注意：考試開始鈴響前，不得翻閱試題，

並不得書寫、畫記、作答。

國立清華大學 110 學年度碩士班考試入學試題

系所班組別：工程與系統科學系
甲組

科目代碼：3002

考試科目：材料熱力學

—作答注意事項—

1. 請核對答案卷（卡）上之准考證號、科目名稱是否正確。
2. 考試開始後，請於作答前先翻閱整份試題，是否有污損或試題印刷不清，得舉手請監試人員處理，但不得要求解釋題意。
3. 考生限在答案卷上標記「⬇ 由此開始作答」區內作答，且不可書寫姓名、准考證號或與作答無關之其他文字或符號。
4. 答案卷用盡不得要求加頁。
5. 答案卷可用任何書寫工具作答，惟為方便閱卷辨識，請儘量使用藍色或黑色書寫；答案卡限用 2B 鉛筆畫記；如畫記不清（含未依範例畫記）致光學閱讀機無法辨識答案者，其後果一律由考生自行負責。
6. 其他應考規則、違規處理及扣分方式，請自行詳閱准考證明上「**國立清華大學試場規則及違規處理辦法**」，無法因本試題封面作答注意事項中未列明而稱未知悉。

國立清華大學 110 學年度碩士班考試入學試題

系所班組別：工程與系統科學系碩士班 甲組(0530)

考試科目（代碼）：材料熱力學 (3002)

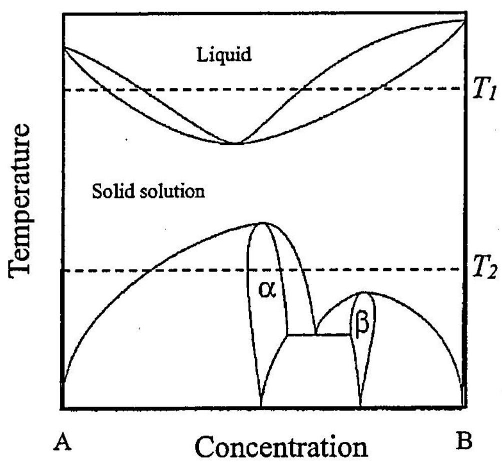
 *請在【答案卷】作答

（可用中文或英文作答。請清楚標明題號以利批改。）

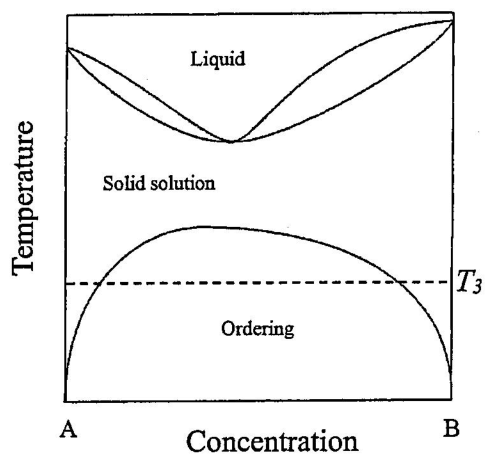
Question 1

(a) The phase diagrams of two alloys (alloy 1 and alloy 2) are illustrated below. In which of the two alloys is there an energetic tendency for the A and B atoms to attract to each other? Briefly explain your answer. (5%)

(b) Schematically draw the free energy curves vs concentration for the A-B alloy at temperatures T_1 and T_2 for alloy 1, and T_3 for alloy 2, and briefly explain how the phase diagrams are constructed from the free energy curves. Make sure to clearly label all the curves. (15%)



Alloy 1



Alloy 2

Question 2

(a) Determine the maximum allowed partial pressure of water vapor in wet hydrogen (H_2 + H_2O) at 1 atm in which manganese (Mn) can be heated without oxidation occurring at 1100°C. (7%)

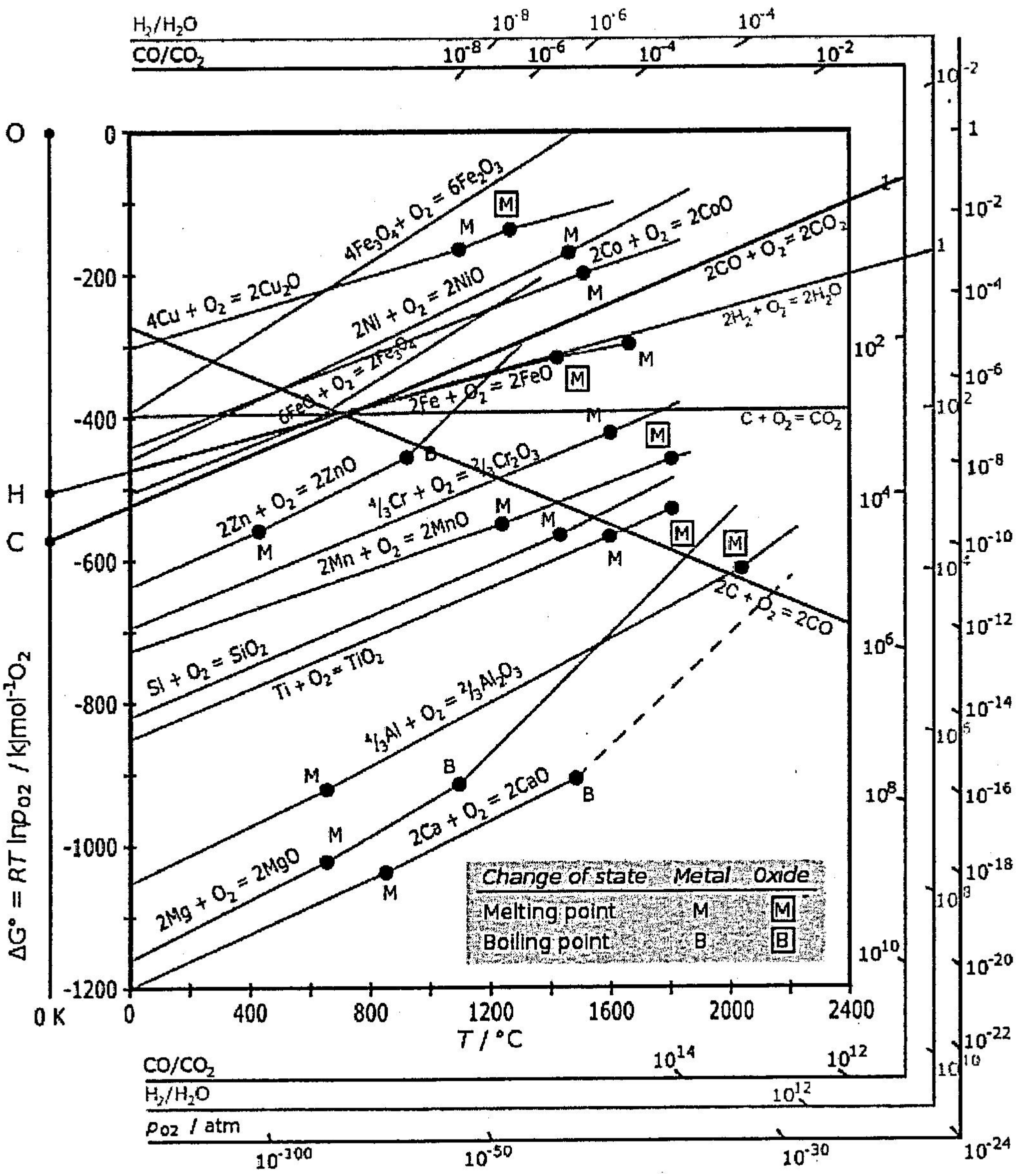
(b) Is the oxidation of Mn by water vapor exothermic or endothermic? Justify your answer with data. (3%)

There is an Ellingham diagram on the next page for you to check the answer.

Data: $H_{2(g)} + \frac{1}{2}O_{2(g)} = H_2O_{(g)}, \Delta G^o = -247{,}500 + 55.85T$ J

$2Mn_{(s)} + O_{2(g)} = 2MnO_{(s)}, \Delta G^o = -777{,}800 + 152.64T$ J

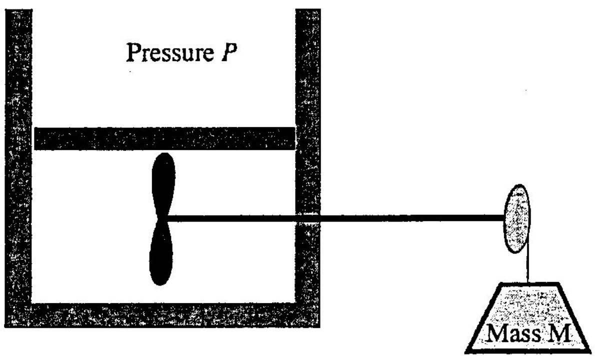
Gas constant, R = 8.314 J/mol-K



The Ellingham diagram for selected oxides.

Question 3

A fluid is held in a container that is covered with a frictionless piston. The container and the piston are thermally insulated (no heat exchange with the environment), and the environment is at constant pressure, P. A paddle is placed within the container, which is rotated by dropping a weight of mass M attached to a frictionless pulley contraption (see the figure below). Assume that the mass M drops by a distance h with the gravity g.



You are lucky that the properties of this fluid, including the heat capacities, C_p and C_v, the isobaric thermal expansivity, α, and the isothermal compressibility, β, have all been measured. It also turns out that they are constant for the process of consideration.

(a) Derive an expression for the change in temperature, ΔT, between the final equilibrated state after M has been dropped and the initial state before M is dropped. Write your answer in terms of M, h, g, and the properties of the fluid. (10%)

(b) Derive an expression for the change in volume ΔV with an initial volume V_1. (10%)

Question 4

Calculate the heat required to form a liquid solution at 1356 K starting with 1 mole of Cu and 1 mole of Ag at 298 K. At 1356 K the molar heat of mixing of liquid Cu and liquid Ag is given by $\Delta H^M = -20{,}590 X_{\text{Cu}} X_{\text{Ag}}$ J/mol. (10%)

Data:

$T_{m,\text{Cu}} = 1356$ K, $T_{m,\text{Ag}} = 1234$ K,

$\Delta H_{m,\text{Cu}} = 12{,}970$ J, $\Delta H_{m,\text{Ag}} = 11{,}090$ J,

$c_{p,\text{Cu}_{(s)}} = 22.64 + 6.28 \times 10^{-3} T$ J/mol · K,

$c_{p,\text{Ag}_{(s)}} = 21.30 + 8.54 \times 10^{-3} T + 1.51 \times 10^{5}/T^2$ J/mol · K,

$c_{p,\text{Ag}_{(l)}} = 30.5$ J/mol · K

Question 5

(a) Derive an expression for $\left(\frac{\partial A}{\partial V}\right)_S$ in terms of the state variables, including T, P, S, V, and the measurable properties of the system, including the heat capacities, C_p and C_v, the isobaric thermal expansivity, α, and the isothermal compressibility, β. A is the Helmholtz free energy defined as $U - TS$. (7%)

(b) Like (a), derive an expression for $\left(\frac{\partial G}{\partial T}\right)_V$ in terms of the state variables and measurable properties of the system. G is the Gibbs free energy defined as $H - TS$. (7%)

(c) Do the quantities you derived in (a) and (b) depend on the size of the system (i.e. is it intensive or extensive)? (6%)

Here are some useful relationships for you to use:

$$\left(\frac{\partial x}{\partial y}\right)_z = \frac{1}{\left(\frac{\partial y}{\partial x}\right)_z},$$

$$\left(\frac{\partial x}{\partial z}\right)_\phi = \left(\frac{\partial x}{\partial y}\right)_\phi \left(\frac{\partial y}{\partial z}\right)_\phi,$$

$$\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x \left(\frac{\partial z}{\partial x}\right)_y = -1$$

Question 6

One mole of a diatomic ideal gas ($c_v = \frac{5}{2}R$, $c_p = \frac{7}{2}R$) initially at 1 Pa and 298 K undergoes the following cycle:

a. A constant volume heating to twice the initial temperature.
b. An adiabatic reversible expansion back to 298 K.
c. An isothermal, reversible compression back to 1 Pa.

Calculate the heat (Q), work (W), internal energy change (ΔU), and entropy change (ΔS) of the entire cycle. (Gas constant, R = 8.314 J/mol-K) (20%)