



MERU UNIVERSITY OF SCIENCE AND TECHNOLOGY

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UNIVERSITY EXAMINATIONS 2022/2023

FOURTH YEAR, SECOND SEMESTER EXAMINATION FOR THE DEGREE OF
BACHELOR OF SCIENCE IN PHYSICS

SPH 3452: MOLECULAR PHYSICS

DATE: APRIL 2023

TIME: 2 HOURS

INSTRUCTIONS: Answer Question ONE and any other TWO questions.

The following constants may be useful

$$\text{Bohr magneton}(\beta_e) = 9.27 \times 10^{-24} \text{JT}^{-1}$$

$$\text{plank's Constant}(h) = 6.626 \times 10^{-34} \text{JS}$$

$$\text{Nuclear Magnetron}(\beta_N) = 5.05 \times 10^{-27} \text{JT}^{-1}$$

$$g_{\text{proton}} = 5.585$$

QUESTION ONE (30 MARKS)

- Define isotope shift and state the effects that cause it. (3 Marks)
- Explain how Doppler broadening occurs clearly outlining while the spectrum is a broad one and not continuous. (5 Marks)
- State any three types of substances that can be analysed using Electron Spin Resonance. (3 Marks)

- d) Calculate the ratio of the number of protons in the upper to that in the lower state in a magnetic field of 2T a temperature of 298K. (4 Marks)
- e) Explain what is means by isomer shift and how it is applied in Mossbauer spectroscopy. (4 Marks)
- f) What are spectral top molecules (2 Marks)
- g) For Fe^{57} nucleus with emission energy of $E = 14400\text{eV}$, calculate the recoil energy. (4 Marks)
- h) The vibrational frequency of H^1Cl^{35} is $8.97 \times 10^{13}\text{Hz}$. find the force constant for the HCl bond. (5 Marks)

QUESTION TWO (20 MARKS)

- a) The sodium atom ($Z = 11, A = 23$) shows hyperfine structure splitting for transition $^2\text{S}_{1/2}$ to $^2\text{P}_{3/2}$. Given that the spin angular momentum is $3/2$.
- Show all the states for the two terms. (8 Marks)
 - Draw a schematic diagram of the hyperfine structure (6 Marks)
 - Explain the source of the splitting (2 Marks)
- b) For potassium D line (7681.94A), the Doppler Broadening is 770 MHz. Calculate the temperature of Potassium vapours ($Z=19, A=39$) (4 Marks)

QUESTION THREE (20 MARKS)

- a) The fundamental vibrational frequency of Cl_2 molecule is at 2940.8cm^{-1} for a molecule in which the atomic mass for each atom is 35.
- Find the corresponding fundamental vibrational frequency for same molecule in which one of the atoms has atomic mass of 37 and other 35. (8 Marks)

- ii. Determine the separation of spectral line (2 Marks)
- b) The $J = 0 \rightarrow J = 1$ rotational absorption line occurs at $1.153 \times 10^{11} \text{ Hz}$ in $\text{C}^{12}\text{O}^{16}$ and at $1.102 \times 10^{11} \text{ Hz}$ in $\text{C}^{\times}\text{O}^{16}$. Give that mass $\text{C}^{12} = 12U$, mass of $\text{O}^{16} = 15.994191 U$, find the mass number of the unknown carbon isotope. (10 Marks)

QUESTION FOUR (20 MARKS)

- a) Explain the differences between fine structure and hyperfine structure (5 Marks)
- b) The chemical shift of the CH_3 proton in acetaldehyde is 2.2 and that of CHO is 9.8. what is the difference in local magnetic field between the two regions of the molecule when an external field of 7.0T is applied. (8 Marks)
- c) Compute the population of two states of an electron spin in a magnetic field of 0.6T at 360K ($g = 2$). (7 Marks)