1-3 Consider the galvanic cell shown below (the contents of each half-cell are written beneath each compartment):

\[
\begin{align*}
\text{Pt} & : \text{0.10 M Br}_2 \\
\text{Cr} & : \text{0.10 M Cr}^{3+}
\end{align*}
\]

1. The standard reduction potentials are as follows:
   \[\text{Cr}^{3+} + 3e^- \rightarrow \text{Cr}(s) \quad E^0 = -0.73 \text{V}\]
   \[\text{Br}_2(aq) + 2e^- \rightarrow 2 \text{Br}^- \quad E^0 = +1.09 \text{V}\]

   the cell reaction: \[2 \text{Cr}(s) + 3 \text{Br}_2(aq) \rightarrow 2 \text{Cr}^{3+} + 6 \text{Br}^-\]
   What is \(E^0\) for this cell?
   (a) 1.82 V  (b) 0.36 V  (c) 4.73 V  (d) -4.73 V  (e) None of these (a-d).

2. What is the value of \(E\) for this cell at 25°C?
   (a) -4.78 V  (b) 1.87 V  (c) -2.12 V  (d) -4.78 V  (e) None of these (a-d).
   (The Nernst Equation: \(E = E^0 - (0.059/n) \log(Q)\))

3. Which of the following statements about this cell is false?
   (a) To complete the circuit, cations migrate into the left half-cell and anions migrate into the right half-cell from the salt bridge.
   (b) Reduction occurs at the Pt electrode.
   (c) The cell is not at standard conditions.
   (d) Electrons flow from the Pt electrode to the Cr electrode.
   (e) None of these (a-d).

4. Consider the reaction: \(4 \text{NH}_3(g) + 2 \text{NO}_2(g) + 2\text{O}_2(g) \rightarrow 3 \text{N}_2(g) + 6 \text{H}_2\text{O}(g)\)

   At a certain instant the initial rate of disappearance of the NO gas is \(X\).
   What is the value of the appearance of water at the same instant?
   (a) 0.67X  (b) X  (c) 1.5X  (d) 3.0X  (e) cannot be determined from the data.

5. Which one is the Lewis base?
   (a) \(\text{Cu}^{+2}\)  (b) \(\text{SnCl}_2\)  (c) \(\text{BeCl}_2\)  (d) \(\text{SO}_3\)  (e) \(\text{S}^-\).

6. Some species with two oxygen atoms only are the oxygen molecule, \(\text{O}_2\), the peroxide ion, \(\text{O}_2^{2-}\), the superoxide ion, \(\text{O}_2^-\), and the dioxygenyl ion, \(\text{O}_2^+\).

   Rank them in order of increasing bond length
國立高雄大學九十五學年度研究所碩士班招生考試試題

科目：普通化學
系所：應用化學系碩士班甲組

考試時間：100 分鐘
本科原始成績：滿分 100 分

(a) O_2^+ < O_2^- < O_2 < O_2^{2-} (b) O_2 < O_2^- < O_2^+ < O_2^{2-}
(c) O_2^{2-} < O_2^- < O_2 < O_2^+ (d) O_2^+ < O_2 < O_2^{-} < O_2^{2-}

(e) None of these (a-d).

7. Rank the following compounds according to increasing surface tension at a given temperature, I. CH_3OH II. CH_3CH_3 III. H_2C=O
(a) I < II < III (b) II < I < III (c) III < II < I (d) II < III < I
(e) None of these (a-d).

8. Which ion is paramagnetic?
(a) Hg^{2+} (Z = 80) (b) Cu^+ (Z = 29) (c) Mn^{4+} (Z = 25) (d) Zn (Z=30)
(e) Zn^{2+} (Z=30)

9. Which one of the following ionic compound would you expect to have no effect of their solubility in the water when the addition of H_3O^+ from a strong acid.
(a) FeS (b) Ca_3(PO_4)_2 (c) CuBr (d) Hg_2(CN)_2 (e) None of these (a-d).

10. For which of the following compound(s) are cis and trans isomers possible?
(a) 3-methyl-2-pentene
(b) 2,3-dimethyl-2-butene
(c) 4,4-dimethylcyclohexanol
(d) ortho-chlorotoluene
(e) All can exhibit cis/trans isomers.

<II> 計算題 (共佔 70 分)

(20%) 1. Methanol, one of the most important industrial feed-stocks, is made by several catalyzed reactions, one of which is CO(g) + 2 H_2(g) → CH_3OH(g)
(a) Is the reaction spontaneous at low or high temperature? Explain.
(b) One concern raised about using CH_3OH as a fuel in cars is that it is partially oxidized in air to yield formaldehyde, CH_2O(g) (or HCHO), which poses a health hazard. Calculate ΔG° at 100°C for this oxidation. (1 kJ = 10^3 J)

\[ \Delta H_f \] of CH_3OH(g) = -240 kJ/mol, CH_3OH(g) = -200 kJ/mol, CH_2O(g) = -100 kJ/mol, CO(g) = -110 kJ/mol, H_2O(g) = -200 kJ/mol, H_2(g) = 0 kJ/mol and O_2 = 0 kJ/mol.

\[ \Delta S_f \] of CH_3OH(g) = 200 J/mol, CH_3OH(g) = -200 J/mol, CH_2O(g) = -100 J/mol, CO(g) = 160 J/mol, H_2O(g) = 160 J/mol, H_2(g) = 120 J/mol and O_2(g) = 200 J/mol.
(10%) 2. Find the solubility of AgI in 2.5 M NH₃ \( (K_{sp} \text{ of AgI} = 8.3 \times 10^{-17}, K_f \text{ of Ag(NH}_3)_2^+ = 1.7 \times 10^7) \)

(10%) 3. Draw all stereoisomers for each of the following and state the type of isomerism:
(a) [Pt(NH₃)₂Br₂] (square planar)
(b) [Cr(en)₃]⁺³ (en = H₂NCH₂CH₂NH₂)

(10%) 4. An environmental chemist needs a benzoic acid-benzoate buffer of pH = 4.0 to study the effects of the acid rain on limestone-rich soils. How many grams of benzoic acid must she add to 5.0 L of freshly prepared 0.050 M sodium benzoate \((\text{C}_₆\text{H}_₅\text{COONa})\) to make the buffer? \( (K_a \text{ of benzoic acid (C}_₆\text{H}_₅\text{COOH}) = 6.3 \times 10^{-5}, M_{\text{C}_₆\text{H}_₅\text{COOH}} = 122 \text{ g/mol}) \)

(10%) 5. An element crystallizes in a face-centered cubic lattice and has a density of 1.45 g/cm³. The edge of its unit cell is 4.52 x 10⁻⁸ cm.
(a) What is the mass of a unit cell.
(b) Calculation an approximate atomic mass (amu) for the element. \( (1 \text{amu} = 1.67 \times 10^{-24} \text{ g}) \)

(10%) 6. One way to prevent emission of the pollutant NO from industrial plants is by reaction with NH₃:
\[ 4 \text{NH}_3(g) + 2 \text{NO}(g) + 2\text{O}_2(g) \rightarrow 3 \text{N}_2(g) + 6 \text{H}_2\text{O}(g) \]
If the NO has a partial pressure of \( 4.5 \times 10^{-2} \text{ atm} \) in the flue gas and the reaction takes place at 1.00 atm and 150°C, how many grams of NH₃ are needed per kL of flue gas?
\( (R = 0.082 \text{ L} \cdot \text{atm/mol-K}, 1 \text{kL} = 10^3 \text{L}, M_{\text{NH}_3} = 17.0 \text{ g/mol}) \)
有機化學 (五十分)

1. Show the full name in the following items: (8 pt)
   (1) SOCl₂; (2) PCC; (3) LAH; (4) Mel; (5) mCPBA; (6) CH₃N₂; (7) DMSO; (8) THF

2. Predict the reaction product. (8 pt)

   \begin{align*}
   \text{(1)} & \quad \text{Cyclohexane} \quad 4\text{-NO}_2\text{-PhNHNH}_2 \rightarrow A \\
   \text{(2)} & \quad \text{Benzaldehyde} \quad \text{Heat} \rightarrow B \\
   \text{(3)} & \quad \text{Ethynylamine} \quad \text{CH}_2\text{O}/\text{HCO}_2\text{H} \rightarrow C \\
   \text{(4)} & \quad \text{Dihexylamine} \quad \text{LDA} \rightarrow D
   \end{align*}

3. Give an example to explain the following Name reaction. (12 pt)
   (a) Wittig reaction; (b) Clemmensen reaction; (c) Umpolung reaction; (d) Favorskii rearrangement

4. Propose the possible reaction mechanism. (8 pt)

   \begin{align*}
   \text{(1)} & \quad \text{Cyclohexene} \quad \text{H}^+ \rightarrow \text{Cyclohexanone} \\
   \text{(2)} & \quad \text{Cyclopropane} \quad \text{ArSO}_2\text{H} \rightarrow \text{Cyclohexane}
   \end{align*}

5. Provide the reaction strategy. (8 pt)

   \begin{align*}
   \text{(1)} & \quad \text{PhCHO} \quad \text{CHO} \rightarrow \text{BrCHO} \\
   \text{(2)} & \quad \text{Ethene} \quad \text{O}^+ \rightarrow \text{BrEthene}
   \end{align*}

6. The partial 	extsuperscript{1}H-NMR spectral information of ethyl 2-vinyl cinnamate was shown as follows. Arrange the peak for each proton A–I. (6 pt)

   \begin{align*}
   \text{D} & \quad \text{C} \\
   \text{E} & \quad \text{B} \\
   \text{F} & \quad \text{A} \quad \text{CO}_2\text{Et} \\
   \text{G} & \quad \text{H} \\
   \end{align*}
Physical Chemistry [50 points]

1. (a) [5pts] Sketch and describe the four steps of a Carnot cycle between two reservoir temperature at $T_{\text{hot}}$ and $T_{\text{cold}}$, respectively.
   (b) [5pts] Derive $q$, $w$, $\Delta U$ and $\Delta S$ for each step and for the overall process of the cycle.

2. For reaction $N_2O_4(g) \rightleftharpoons 2 NO_2(g)$
   $\Delta G(N_2O_4, g) = +97.89 \text{ kJ/mol}$; $\Delta H(N_2O_4, g) = +9.16 \text{ kJ/mol}$;
   $\Delta G(NO_2, g) = +51.31 \text{ kJ/mol}$; and $\Delta H(NO_2, g) = +33.18 \text{ kJ/mol}$ at 298 K.
   (a) [5pts] Calculate the equilibrium constant of the reaction at 298 K.
   (b) [5pts] Assume the reaction enthalpy is temperature independent over the temperature range of interest, estimate the equilibrium constant at 70°C.

3. To study a particle of mass $m$ in one dimensional box (with box length $L = 2$, range $-1 \leq x \leq 1$), student A uses wave function $\psi = x^2 - 2x + 1$ and student B uses wave function $\psi = x^4 - 2x^2 + 1$
   (a) [2pts] Which approach is more appropriate and why?
   (b) [2pts] Normalize the wave function of the correct approach.
   (c) [3 pts] Calculate the expectation value of the ground-state energy using the normalized wave function.
   (d) [3 pts] If the bottom of the box is re-shaped and represented by the function $f(x) = x/2$ for $-1 \leq x \leq 1$. Calculate the first order correction to the ground-state energy.

4. [4 pts] Which system is more stable? Two ethylene molecules or cyclobutadiene? Use Hückel MO theory to explain why.

5. [3 pts] If a student performs an isotope substitution to the hydrogen molecule and forming the HD and D$_2$ molecules what happen to the vibrational frequency and the rotational constants assuming the force constant and the internal structure of the molecules doesn’t change during the substitution? You can use harmonic oscillator and rigid rotator approximation.
6. [3 pts] Determine the term symbols for the electron configuration \((ns)^1(np)^1\). Which term symbol corresponds to the lowest energy?

7. (a) [4 pts] Derive the rate law for the formation of P according to the Lindemann-Hinshelwood mechanism:

\[
\begin{align*}
A + M & \rightarrow A^* + M & k_1 \\
A^* + M & \rightarrow A + M & k_{-1} \\
A^* & \rightarrow P & k_2
\end{align*}
\]

Where \(A^*\) is the activated molecule and the unimolecular reaction is slow.

(b) [3 pts] Derive the rate law at the high- and low-pressure limit.

8. [3 pts] Calculate the translational partition function of HCl in a 500 cm\(^3\) container at 300 K. A one-dimensional container of length \(X\) is: \(q_X = (2 \pi m kT / h^2)^{1/2} X\).

\[\text{(H: 1.008 g/mol; Cl: 35.45 g/mol; } h = 6.626 \times 10^{-34} \text{ Js; k = 1.38 \times 10^{-23} JK}^{-1}\]\n
Analytical Chemistry [50 points]

9. [10 pts] Explain the difference between

- a. qualitative and quantitative analysis
- b. constant and proportional error
- c. a crystalline and a colloidal precipitate
- d. blue and red shift
- e. bulk and solute property detector in HPLC

10. [10 pts] Describe how to prepare a buffer solution with pH 5.2 by acetic acid (pKa = 4.76) and sodium acetate without using a pH meter

11. [10 pts] Describe the relationship between resolution and linear velocity of the mobile phase in chromatographic separation.

12. [6 pts] What is voltammetry? [4 pts] Why the voltammetric methods are performed without stirring and agitation?

1. Helium enters a reversible isothermal compressor at 540 °R and 12 atm and is continuously compressed to 180 atm. Calculate the work per lb-mole (Btu/lb-mol) of helium needed to run the compressor and the amount of heat per lb-mole (Btu/lb-mol) of helium that must be removed from the compressor if
   a. Helium behaves as an ideal gas. (8%)
   b. Helium behaves according to the equation of state (10%) 
   \[ PV = RT - \frac{a}{T} P + bP \] (V is molar volume)
   where \( a = 11.13 \text{ °Rft}^3/\text{lb-mol} \);
   \( b = 0.2445 \text{ ft}^3/\text{lb-mol} \)

2. The following vapor pressure data are available

<table>
<thead>
<tr>
<th>T(°C)</th>
<th>P (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4</td>
<td>3.280</td>
</tr>
<tr>
<td>-2</td>
<td>3.880</td>
</tr>
<tr>
<td>+2</td>
<td>5.294</td>
</tr>
<tr>
<td>+4</td>
<td>6.101</td>
</tr>
</tbody>
</table>

   Estimate each of the following: (20%)
   a. Heat of sublimation of ice (kJ/mol)
   b. Heat of vaporization of water (kJ/mol)
   c. Heat of fusion of ice (kJ/mol)
   d. The triple point of water (°F)

3. A reversible cycle executed by 1 mol of an ideal gas for which \( C_p = (5/2)R \) and \( C_v = (3/2)R \) consists of the following:
   ◆ Starting at \( T_1 = 700 \text{ K} \) and \( P_1 = 1.5 \text{ bar} \), the gas is cooled at constant pressure to \( T_2 = 350 \text{ K} \).
   ◆ From 350 K and 1.5 bar, the gas is compressed isothermally to pressure \( P_2 \).
   ◆ The gas returns to its initial state along a path for which \( PT = \text{constant} \).
   What is the thermal efficiency of the cycle? (15%)

4. A concentrated binary solution containing mostly species 2 (but \( x_2 \neq 1 \)) is in equilibrium with a vapor phase containing both species 1 and 2. The pressure of this two-phase system is 1 bar; the temperature is 25°C. Determine from the following data good estimates of \( x_1 \) and \( y_1 \). (14%) \( H_1 = 200 \text{ bar} \); \( P_{2sat} = 0.10 \text{ bar} \)
5. A vessel, divided into two parts by a partition, contains 4 mol of nitrogen gas at 75 °C and 30 bar on one side and 2.5 mol of argon gas at 130 °C and 20 bar on the other. If the partition is removed and the gases mix adiabatically and completely, what is the change in entropy (J/K)? Assume nitrogen to be an ideal gas with \( C_v = \frac{5}{2}R \) and argon to be an ideal gas with \( C_v = \frac{3}{2}R \). (15%)

6. A liquid mixture of cyclohexanone(1)/phenol(2) for which \( x_1 = 0.6 \) is in equilibrium with its vapor at 144°C. Determine the equilibrium pressure \( P(\text{kPa}) \) and vapor composition \( y_1 \) from the following information: (18%)

- \( \ln y_1 = Ax_1^2; \ln y_2 = Ax_2^2 \)
- At 144°C, \( P_1^{\text{sat}} = 75.20 \text{ kPa} \) and \( P_2^{\text{sat}} = 31.66 \text{ kPa} \)
- The system forms as azoetrope at 144°C for which \( x_1^{\text{aez}} = y_1^{\text{aez}} = 0.294 \)

---

**Table: Values of the universal gas constant**

\[
\begin{align*}
R &= 8.314 \text{ J mol}^{-1} \text{ K}^{-1} = 8.314 \text{ m}^3 \text{ Pa mol}^{-1} \text{ K}^{-1} \\
   &= 83.14 \text{ cm}^3 \text{ bar mol}^{-1} \text{ K}^{-1} = 8314 \text{ cm}^3 \text{ kPa mol}^{-1} \text{ K}^{-1} \\
   &= 82.06 \text{ cm}^3 \text{ (atm) mol}^{-1} \text{ K}^{-1} = 62356 \text{ cm}^3 \text{ (torr) mol}^{-1} \text{ K}^{-1} \\
   &= 1.987 \text{ (cal) mol}^{-1} \text{ K}^{-1} = 1.986 \text{ (Btu) (lb mole)}^{-1} \text{ (R)}^{-1} \\
   &= 0.7302 \text{ (ft)}^3 \text{ (atm) (lb mol)}^{-1} \text{ (R)}^{-1} = 10.73 \text{ (ft)}^3 \text{ (psia)(lb mol)}^{-1} \text{ (R)}^{-1} \\
   &= 1545 \text{ (ft)(lb)(lb mol)}^{-1} \text{ (R)}^{-1}
\end{align*}
\]
1. (20%) For the flow of a fluid over a flat membrane of length 10 cm, determine the length-average mass transfer coefficient. The relevant properties of the system are \( v = 0.01 \text{ cm}^2/\text{s} \), \( D_l = 5 \times 10^{-6} \text{ cm}^2/\text{s} \), and \( v_{avg} = 5 \text{ cm/s} \). Use \( v = 0.03 \text{ cm}^2/\text{s} \). \( k_{loc} \): local mass transfer coefficient.

[Hint] Laminar flow along a flat plate: \( \frac{k_{loc}L}{D_l} = 0.323 \text{Re}^{1/2} \text{Sc}^{1/3} \)

2. (20%) A source of strength 3 \text{ m}^3/\text{s} at the origin is combined with a uniform stream moving at 9 \text{ m/s} in the x direction. For the half-body which results, find
   (a) The stagnation point. (5%)
   (b) The body height as it crosses the y axis. (5%)
   (c) The body height at large x. (5%)
   (d) The maximum surface velocity and its position (x, y). (5%)

3. (20%) Tetraethoxysilane, also called TEOS or Si(OC\text{2}H\text{5})\text{4}, is a liquid chemical used in the semiconductor industry to produce thin films of silicon dioxide by chemical vapor deposition (CVD). In order to deliver the TEOS vapor to the CVD reactor, liquid TEOS is fed to a wetted-wall column. The TEOS liquid uniformly coats the inner surface of the tube as a thin liquid film as it flows downward. The falling liquid film of TEOS evaporates into an insert helium carrier gas flowing upward at a volumetric flow rate of 3000 \text{ cm}^3/\text{s}. The wetted-wall column has an inner diameter of 10 cm and a length of 2 m. The column temperature is maintained at 333K, and the total system pressure is 1 atm. At 333K, the kinematic viscosity of helium gas is 1.47 \text{ cm}^2/\text{s}, the diffusion coefficient of TEOS vapor in helium gas is 1.315 \text{ cm}^2/\text{s}, and the vapor pressure of liquid TEOS is 2133 Pa.
   (a) What is the gas-film mass-transfer coefficient, \( k_G \)? (5%)
   (b) What is the mole fraction of TEOS vapor exiting the column? (5%)
   (c) What is the required mass flow rate of liquid TEOS liquid into the column if all of the liquid TEOS evaporates by the time it reaches the bottom of the column? (10%)

4. (20%) A fluid flows in the positive x-direction through a long flat duct of length L, width W, and thickness B, where \( L >> W >> B \). The duct has porous walls at \( y = 0 \) and \( y = B \), so that a constant cross flow can be maintained, with \( v_x = v_0 \), a constant, everywhere. Flows of this type are important in connection with separation processes using the sweep diffusion effect. By carefully controlling the cross flow, one can concentrate the larger constituents (molecules dust particles, etc) near the upper wall.

Figure Q4. Flow in a slit of length L, width W and thickness B. The walls at \( y = 0 \) and \( y = B \) are porous, and there is a flow of the fluid in the y direction, with a uniform velocity \( v_y = v_0 \).
5. (20%) A black solar collector, with a surface area of 80 m², is placed on the roof of a building at National University of Kaohsiung (NUK). Incident solar energy reaches the collector with a flux of 800 W/m². The surroundings are considered black with an effective temperature of 32°C. The convective heat-transfer coefficient between the collector and the surrounding air, at 32°C is 30W/m²-K. Neglecting any conductive loss from the collector, determine:

(a) the net radiant exchange between the collector and its surroundings;
(b) the equilibrium temperature of the collector.
1. For a 52 wt% Zn-48 wt% Cu alloy, make schematic sketches of the microstructure that would be observed for conditions of very slow cooling at the following temperatures: 950°C (1740°F), 860°C (1580°F), 800°C (1470°F), and 600°C (1100°F)(12%). Label all phases (12%) and indicate their approximate compositions (12%).

![Phase Diagram](image)

**Figure 9.17** The copper-zinc phase diagram. [Adapted from Binary Alloy Phase Diagrams, 2nd edition, Vol. 2, T. B. Massalski (Editor-in-Chief), 1990. Reprinted by permission of ASM International, Materials Park, OH.]

2. Measured mechanical strengths of ceramics are usually much smaller than theoretical values calculated from bonding strengths (with assumptions that the ceramics are perfect crystals). Explain why? (8%)

3. Briefly explain how each of the following factors influences the tensile or yield strength of a semicrystalline polymer and why: (12%)
   - (a) Molecular weight
   - (b) Degree of crystallinity
   - (c) Deformation by drawing
   - (d) Annealing of an undeformed material

4. Describe the phenomena shown in the following figure (9%) and explain why (9%).

第 1 頁，共 2 頁
5. For a brass alloy, the stress at which plastic deformation begins is 345 MPa (50,000 psi), and the modulus of elasticity is 103 GPa (15.0 x 106 psi). mm

(a) What is the maximum load that may be applied to a specimen with a cross-sectional area of 130 mm² (0.2 in²) without plastic deformation? (5%) 

(b) If the original specimen length is 76 mm (3.0 in.), what is the maximum length to which it may be stretched without causing plastic deformation? (5%) 

6. How many slip systems does a BCC crystal have with the slip planes of \{110\}? (6%) Draw a figure (or figures) to show your answer. (10%)
1. A Carnot heat engine operates between reservoirs at 1000°C and 200°C. The isothermal process at the hotter reservoir consists of an expansion (reversible) from an initial pressure of $5 \times 10^5$ N/m$^2$ to $4 \times 10^4$ N/m$^2$. Assuming that the working substance is a kilomole of ideal gas, calculate (a) the efficiency of the heat engine, (b) the heat absorbed from the hotter reservoir, and (c) the heat rejected to the colder reservoir. (15%)

2. The vapor pressures of zinc have been written as

$$ \ln p \text{ (atm)} = - \frac{15780}{T} - 0.755 \ln T + 19.25 $$

(I)

and

$$ \ln p \text{ (atm)} = - \frac{15250}{T} - 1.255 \ln T + 21.79 $$

(II)

Which of the two equations is for solid zinc? (10%)

3. For sulfur dioxide, $T_c = 430.7$ K and $P_c = 77.8$ atm. Calculate
   a. the critical van der Waals constants for the gas, (5%)
   b. the critical volume of van der Waals SO$_2$, (5%)
   c. the pressure exerted by 1 mole of SO$_2$ occupying a volume of 500 cm$^3$ at 500 K. Compare this with the pressure which would be exerted by an ideal gas occupying the same molar volume at the same temperature. (5%)

4. One mole of solid Cr$_2$O$_3$ at 2500 K is dissolved in a large volume of a liquid Raoultian solution of Al$_2$O$_3$ and Cr$_2$O$_3$ in which $X_{Cr_2O_3} = 0.2$ and which is also at 2500 K. Calculate the changes in enthalpy and entropy caused by the addition. The normal melting temperature of Cr$_2$O$_3$ is 2538 K, and it can be assumed that the $\Delta S_{m, Al_2O_3} = \Delta S_m$, Cr$_2$O$_3$. ($\Delta H_{m, Al_2O_3} = 107500$ J, $T_{m, Al_2O_3} = 2324$ K) (15%)
5. For an A-B binary eutectic alloy, please draw the phase diagram for the system with the following informations: $T^A_m > T^B_m$, $\alpha$-phase is enriched with A element and $\beta$-phase is enriched with B element. Please draw the diagrams to indicate the effects of temperature on the free energy of mixing and the activity of the A-B system for the following temperatures respectively. (1) $T^A_m > T_1 > T^B_m$, (2) $T^B_m > T_2 > T_E$, (1) $T_3 = T_E$, (1) $T_4 < T_E$. (15%)

6. One mole of each of hydrogen, iodine vapor and HI gas are allowed to react at 1500 K and P = 1 atm. Calculate the mole fractions of H$_2$, I$_2$ and HI in the equilibrium mixture. (for H$_2$ + I$_2$ = 2HI, $\Delta G^0_{1500} = -34845$ J) (10%)

7. What is the minimum value that the activity of MgO can have in MgO.Al$_2$O$_3$ at 1000°C? (10%)
(For MgO + Al$_2$O$_3$ = MgO.Al$_2$O$_3$, $\Delta G^0_{1273} = -38220$ J)

8. The EMF of the galvanic cell Pb(s)|PbCl$_2$(s)|HCl(aqueous)|AgCl(s)|Ag(s) where all components are present as pure solids in contact with an HCl electrolyte, is 0.490 volt at 25°C and, at that temperature, the temperature coefficient of the EMF is $-1.84 \times 10^{-4}$ volt/degree. Write the cell reaction and calculate the free energy and entropy changes for this reaction at 298K. (10%)