PHYS 323

KISII UNIVERSITY

UNIVERSITY EXAMINATIONS
THIRD YEAR EXAMINATION FOR THE AWARD OF
THE DEGREE OF BACHELOR OF SCIENCE IN EDUCATION AND BACHELOR OF SCIENCE

SECOND SEMESTER 2021/2022
(JUNE – SEPTEMBER, 2022)

PHYS 323: ATOMIC AND MOLECULAR PHYSICS

STREAM: **Y3 S2** **TIME: 2 HOURS**

DAY: **WEDNESDAY** **DATE: 14/05/2022**

INSTRUCTIONS

1. ***Do not write anything on this question paper.***
2. ***Answer Question ONE (Compulsory) and any other TWO questions.***
3. ***The following constants may be useful:***

$\hbar = 1.055 \times 10^{-34}$ Kgm^2/s = 6.58×10^{-16}eV.s
h= 6.63×10^{-34}Js
Speed of light = 2.99979×10^8 m/s^2
Atomic mass of carbon-12 =12u
Atomic mass of Oxygen -16 = 16u
Mass of an electron, m_e=0.0005486u
Mass of neutron, m_n=1.008665u
Electron charge, e=$1.6021773 \times 10^{-19}$C
Rydberg constant R=0.011nm^{-1}
$\mathbf{1u = 1.66 \times 10^{-27}}$ Kg

QUESTION ONE [30MARKS]

a. Distinguish absorption and emission spectra by use of diagrams [4marks]

b. Calculate the longest wavelengths of the Lyman series. [3marks]

c. Define principal quantum number. [1mark]

d. Using de Broglie relation, derive Bohr condition $mvr = n\hbar$ for the angular momentum of an electron in a hydrogen atom. [3marks]

e. What is the electronic configuration of the following atoms? [2marks]
   (i) Na (Z=11),
   (iii) Zr (Z=40)

f. Calculate the $\lambda[K_\alpha]$ for Mg (Z=12)according to Moseley's law. [3marks]

g. Consoder Balmer series for the hydrogen atom to:
   (i) Find the longest-wavelength photon emitted and determine its energy. [4marks]
   (ii) Find the shortest-wavelength photon emitted in the Balmer series. [3marks]

h. Derive expression for total vibration energy in a molecule [6marks]

QUESTION TWO [20MARKS]

(a) Briefly explain the types of molecular bonds (10 marks)

(b) Figure below shows a diatomic molecule of masses m_1 and m_2 rotating about its center of mass at velocities v_1 and v_2 respectively.
   (i) Show that the rotation is quantized and that the allowed energy of rotation is given as

$$E_{rot} = \frac{l(l+1)\hbar^2}{2I} \qquad l = 0,1,2...$$

   where l is the rotational quantum number and I is the moment of inertia. [5marks]
   (ii) Find an expression for the moment of inertia if the axis of rotation passes through the center of mass and that atomic separation is R [5marks]

QUESTION THREE [20MARKS]

(a) (i) Find the wavelength of light emitted by hydrogen as predicted by Rydberg formula with n = 3 and n =2. [3marks]
   (ii) State three deficiencies of Bohr model [3marks]

(b) The electron in a hydrogen atom at rest makes a transition from the n =3 energy state to the n =2 ground state. Find the wavelength, frequency, and energy (eV) of the emitted photon. [4marks]

(c) By use of appropriate diagram describe the Frank Hertz experiment [10marks]

QUESTION FOUR [20MARKS]

(a) Calculate the magnetic energy and the Larmor frequency for an electron in the n=3 state of hydrogen atom in a magnetic field strength of B=2T. [3marks]

(b) Obtain an expression for the Bohr magneton. What is its value? [7marks]

(c) Evidence for space quantization was provided by the Stern–Gerlah experiment. Sketch and briefly describe the key features of the experiment. Explain what was observed in the experiment and give its implication. [10marks]

QUESTION FIVE [20MARKS]

(a) Distinguish between normal and Zeeman Effects. [2marks]

(b) Consider an atomic electron in the n = 4 state to determine the minimum magnitude angle Θ_L between vector L and the z-axis [6marks]

(c) Carbon monoxide (CO) absorbs energy due to atransition between the $l=0$ and $l=1$ rotational states.

(i) Calculate the reduced mass μ. (C=12 times, and O=16 times the unified atomic mass constant.) [3marks]

(ii) Calculate the interatomic distance for this molecule. [3marks]

(d) show that the total photon energy released by transiting electrons is given by $E = -\frac{E_R}{n^2}$ [6marks]