MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

THIRD YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN ANALYTICAL CHEMISTRY

SAN 303: FUNDAMENTALS OF NANOTECHNOLOGY

DATE: 29/8/2022   **TIME: 2.00-4.00 PM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory**.
- Answer any **two** questions from section **B**.
- Plank's constant (h) = 6.626 x10^{-34} J/mol
- Speed of light (C) = 3x10^8 m/s
- Electron mass (m) = 9.1 x 10^{-31} kg

SECTION A – COMPULSORY (30 MARKS)

QUESTION ONE (30 MARKS)

a) Define the following terms as used in nano-chemistry giving one example of its application in each case.

    i.   Nanofabrication. (2 marks)

    ii.   Nanocomposites. (2 marks)

b) Differentiate between the terms, band gap and conduction band. (2 marks)

c) Briefly explain

    i.   The relationship between silver nanoparticle size and color of wavelength emitted. (2 marks)

    ii.   How the above (ci) relationship relates to energy. (2 marks)

    iii.   The trend of nanoparticle size and energy. (2 marks)

    iv.   How the kinetic energy of an electron changes with increasing particle size of various nanoparticles. (2 marks)

    v.   Effect of particle size on maximum wavelength of absorbance and molar extinction coefficient of gold nanoparticles. (2 marks)

d) Outline three practical applications of quantum dots. (6 marks)

e) Explain the two main reasons as to why the properties of materials can be different at the nanoscale level. (4 marks)

f) Compare and Contrast Scanning Electron (SEM) and Transmission Electron (TEM) as used in nanoscience. (4 marks)

SECTION B: ANSWER ANY TWO QUESTIONS (EACH QUESTION IS 20 MARKS)

QUESTION TWO (20 MARKS)

a) By drawing a representative plot of absorbance versus concentration using self-generated data, explain

    i.   How one could use this plot to determine the molar extinction coefficient and concentration of the analyte being investigated. (5 marks)

    ii.   Which other method can one use to determine the molar extinction coefficient? Explain your answer. (2 marks)

iii. Calculate the de-Broglie wavelength of an electron moving at a speed of 7×10^3 km/s. (2 marks)

b) With relevant examples, explain the following terms as used in nanotechnology.

i. Fermi energy. (2 marks)

ii. Quantum confinement. (4 marks)

c) A student was given two quantum dot solutions by his laboratory instructor. Solution one emits a red color of approximate wavelength 700×10^{-9} m. Solution two emits a yellow color of approximate wavelength 560×10^{-9} m. Determine which solution has a larger energy and higher frequency. How much larger is its energy? (5 marks)

QUESTION THREE (20 MARKS)

a) Briefly explain the principles of atomic force microscopy (AFM) and draw a schematic diagram of AFM showing the interactions between tip and surface and the tunneling current generated from tip and surface. (5 marks)

b) Using two relevant examples, explain the application of scanning tunneling microscopy in nanoscience. (4 marks)

c) STEM-EELS works by combining two instruments, obtaining an image through STEM and applying EELS to detect signals on the specific selected area of the image.

i. What does the abbreviation STEM-EELS stand for? (1 mark)

ii. Briefly explain the basics of STEM-EELS laying emphasis on electrons-sample interactions. (4 marks)

iii. List two advantages and one disadvantage of STEM-EELS instrument. (3 marks)

d) In a colorimetric experiment, a student was given two samples one had a brilliant-bright color while the other was very dull colored. Draw a molar extinction graph that would be observed for the two samples. (3 marks)

QUESTION FOUR (20 MARKS)

a) Aerogels are known as the best thermal insulation material because they can neutralize the two mechanisms of heat transfer namely convection and conduction. Briefly explain this property of aerogels. (2 marks)

b) Nanotechnology is used in sectors of science and technology such as energy, medicine and drugs, nanobiotechnology, nanodevices, optical engineering among others.

    i. Explain three (3) applications of UV-visible spectroscopy in analysis of nanoparticles. (6 marks)

    ii. List and explain the two formation processes that take place during chemical synthesis of nanomaterials. (4 marks)

c) Using relevant equations explain how you can chemically synthesize silver nanorods using silver nitrate as a precursor. (4 marks)

d) Which relevant technique can a student use to confirm the successful synthesis of the silver nanorods in Q4c above? Explain your answer. (2 marks)

e) Analytical Chemistry students carried out spectrophotometric experiments using nanosized and bulk materials. The results obtained showed that nanoparticles emit colors with an equivalent energy proportional to the nanoparticle size unlike the bulk materials. Explain this observation. (2 marks)

QUESTION FIVE (20 MARKS)

a) Define aerogels and list four types of aerogels. (3 marks)

b) Sol-gel chemistry offers a flexible approach to preparing advanced materials using colloidal solutions (sol) as starting materials.

    i. Briefly describe the three main sol-gel process steps. (6 marks)

    ii. List two advantages of sol-gel method. (1 mark)

c) With well labelled schematic diagrams, briefly explain the principles of the following techniques as used in characterization of nanoparticles

    i. Fourier Transmission Infrared (FT-IR) technique. (5 marks)

    ii. Surface Electron Microscopy. (5 marks)