

國立臺灣科技大學
九十學年度碩士班招生考試試題

系所組別：工程技術研究所材料科技學程

科目：熱力學

總分 100 分

Parameter definition: T = temperature, P = pressure, V = volume, U = internal free energy, H = enthalpy, S = entropy, A = Helmholtz free energy, and G = Gibbs free energy, C_p = heat capacity at constant pressure, α = isobaric thermal expansivity.

1. (35%)

For a system containing N components, each component has n_I moles; $I = 1, 2, 3, \dots, N$.

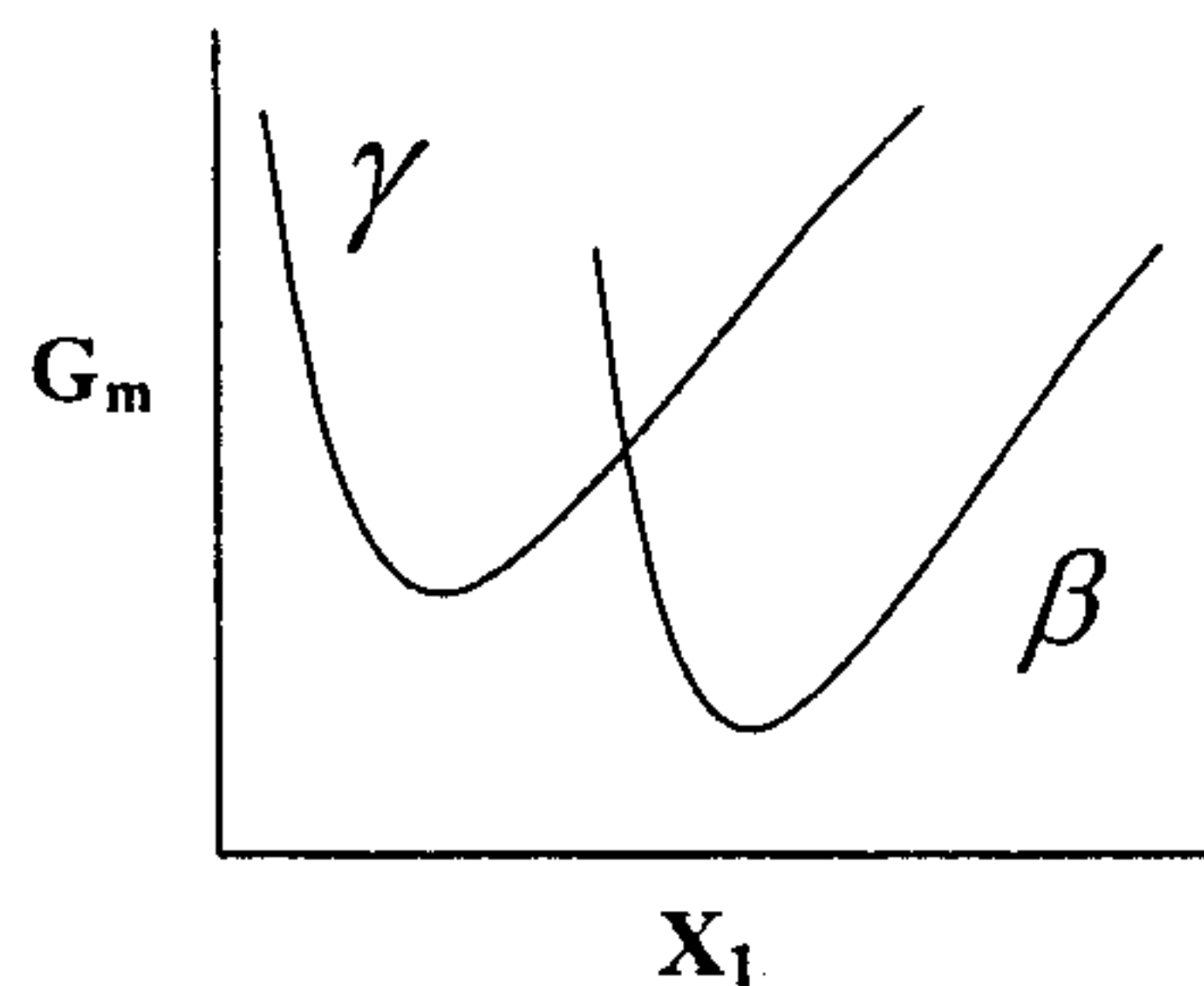
(a) (5%) Please write down the differential form of the Gibbs free energy.

(b) (5%) Please derive $G = \sum_I \mu_I n_I$, where $\mu_I = \left. \frac{\partial G}{\partial n_I} \right|_{T, P, n_{j \neq I}}$; $I = 1, 2, 3, \dots, N$.

(c) (10%) Please derive the Gibbs-Duhem equation.

(d) (5%) From the Gibbs-Duhem equation, please answer the criteria for two phases γ and β coexisting at constant T and P .

(e) (10%) For a system with 2 components at constant T and P , the molar Gibbs free energy G_m of two possible phases γ and β is plotted as a function of mole fraction of the first component X_1 :



What is the phase transition with X_1 increasing from 0 to 1. Please identify your answer.

2. (25%)

(a) (10%) Please describe the third law of thermodynamics.

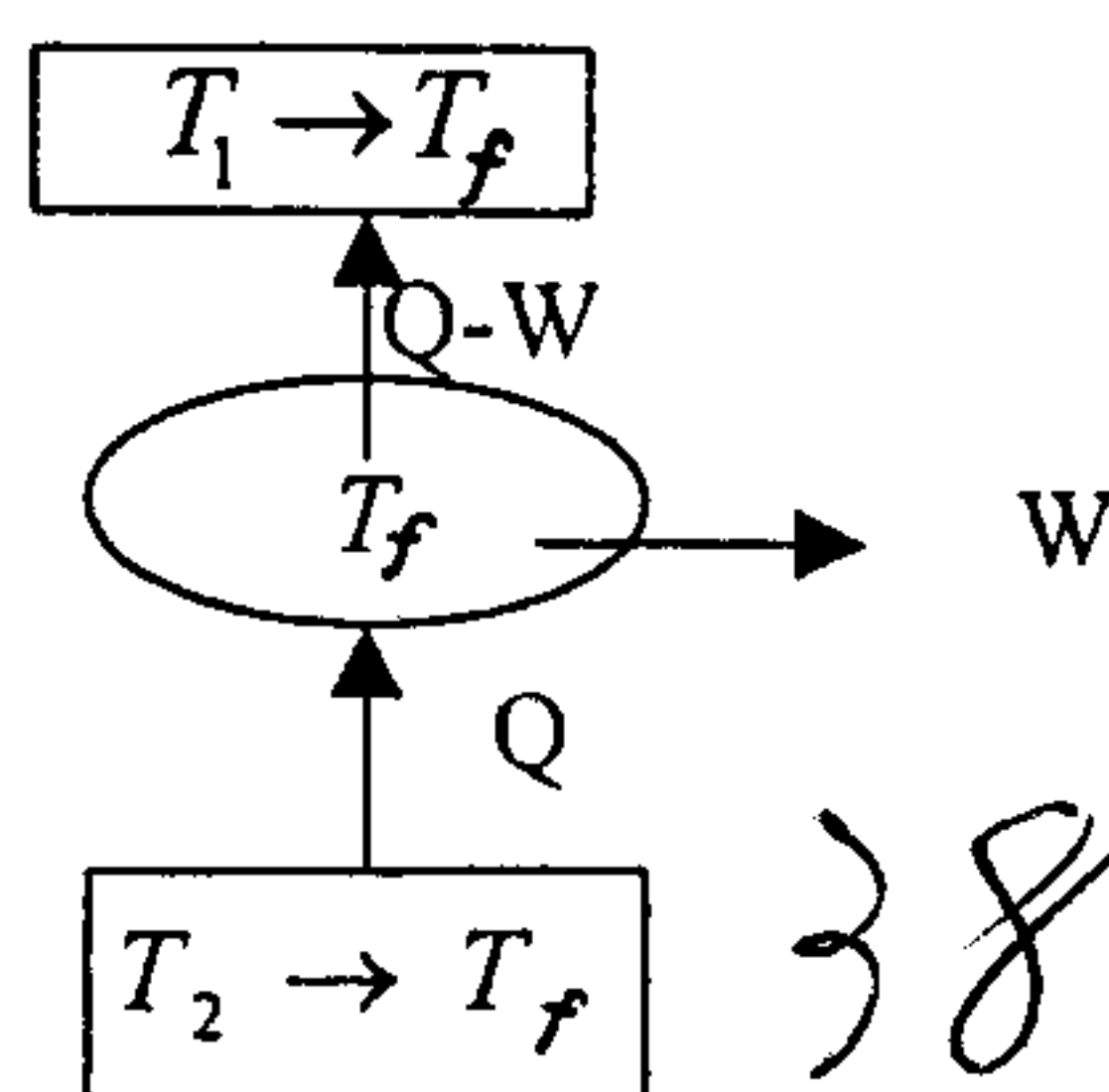
(b) (15%) Please identify the possibility of an element with

(i) C_p is a constant in the whole range of temperature $T \geq 0$ K.

(ii) $C_p \propto \frac{1}{T^n}$; $n = 1, 2, 3, \dots$; $T \geq 0$ K.

(iii) $C_p \propto T^n$; $n = 1, 2, 3, \dots$; $T \geq 0$ K.

3. (20%) Two materials at temperature T_1 and T_2 , respectively, are connected through a heat reservoir at temperature T_f , as shown in the below figure. Assume that both materials have the same heat capacity. The process is kept at pressure P . Assume that Q is the heat transfer from 2nd material to heat reservoir, and W is the work output from heat reservoir.



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(a) (10%) Please show that $W = C_p(T_1 + T_2 - 2T_f)$.

(b) (10%) Please prove that $T_f = \sqrt{T_1 T_2}$, when W is a maximum.

4. (20%) Joule and Thomson showed experimentally that when a steady stream of non-ideal gas is passed through a thermally insulated tube, in which is inserted a throttle valve, the temperature of the gas changes and the state of the gas is changed from P_1, T_1 , to P_2, T_2 .

(a) (5%) Show that this process is isenthalpic.

(b) (10%) The change in T is described in terms of the Joule-Thomson coefficient, $\mu_{J-T} = \left(\frac{\partial T}{\partial P} \right)_H$. Please

show that $\mu_{J-T} = -\frac{V}{C_p}(1 - \alpha T)$.

(c) (5%) Show that the Joule-Thomson coefficient for an ideal gas is 0.



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