# UNIVERSITY OF GHANA



**BSC. (Eng.) MATERIALS SCIENCE AND ENGINEERING**

**SECOND SEMESTER EXAMINATIONS: 2016/2017**

**SCHOOL OF ENGINEERING SCIENCES**

**DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING**

**MTEN 204: THERMODYNAMICS OF MATERIALS (2 CREDITS)**

**INSTRUCTIONS: ANSWER ALL QUESTIONS IN SECTION A, AND ONE QUESTION IN SECTION B. SOME EQUATIONS ARE PROVIDED ON PAGE 4.**

**TIME ALLOWED: TWO (2) HOURS**

**SECTION A**

1.

a. Nitrogen has a triple point at $P = 4650\ atm\ and\ T = 44.5\ K$, at which state the allotropes α, β and γ coexist in equilibrium with one another. At the triple point, $V_\beta - V_\alpha = 0.043\ cc/mole$ and $V_\alpha - V_\gamma = 0.165\ cc/mole$. Also at the triple point $S_\beta - S_\alpha = 4.59\ J/K$ and $S_\alpha - S_\gamma = 1.25\ J/K$. The state of P = 1 atm, T = 36 K lies on the boundary between the fields of stability of the α and β phases, and at this state, for the transformation of $\alpha \rightarrow \beta$, $\Delta S^{\alpha \rightarrow \beta} = 6.52\ J/K\ and\ \Delta V^{\alpha \rightarrow \beta} = 0.22 \frac{cc}{mole}$.

Sketch the phase diagram for nitrogen at low temperatures. ***( 15 Marks)***

b. Two molecules A and B are mixed to form a solution in a closed, initially evacuated vessel at temperature T. Consider the case where A-B bond energy is considerably more negative than the A-A and B-B bond energies. Also consider a solution of A in B which is sufficiently dilute that every A atom on the surface of the liquid is surrounded by ***only*** be B atoms.

I. Will this binary solution exhibits a **POSITIVE** or **NEGATIVE** deviation from Raoultian Behavior? Explain your answer. *(5 Marks)*

II. Sketch a plot of the vapor pressure as a function of composition for this binary solution. Hint: sketch both the Henry's and Raoult's Law behavior indicating whether or not the binary solution exhibits positive or negative deviation from Raoultian Behvaior. *(5 Marks)*

**2.**

a. Zn-Cd alloy is a simple eutectic system which has been widely studied due to its low melting point. Zn-Cd alloys are used as solders at medium temperature which provides excellent corrosion resistance on most metals. The integral heat of mixing ($\Delta H^M, J/mol$) of Zn-Cd alloy with its mole fraction ($X_{Zn}$) are reported in the Table 1 below.

I. Plot a graph of $\Delta H^M$ on the y-axis against the mole fraction ($X_{Zn}$) on the x-axis. *(7 Marks)*

II. Determine graphically the partial molar heats of mixing of Cd ($\overline{\Delta H}^M_{Cd}$) and Zn ($\overline{\Delta H}^M_{Zn}$) for a solution containing 0.6 atom fraction of Zn ($X_{Zn} = 0.6$). *(6 Marks)*

Table 1

| $X_{Zn}$ | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 |
|---|---|---|---|---|---|---|---|---|---|
| $\Delta H^M$ | 750 | 1330 | 1730 | 1960 | 2050 | 2000 | 1770 | 1380 | 790 |

b. Using the conditions of equilibrium (chemical, mechanical and thermal conditions of equilibrium), derive the form of the Clausius–Clapeyron equation below for a binary heterogeneous system made up of the phases α and β, where α is the liquid phase and β is the gaseous phase. The symbols in the equation have their usual meanings. State all assumptions used in the derivation.

$$ln\frac{P_2}{P_1} = -\frac{\Delta H^{\alpha\rightarrow\beta}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

*(12 Marks)*