JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY

SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES

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

4RD YEAR SECOND SEMESTER 2019/2020 ACADEMIC YEAR

MAIN REGULAR

SPECIAL EXAM NOVEMBER 2020

COURSE CODE: SCH 408

COURSE TITLE: STATISTICAL THERMODYNAMICS

EXAM VENUE: ZOOM ONLINE **DATE: 09/11/2020**

TIME: 07.00-10.00 **EXAM SESSION:**

STREAM:

INSTRUCTIONS:

1. **Answer question 1 (Compulsory) in section A and ANY other 2 questions in Section B.**

SECTION A (30 MARKS)

Question 1.

(a) Write down the Boltzmann probability expression. Define each of the terms involved and explain its relevance to a molecular understanding of thermodynamics (4 marks)

(b) Give the molecular statistical definition of entropy, and explain how this definition may be used to explain the second law of thermodynamics (3 marks)

(c) Explain why calculation of the exact motion of atoms or molecules in a typical sample is neither feasible nor useful in understanding the thermodynamic properties of matter (3 marks)

(d) Give three examples of chemical, physical, or everyday phenomena that support the molecular statistical view of matter. Explain each case. (3 marks)

(e) You wish to choose three marbles at random from an urn containing four marbles labelled A,B,C and D. Determine the number of permutations and combinations for the above scenario (3 marks)

(f) A dilute system at thermodynamic equilibrium consists of 50 independent, indistinguishable particles. Each particle has three energy levels of energy 0, Ɛ and 2Ɛ with degeneracies of 300, 600 and 1200 respectively. The system is at a constant temperature T= Ɛ/k, where k is Boltzmann's constant.
   - (i) Calculate the molecular partition function for this thermodynamic system (3 marks)
   - (ii) Using the Boltzmann's relation, determine the entropy of this system (3 marks)
   - (iii) Determine the internal energy for this thermodynamic system (3 marks)
   - (iv) Calculate the entropy directly from the partition function (2 marks)
   - (v) Evaluate the Helmholtz energy of the system (3 marks)

SECTION B

Question 2 (20 marks)

a) Explain what is meant by;
   - i) Population of a state (2 marks)
   - ii) Thermodynamic system (2 marks)
   - iii) Property of a system (2 marks)
   - iv) Weight of a configuration (2 marks)

b) i) Write an expression for the weight of a configuration (2 marks)
   - ii) Calculate the number of ways of distributing 20 identical objects with the arrangement 1, 0, 3, 5, 10, 1. (3 marks)

c) How is the internal energy related to the derivative of the partition function (3 marks)

d) What is the significance of the molecular partition function (4 marks)

Question 3 (20 marks).

a) Derive an expression for the pressure of a gas of independent particles (5 marks)

b) The Boltzmann formula for the entropy is given by the equation;

$$S = k \ln W$$

Explain what happens to *W* and hence S as the temperature is lowered. (5 marks)

c) The **Sackur–Tetrode equation** for the entropy of a monatomic gas is given by;

$$S(T) = nR \ln\left(\frac{e^{5/2}V}{nN_A\Lambda^3}\right) \qquad \Lambda = \frac{h}{(2\pi mkT)^{1/2}}$$

   - i) What does it imply (5 marks)
   - ii) Because the gas is perfect, use the relation $V = nRT/p$ to express the entropy in terms of the pressure (5 marks)

Question 4 (20 marks)

a) What is meant by, ‘a canonical ensemble’ (2 marks)
b) State the first and second laws of thermodynamics (2 marks)
c) Describe the usefulness of statistical thermodynamics (2 Marks)
d) Write an expression for the partition function of a linear molecule (such as HCl) treated as a rigid rotor. (5 marks)
a) Derive an expression for the relation between internal energy (*U)* and the partition function (q). (5 marks)
b) Write the partition function for a particle in a one-dimensional box (4 marks)

Question 5 (20 marks).

a) The energy of a molecule is the sum of contributions from its different modes of motion. Explain (5 marks)
b) Determine the contribution to the Helmholtz free energy from the translational energy mode at 500 K and 2 bars for monoatomic helium (7 marks).
c) Evaluate the entropy for NO2 at 500K and 1 bar (8 marks)