MAASAI MARA UNIVERSITY

REGULAR UNIVERSITY EXAMINATIONS

2022/2023 ACADEMIC YEAR SECOND SEMESTER

SCHOOL OF PURE APPLIED AND HEALTH SCIENCES

MASTER OF SCIENCE IN CHEMISTRY

COURSE CODE: CHE 8213

COURSE TITLE: ATOMIC AND MOLECULAR SPECTROSCOPY

DATE: **TIME:**

INSTRUCTIONS TO CANDIDATES

Answer Question **ONE** and any other **TWO** questions.

QUESTIONONE (20 mks)

a) The wavefunction for the 2*s* orbital of a hydrogen atom is $N(2 - r/a_o)e^{-r/2ao}$. Determine the normalization constant N. **(3mks)**

b) Write the term symbols arising from the ground-state configurations of (a) Na and (b) F. **(4mks)**

c) To what orbitals may a 4*s* electron make electric-dipole allowed radiative transitions **(2mks)**

d) Calculate the average kinetic and potential energies of a 2s electron in a hydrogenic atom of atomic number Z **(4mks)**

e) When ultraviolet radiation of wavelength 58.4 nm from a helium lamp is directed on to a sample of xenon, electrons are ejected with a speed of 1.79 Mm s^{-1}. Calculate the ionization energy of xenon **(3mks)**

f) Calculate the moment of inertia of an H2O molecule around the axis defined by the bisector of the HOH angle (3). The HOH bond angle is 104.5° and the bond length is 95.7 pm **(3mks)**

g) Distinguish between singlet and triplet states **(1mk)**

QUESTION TWO (20 mks)

a) State the number and type of orbitals at n = 1, 2 and 3 respectively **(3mks)**

b) Describe the three types of atomic emission spectra **(6mks)**

c) An electronic transition takes place from n = 4 to n = 2. Calculate a) Wavelength b) frequency c) Energy emitted and state the name of the series (Take R_H = 109677 cm^{-1}, C = 3 x 10^8 ms^{-1}, h = 6.63 x 10^{-34}) **(5mks)**

d) Given the principal quantum number, n = 4, state the values of l and m_l for this shell **(2mks)**

e) The orbital wavefunction for a hydrogenic atom with z = 1 is given by the expression;

$$\psi = \frac{1}{(\pi a_o^3)^{\frac{1}{2}}} e^{\frac{-r}{a_o}}$$

Derive the wavefunction for a two electron system with electrons positioned at distance r_1 and r_2 respectively from the nucleus. **(3mks)**

f) Explain the Hund's rule **(2mks)**

QUESTION THREE (20 mks)

a) Distinguish penetration and shielding as used to describe atomic orbitals and list the s, p, d and f orbitals in the order of decreasing energy **(3mks)**
b) Calculate the effective nuclear charge of a Helium atom whose charge is 3.6875 C and shielding constant is 2. **(3mks)**
c) State and explain the electronic configuration of Nitrogen (Z = 7) **(3mks)**
d) Briefly explain the two factors that affect linewidths of spectral lines **(6mks)**
e) Calculate the spin–orbit coupling energy in the ground state of an alkali metal atom **(5mks)**

QUESTION FOUR (20 mks)

a) Which of the following transitions are allowed in the normal electronic emission spectrum of an atom: (a) 5d→2*s*, (b) 5*p*→3*s*, (c) 6*p*→4f **(3mks)**
b) Calculate the shortest wavelength line in the Paschen series (Take R_H = 109677 cm^{-1}) **(3mks)**
c) Explain the origin of spin–orbit coupling and how it affects the appearance of a spectrum. **(4mks)**
d) State the electronic configurations of a helium atom in the singlet and triplet states and explain the energy difference of the states **(4mks)**
e) Identify the levels of the configurations (a) p^1 and (b) f^1 **(2mks)**
f) Find the terms that can arise from the configurations (a) f^1d^1 and (b) d^3 **(4mks)**