MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

FOURTH YEAR FIRST SEMESTER EXAMINATION FOR

BACHELOR OF EDUCATION (SPECIAL NEEDS EDUCATION)

BACHELOR OF EDUCATION (SCIENCE)

SCH 404: INSTRUMENTAL METHODS

DATE: 29/8/2022 **TIME: 8.30-10.30 AM**

INSTRUCTIONS:

- The paper consists of **two** sections.
- Section **A** is **compulsory** (30 marks).
- Answer any **two** questions from section **B** (each 20 marks).

Useful data

Planck constant = 6.625×10^{-34} JS

$c = 3 \times 10^{8}$ ms^{-1}

$m = 10^{9}$ nm

QUESTION ONE (30 MARKS)

a) Spectroscopy deals with the interaction of matter with electromagnetic radiation which results in the absorption of radiation which can be used to characterize the substance and at the same time quantify it by the amount of radiation absorbed. Explain how the following parameters vary in the various regions of electromagnetic spectrum (from left to right). (6 marks)

i. Velocity

ii. Frequency

iii. Energy

iv. Wavenumber.

b) The UV-Vis spectroscopy is concerned with the interaction of molecules which result from chemical bonding as a result of overlap of atomic orbitals resulting in molecular orbitals. The absorption of radiation in the UV-Vis region involves the transition of an electron from a molecular orbital of lower energy to that of higher energy.

i. With the help of an energy level diagram, show how the molecular orbitals are arranged from the lowest to the highest energy. (3 marks)

ii. Show the allowed energy transitions which occur between the molecular orbitals in b (i) above. (2 marks)

iii. Show which transitions require the least and most energy during absorption of radiation, respectively. (2 marks)

c) Given the following molecules ethane, methanol, ethylene and benzene.

i. Draw their chemical structures, respectively. (2 marks)

ii. Indicate the possible electronic transitions that are expected in the respective molecules. (2 marks)

iii. Comment on the trend in the amount of energy absorbed by the respective molecules. (2 marks)

d) Explain how a molecule absorbing in the UV region can be modified to absorb in the visible region of the electromagnetic spectrum. (2 marks)

e) The equation governing the amount of electromagnetic energy absorbed by substance is governed by the Beer -Lambert law.

i. Derive the Beer Lambert law based on the incident radiation, the transmitted radiation, the concentration of the absorbing solution, its molar absorptivity and pathlength of the sample cell.

(2 marks)

ii. State various components of a UV-VIS spectrometer mentioning what material makes up each component of the spectrophotometer. (3 marks)

f) The typical range of a UV-Vis spectrophotometer is 195 nm to 900 nm. What is its corresponding frequency range in Hertz? (4 marks)

QUESTION TWO (20 MARKS)

a) Infrared (IR) spectroscopy generates a spectrum that gives information on the structure of a compound.

i. Explain in details what a molecule requires to be IR active. (2 marks)

ii. State two equations which respectively predict the number of fundamental absorption bands for non-linear and linear molecules, respectively. (2 marks)

iii. State three reasons why the number of fundamental absorption bands predicted in part (ii) are more than those that are actually observed an IR spectrophotometer. (3 marks)

b) The energy absorbed by an IR active molecule is determined by the following equation,

$\ddot{\upsilon} = 1/2\pi c(K/\mu)^{1/2}$. Where $\mu = m_1m_2/m_1+m_2$.

i. Show how the above equation is derived from the following equation, $v = 1/2\pi(K/\mu)^{1/2}$.

(2 marks)

ii. Explain from the equation above how the values of K and μ, respectively affect the value of $\ddot{\upsilon}$. (2 marks)

iii. Explain the main factor that affects the intensity of the fundamental absorption bands of molecules. (2 marks)

iv. What are absorption overtones in the IR spectrum and how are they generated? (2 marks)

c) The IR spectrum of a compound is divided into two major regions, the group frequency region and the finger print region.

i. Describe what each region of the IR spectrum represents in details. (3 marks)

ii. How do the two regions together enable the identification of the compound from which the spectrum is generated? (2 marks)

QUESTION THREE (20 MARKS)

a) i. Explain in details how the spinning nucleus in applied external magnetic field of strength of H_o interacts with a specific wavelength of frequency called resonance frequency to generate NMR peaks. (6 marks)

ii. Explain how nuclei of atoms of various elements are assigned the spin value I which determines if a nucleus of an atom is NMR active. (4 marks)

b) The frequency V_o, which is the resonance frequency at which the spinning nucleus absorbs in the radio region is given by the equation $V_o = \gamma/2\Pi\ (B_o)$ where γ is the gyromagnetic ratio of the spinning nucleus and is closely related with the magnetic moment of the spinning nucleus.

i. From the equation above, explain why different nuclei of atoms of different elements will have different values of V_o. (2 marks)

ii. Explain what is chemical shift and how chemical shift values are assigned to a compound. (4 marks)

iii. Explain clearly why ^{1}H NMR instrument is more sensitive than the ^{13}C NMR instrument. (2 marks)

iv. What advantages does ^{13}C NMR Instrument have over the ^{1}H NMR instruments? (2 marks)

QUESTION FOUR (20 MARKS)

a) i. Explain in details the theory behind the atomic spectroscopy which embraces AAS,

AES and AFS. (4 marks)

ii. Briefly explain the different principles in the AAS, AES and AFS. (6 marks)

iii. Explain how the Hollow Cathode Lamp (HCL) functions and what is its role in the Atomic spectrometry. (4 marks)

iv. Distinguish clearly between Flame photometry and the Electrothermal atomic spectroscopy. (6 marks)

QUESTION FIVE (20 MARKS)

a) Mass spectrometry (MS) is a powerful analytical technique widely used by chemists, biologists, medical researchers, and environmental and forensic scientists, among others.

i. Describe how the two methods, Electron and Chemical ionization methods are used in the gas phase to generate ion fragments for generation of mass spectra of compounds. (8 marks)

ii. Explain main differences between the two methods and explain why they are considered to be complementary to each other. (4 marks)

b) The following spectra A and B are for 2-methyl-2-hexene and 2-heptene, not necessarily in that order. Decide which spectrum belongs to the correct molecule. Explain your answers. (8 marks)

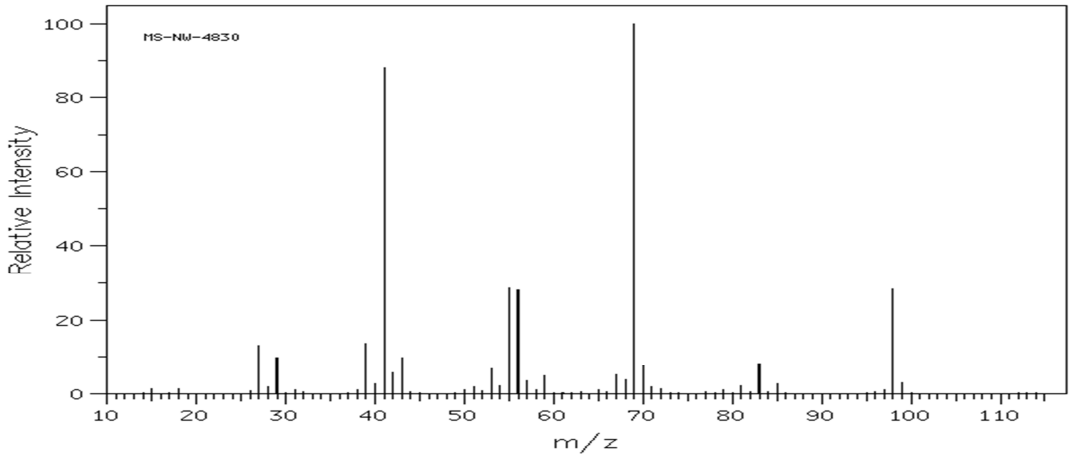

Figure A

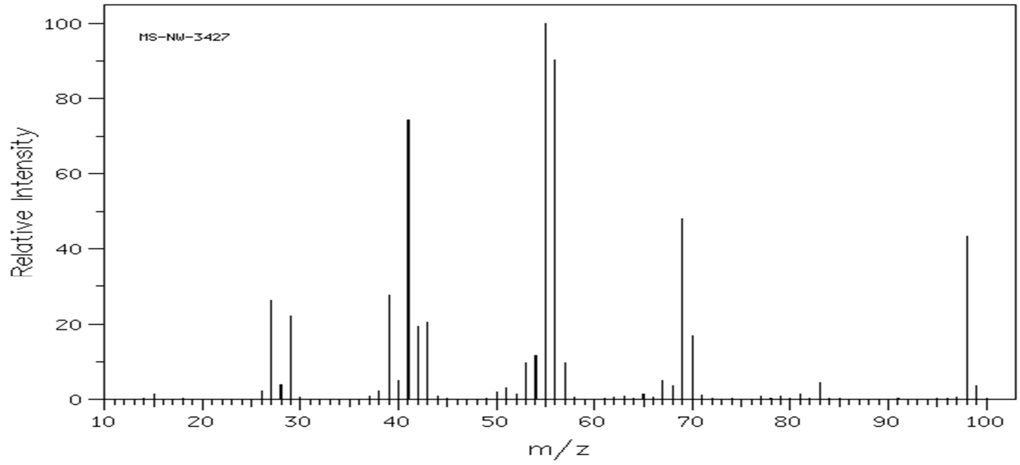

Figure B