

JARAMOGI OGINGA ODINGA UNIVERSITY OF SCIENCE AND TECHNOLOGY
SCHOOL OF BIOLOGICAL AND PHYSICAL SCIENCES
UNIVERSITY EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION
(SCIENCES)
3RD YEAR SECOND SEMESTER 2023/2024 ACADEMIC YEAR
MAIN REGULAR

COURSE CODE: SCH 301

COURSE TITLE: CHEMICAL THERMODYNAMICS

EXAM VENUE:

DATE:

TIME:

EXAM SESSION:

STREAM:

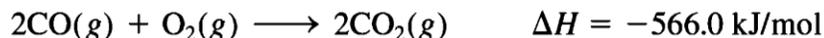
INSTRUCTIONS:

- 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.**
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SECTION A

Question 1 (30 marks)

- Calculate the change in entropy (ΔS) for volume occupied by 1.00 mol of any perfect gas molecules by doubling the volume at constant temperature, $V_f/V_i = 2$; (5 marks)
- Explain the relation between the amount of heat transferred to a body, and the ensuing change in temperature (5 marks)
- Derive an expression that shows the relationship between heat capacity at constant volume C_V , and heat capacity at constant pressure, C_P (5 marks)
- The standard free energy of nitrogen is defined as zero at 298 K and 1 atm pressure. Calculate its value at 10 atm and 0.20 atm at the same temperature (5 marks)
- Consider the flow of heat from a large body maintained at temperature T_h to one maintained at temperature T_c . Write an equation illustrating the overall entropy change. (4 marks)
- Calculate the change in internal energy when 2 moles of CO are converted to 2 moles of CO_2 at 1 atm and 25°C (3 marks)



- How much heat is given off when an 869 g iron bar cools from 94°C to 5°C ? (3 marks)

SECTION B

Question 2 (20 marks)

- Write an expression for;
 - Helmholtz free energy (3 marks)
 - Gibbs free energy (3 marks)
 - Pressure dependence of free energy (3 marks)
 - Temperature variation of free energy (3 marks)
 - Chemical potential (3 marks)
- Calculate the thermodynamic efficiency of a heat engine operating between the temperatures 400 K and 300 K (1 marks)
- Describe four processes of a carnot cycle (4 marks)

Question 3 (20 marks)

- Derive the Clapeyron equation and explain its significance (5 marks)
- At 273.16 K the enthalpy change on fusion of water is 6.0 kJ/mol and the corresponding volume change $-1.6 \times 10^{-6} \text{ M}^3/\text{mol}$ (take $1 \text{ atm} = 10^5 \text{ Nm}^{-2}$). Estimate the temperature at which ice will melt at 1000 atm pressure. (5 marks)
- The enthalpy change when water freezes at 273 K is -6.00 kJ/mol. C_p for water is 75.3 J/K/mol and for ice 37.6 J/K/mol. Calculate the enthalpy change when water freezes at 253 K (5 marks)
- State the Gibbs phase rule (2 marks)
- What is the degrees of freedom of a system with 2 phases and 1 component (1 mark)

- f. What is the number of components in a system with 3 degrees of freedom and 2 phases (2 marks)

Question 4 (20 marks)

- a. Derive the Clausius-Clapeyron equation and explain its significance (5 marks)
- b. Consider a Carnot heat engine operating between a high-temperature source at 900 K and rejecting heat to a low-temperature reservoir at 300 K.
- (i) Determine the thermal efficiency of the engine (3 marks)
 - (ii) Show how the thermal efficiency changes as the temperature of the high-temperature source is decreased; (3 marks)
 - (iii) Determine the change in thermal efficiency as the temperature of the low-temperature sink is decreased (3 marks)
- c. Sketch the phase diagram for two component system A and B form a compound which melts congruently at 133 K. The system exhibits two eutectics, one at 25 mole percent B and 123 K and a second at 90 mole percent B and 104K. The melting points of pure A and B are 131K and 110K respectively (6 marks).

Question 5 (20 marks)

- a. A reversible heat engine operates between two reservoirs, T_C and T_H . The cold reservoir can be considered to have infinite mass, i.e., $T_C = T_1$ remains constant. However the hot reservoir consists of a finite amount of gas at constant volume (1 mole with a specific heat capacity c_v), thus T_H decreases with time (initially, $T_H = T_2$, $T_2 > T_1$). After the heat engine has operated for some long period of time, the temperature T_H is lowered to $T_C = T_1$
- i. Show how the heat extracted from the hot reservoir during this period can be calculated. (3 marks)
 - ii. Show how the change of entropy of the hot reservoir during this period can be calculated? (3 marks)
 - iii. Show how work done by the engine do during this period can be calculated? (3 marks)
- b. A sample of nitrogen gas expands in volume from 1.6 L to 5.4 L at constant temperature. What is the work done in joules if the gas expands;
- i. against a vacuum (3 marks)
 - ii. against a constant pressure of 3.7 atm (3 marks)
- h. Define the following terms;
- i. Enthalpy (1 mark)
 - ii. Entropy (1 mark)
 - iii. Adiabatic Process(1 mark)
 - iv. Isochoric Process (1 mark)
 - v. Isobaric Process(1 mark)