MACHAKOS UNIVERSITY

University Examinations for 2021/2022 Academic Year

SCHOOL OF PURE AND APPLIED SCIENCES

DEPARTMENT OF PHYSICAL SCIENCES

SECOND YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (TELECOMMUNICATION INFORMATION TECHNOLOGY)

BACHELOR OF EDUCATION (SPECIAL NEEDS EDUCATION)

BACHELOR OF SCIENCE IN ANALYTICAL CHEMISTRY

BACHELOR OF SCIENCE (MATHEMATICS)

BACHELOR OF EDUCATION (SCIENCE)

SCH 203: THEORY OF SPECTROSCOPIC METHODS

DATE: **TIME:**

INSTRUCTIONS:

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

CONSTANTS

Given that, $B = \frac{h}{8\pi^2 Ic}$ and $I = \mu r_o^2$, $J_{max} = \sqrt{\frac{kT}{2Bhc}} - \frac{1}{2}$, where $h = 6.626 \times 10^{-34}$ Js, velocity of light, c = 2.998×10^8 m/s, Boltzmann constant, k = 1.38×10^{-23} J/K, Avogadros constant, L = 6.023×10^{23} particles and $\pi = 3.14$, $k = 4\pi^2 c^2 \mu \bar{\omega}_e^2$ where k is Force constant, 1Js = 1 Kgm^2s^{-1}, 1N/m = $10^3 g/s^2$.

SECTION A (COMPULSORY)

QUESTION ONE (30 MARKS)

a) All electromagnetic radiations are propagated with the same velocity but they differ in their wave length and correspondingly in their frequency resulting to different regions of the electromagnetic spectrum. Define the underlined spectroscopic terms. (4 marks)

b) The wavelength of radiation absorbed during a spectroscopic transition is 35 μm. Determine the: -

i) Frequency (2 marks)

ii) Wavenumber (2 marks)

iii) Energy of the radiation? (2 marks)

c) The rotational spectrum of $^{79}Br^{19}F$ shows a series of lines 0.71433 cm^{-1} apart. Given that the masses ^{79}Br and ^{19}F are 79.90 and 19.00 amu respectively, calculate

i) the rotational constant B (1 mark)

ii) the moment of inertia. (4 marks)

iii) the bond length of the molecule (4 marks)

d) The total energy of a molecule is the sum of translational, rotational, vibrational and electronic energies. It is found that the translational energy is negligibly small.

(i) Which one of the four types of energies is continuous? (1 mark)

(ii) The transitions of energies can take place only between the three quantized energy levels of a molecule resulting to a molecular spectrum. Using a diagram illustrate a molecular spectrum resulting from the three quantized energy levels of a molecule. (4 marks)

e) Spectrometric instruments are widely applied in laboratory analytical instrumentation both in research and industrial institutions. Describe any three applications of Infra-Red spectroscopy. (6 marks)

SECTION B (ANSWER ANY TWO QUESTIONS)

QUESTION TWO (20 MARKS)

a) Which of the following molecules have a pure rotational microwave spectrum: (a) H_2, (b) CO, (c) IF, (d) Cl_2? Explain. (3 marks)

b) The rotational constant of CO is 1.9314 cm^{-1}. What is the J value of the rotational level with maximum population at 20°C? (4 marks)

c) Under Raman spectra, when an intense beam of light is passed through a transparent medium, some of the light is scattered by the molecules of the medium. Describe the two types of scattering that can be observed under Raman spectra. (4 marks)

d) Explain the following terms as used in Raman spectroscopy (9 marks)

i) Polarizability
ii) Inelastic collision
iii) Stokes' radiation
iv) Hot band transition
v) Prolate ellipsoid
vi) Raman anti-stokes lines

QUESTION THREE (20 MARKS)

a) The IR spectrum of HCl shows a strong line at 2886 cm^{-1}, a weak one at 5668 cm^{-1} and a very weak one at 8347 cm^{-1}. Calculate the force constant of HCl. (10 marks)

b) By using well labeled potential energy curve diagrams, differentiate between harmonic and anharmonic oscillations of a diatomic molecule undergoing vibrations. (10 marks)

QUESTION FOUR (20 MARKS)

a) Differentiate between atomic and molecular spectroscopy. (6 marks)

b) Rotational spectra are used to determine the bond lengths in diatomic molecules (AB). Such molecules have a permanent dipole moment and produce electric field while rotating. The first approximation in the study of the rotational spectrum of a diatomic molecule is that the molecule behaves like a rigid rotator. Using an illustration of a rigid rotator with two spherical particles of unequal atomic masses m_1 and m_2 and located at fixed distances x_1 and x_2 respectively from the center of gravity of the system C. Derive systematically the equation, which can be used to calculate the moment of inertia, I and hence the bond length, x in the diatomic molecule. (10 marks)

c) An electromagnetic radiation is an alternating electrical and associated magnetic force in space. Thus, an electromagnetic wave has an electric component and magnetic component. The two components oscillate in planes perpendicular to each other and perpendicular to the direction of propagation of the radiation. Using the corrent, symbols deduce the relationship between wavelength, wavenumber and frequency of an electromagnetic wave. (4 marks)

QUESTION FIVE (20 MARKS)

a) In mass spectroscopy, the ion source is where the sample of interest is ionized with a positive or negative charge and converted into the gas phase. Briefly explain how the Electron Impact and Field ionization sources differ from one another as applied in Mass Spectroscopy. (4 marks)

b) Using an example in each case, briefly explain how the concept of fluorescence, phosphorescence and chemiluminescence works under photo physical processes. (8 marks)

c) Considering the molecular vibrations of carbon dioxide, CO_2, with respect to symmetric and asymmetric stretch as well as in plane and out of plane bending, show whether or not these vibrations result to an Infra-Red active mode for CO_2 molecule. (8 marks)