2013
Interdisciplinary Graduate School of Medicine and Engineering, Master Course

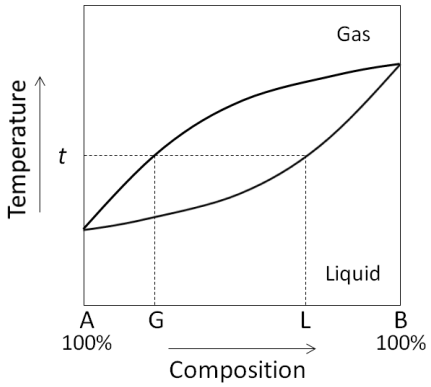
Entrance Examinations

No 1

Course or Program	Special Doctoral Program for Green Energy Conversion Science and Technology	Subject	Chemistry A

Problem 1.
Answer the following questions.
(1) Calculate the theoretical efficiency of a heat engine operating at T_H = 500 K and T_L = 400 K.
Calculate the heat input q_H to the engine and the heat output q_L from the engine, when the engine generates a work of 1.00 kJ.
(2) The standard enthalpy for the vaporization $\Delta H°_{vap}$ of ethanol is 38.6 kJ mol^{-1} at 350 K and ambient pressure (101.3 kPa). Calculate the standard entropy $\Delta S°_{vap}$ for the vaporization of ethanol at 350 K. Explain the thermodynamic meaning of $\Delta S°_{vap}$ (especially, sign of the value).

Problem 2.
Figure on the right shows the boiling-point-composition diagram of the mixture of liquids, A and B. Answer the following questions.
(1) Show the compositions of liquid and gas phases in the equilibrium state at the boiling point, *t*, using A, B, G and L.
(2) Show how the boiling point will change when the mixture of the liquids continues boiling.



Problem 3.
Answer the following questions.
A first-order reaction of the type A(g)→B(g)+C(g) was carried out in a gas phase at 25°C. The initial pressure of A and the rate constant for the reaction are 40 kPa and 5.0×10^{-3} s^{-1}, respectively.
(1) Calculate the partial pressure of A after 50 s and 5 min.
(2) What is the half life of A?

Problem 4.
Suppose there are two hydrogen atoms, H_a and H_b, with 1*s* orbitals, ϕ_a and ϕ_b, respectively, around the atoms. H_a and H_b form a hydrogen molecule.
(1) Based on the linear combination of atomic orbitals (LCAO) method, how are the bonding (Φ_+) and anti-bonding (Φ_-) orbitals formulated?
(2) Let the energy of ϕ_a and ϕ_b be E_0 and the energy of Φ_+ be E_+, where $E_0 > E_+$. How large is the bonding energy E at the steady state?
(3) How is the probability density of electrons in Φ_+ formulated around the hydrogen molecule?
(4) Based on the LCAO method, explain why He_2 atoms are not stable.

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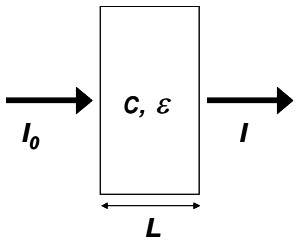
Problem 1.
In the absorption spectroscopy, relationships are investigated between the absorption of light and the properties of the material through which the light travels. Let the transmission be T, the distance the light travels through the material, L, the absorption coefficient of the material, ε, and the molar concentration of absorbing species in the material, c. For liquid, there is a relationship written as follows:



$$T = \frac{I}{I_0} = 10^{-\varepsilon Lc} \qquad \cdots\cdots \text{ (Eq. 1)}$$

1) Suppose I_0= 62,500 counts/s and I= 62,200 counts/s, calculate the transmission, T, and the absorbance, A.
2) Suppose T = 0.9, ε = 11.0 m^{-1} M^{-1} and L = 10.0 mm, calculate the concentration of the liquid.
3) In optics, what is this relationship stated in Eq. 1 called?

Problem 2.
Calculate the d_{200} and $2\theta_{200}$ values for the 200 line in X-ray diffraction pattern, Cu $K\alpha$ radiation (wavelength λ = 0.1541 nm), of a cubic structure with a lattice constant a = 0.50 nm.

Problem 3.
Answer the following questions.
(1) What elements are added to silicon to make it p-type?
(2) Sketch the energy band structure of p-type silicon with a band gap of 1.1 eV and an energy gap 0.1 eV for the acceptor levels.

Problem 4.
Answer the following questions for the reaction.

$$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$$

(1) What are the anode and cathode reactions?
(2) Calculate the standard electromotive force for $\Delta G^o = -212.3$ kJ at 25 ^oC.
(3) Calculate the electromotive force at 25 ^oC when the activities of Cu^{2+} and Zn^{2+} are 0.2 and 0.6, respectively.
If necessary, the following values may be used;
Faraday constant, F = 96500 C mol^{-1}
Molar gas constant, R = 8.314 J K^{-1} mol^{-1}