Topics in Nanosciences
Mid-Term Examination: Monsoon 2022
IIIT-Hyderabad

Full Marks: 45

Time: 1:30 hr

Use of non-programmable scientific calculator is allowed.

Q1. (a) The fine powder of aluminum metal is used as fuel for rocket engines whereas frying pans made of aluminium metal are safely employed for everyday cooking. How can you justify it? (3)

(b) For a spherical particle of radius R, derive an expression for the ratio of surface atoms (N_s) to total atoms (N_v). Show the steps of calculations and assume the radius of an atom is r. (3)

(c) Show that for a gold nanoparticle (Au atomic radius = 0.179 nm), the ratio of surface atoms (N_s) to total atoms (N_v), i.e., $N_s/N_v \approx 1/R$ (when the particle radius, R, is given in nm unit). (2)

Based on this, calculate how many gold atoms will be at the surface of a spherical gold nanoparticle of radius, 5 nm, having around 8,000 total atoms. (1)

Q2. (a) Name three characterization techniques that can be used to resolve the hexagonal arrangement of atoms in the graphene. (1.5)

(b) Briefly describe the working principles (with schematic diagram) of a scanning probe microscopy (SPM) technique used for the characterization of nanomaterials. (3.5)

(c) What do you mean by the "sintering (firing)" and how is it related to nanoscience? Explain with the help of an appropriate thermodynamic equation. (1,3)

Q3. (a) What is meant by a "superhydrophobic self-cleaning surface"? Write down the conditions in terms of the dynamic contact angles and the roll-off angles. (1,2)

(b) The air trapped within the structures on the surface plays a great role in creating a "superhydrophobic self-cleaning surface". Justify the statement with the help of an appropriate model. (6)

Q4. (a) What happens to the solubility of nanoparticles when their size decreases? (1)

(b) Derive an appropriate thermodynamic equation to describe the effect of the particle size on its solubility and justify your answer (to the above question) with the help of this thermodynamic equation. (6)

(c) Why are fullerenes not generally considered to be aromatic? (2)

Q5. (a) Vectors along the circumference of some nanotubes are given as follows:

$6a_1 + 6a_2$; $5a_1$; $6a_1 + 3a_2$; $11a_1 + 7a_2$.

(i) Write the type (chiral, zigzag, etc.) of nanotube in each case. (2)

(ii) Which of these tubes is metallic and which is semiconducting? Why? (2,2)

(b) The semiconductor CdSe has a bandgap of 1.74 eV. Quantum dots of varied sizes of CdSe passivated with ZnS are used to produce fluorescence of different colors. Determine the size (in **nm**) of the CdSe quantum dot core required to produce fluorescence at a wavelength of 400 nm (violet). Use the electron and hole effective masses given as $m_e^* = 0.13m_0$, and $m_h^* = 0.45m_0$, where m_0 is the rest mass of the electron. (3)

Given:

1 eV = 1240/(wavelength in nm).

h (Planck's constant) = 6.626×10^{-34} J.s

1 eV = 1.6×10^{-19} J

$m_0 = 9.11 \times 10^{-31}$ kg

$$E = E_g + \frac{h^2\pi^2}{2\mu r^2}$$