tetrahedrally coordinating, resulting in a C-C-C bond $\angle$le of $109.5°$.

(b) For a single sheet in graphite, the carbon atoms are sp^2 hybridized, which results in a triagonal planar geometry, giving a C-C-C angle of $120°$

$\therefore$ (a) $109.5°$ (sp^3)
(b) $120°$ (sp^2)

Q20) Diameter of Silicon Atom = 220 pm

Length of fabricated lines = 14 nm.

$\therefore$ Number of Si atoms $= \frac{14 \times 10^{-9} m}{220 \times 10^{-12} m}$

$= \frac{14}{22\cancel{0}} \times 100\cancel{0} \simeq 63.63$

$\simeq$ 63 atoms.

Hence, it corresponds to 63 atoms!