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.**

SECTION A

Question 1 (30 marks)

a. 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)
b. Explain the relation between the amount of heat transferred to a body, and the ensuing change in temperature (5 marks)
c. 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)
d. 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)
e. 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)
f. 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)

$$2CO(g) + O_2(g) \longrightarrow 2CO_2(g) \qquad \Delta H = -566.0 \text{ kJ/mol}$$

g. 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)

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

Question 3 (20 marks)

a. Derive the Clapeyron equation and explain its significance (5 marks)
b. At 273.16 K the enthalpy change on fusion of water is 6.0 kJ/mol and the corresponding volume change -1.6×10^{-6} M^3/mol (take 1 atm = 10^5 Nm^{-2}). Estimate the temperature at which ice will melt at 1000 atm pressure. (5 marks)
c. 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)
d. State the Gibbs phase rule (2 marks)
e. 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)