JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES

UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCES)

4TH YEAR SECOND SEMESTER 2023/2024 ACADEMIC YEAR

MAIN REGULAR

COURSE CODE: SPB 9406

COURSE TITLE: STATISTICAL THERMODYNAMICS

EXAM VENUE: **DATE:**

TIME: **EXAM SESSION:**

STREAM:

INSTRUCTIONS:

1. **Answer question 1 (Compulsory) in section A and ANY other 2 questions in Section B.**
2. **Candidates are advised not to write on the question paper.**
3. **Candidates must hand in their answer booklets to the invigilator while in the examination room.**

SECTION A (30 MARKS)

Question 1.

a. Explain what is meant by;
   i) Phase space (2 mark)
   ii) Microstate (2 marks)
   iii) Ensemble (2 marks)
b. Derive the equation for the Boltzmann's distribution and explain its significance (6 marks)
c. Find the value of translational partition for argon atoms confined in a box of volume 25.0 L at 298.15 K. The Boltzmann's constant is equal to 1.3807 x 10^{-23} JK^{-1} (6 Marks)
d. Derive an expression for the vibrational partition function (6 Marks)
c. Calculate C_v and C_p for 1.00 mol of $^{35}Cl_2$ at 298.15 K. (5 marks)

$\tilde{\nu}_e = 559.7\ cm^{-1}$.

SECTION B
Question 2 (20 marks)

a. The vibrational frequency of CO is equal to 6.5048 × 1013 cm−1.
   i. Find the value of the vibrational partition function at 298.15 K (4 Marks).
   ii. Find the vibrational contribution to the molar energy at 298.15 K (4 Marks).

b. Calculate the chemical potential and the Gibbs energy of 1.000 mol of $^{35}Cl_2$ at 298.15 K and 1.0 atm. (5 Marks).
c. Find the vibrational contributions to the thermodynamic energy, Helmholtz energy, and entropy of 1.000 mole of water vapor at 1.00 atm and 100°C. There are three vibrational normal modes, with frequencies 1.0947 × 1014 s^{-1}, 4.7817 × 1013 s^{-1}, and 1.1260 × 1014 s^{-1}. (7 Marks).

Question 3 (20 marks)

a. Derive an expression for the translational partition function (5 Marks)
b. Write Boltzmann formula for the entropy and explain what happens to *entropy* as the temperature is lowered (5 marks)
c. Calculate the molar entropy of helium gas at 1.000 bar pressure and 298.15 K (3 Marks).
d. Describe the basic postulates of Maxwell-Boltzmann (MB) Statistics (7 Marks).

Question 4 (20 marks)

a. Derive an expression for the rotational partition function (5 Marks)
b. Derive the Sackur–Tetrode equation and explain its significance (5 marks)
c. Calculate the vibrational partition function of $^{35}Cl_2$ at 298.15K. The vibrational frequency is 1.678 x 10^{13} S^{-1}(5 Marks)
d. Describe the basic postulates of Bose- Einstein statistics (5 Marks).

Question 5 (20 marks)

a. Derive an expression for the relation between Entropy (*S)* and the partition function . (5 marks)
b. Write equations for the Helmholtz free energy and Gibbs free energy for a perfect gas in terms of partition function (4 marks)
c. Describe the basic postulates of Fermi-Dirac statistics (5 Marks)
d. Describe the various types of ensembles (6 Marks).