2019

Integrated Graduate School of Medicine, Engineering, and Agricultural Sciences, Master's Course, University of Yamanashi

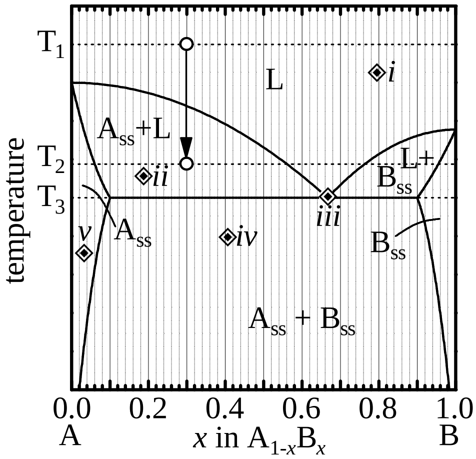
Entrance Examination

No 1/2

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

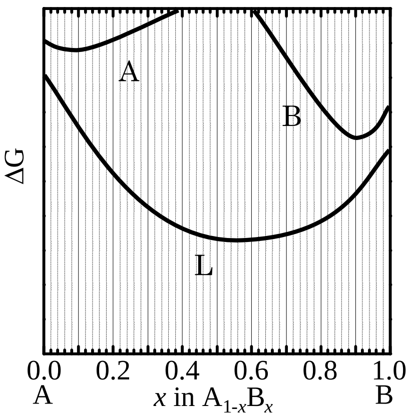
Question 1

Right-hand side figure shows a binary eutectic phase diagram. This diagram indicates the condensed phases system at atmospheric pressure. Answer the following questions.



(1) Answer degree of freedom for each point, ◈*i*, ◈*ii*, ◈*iii*, ◈*iv*, and ◈*v*.

(2) When the solid composed of A and B material with a ratio of 7:3 was heated at T_1 until complete melt and then cooled down to T_2 for the equilibrium. Answer the chemical compositions of solid and liquid phase, and solidification degree.



(3) Relationships among free energy curves for solid A_{ss}, solid B_{ss}, and liquid phases versus chemical composition at T_1 were shown schematically in a left-hand side figure. Draw the free energy curves for each phase at T_3 and add necessary explanations (additional lines, phase name etc.).

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No 2/2

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Question 2

Answer the questions related to the following reversible linear reaction, where k_1 and k_2 are the rate constants for reactions A→B and B→A, respectively. Let the initial concentrations of A and B be $[A]_0$ and $[B]_0$, respectively.

$$\mathrm{A} \underset{k_2}{\overset{k_1}{\rightleftarrows}} \mathrm{B}$$

(1) Let the amount of decrease in the concentration of A at time t be x. Show the concentrations of A and B at time t using $[A]_0$, $[B]_0$, and x.
(2) Show the derivative of x with respect to t using $[A]_0$, $[B]_0$, k_1, k_2, and x.
(3) Show x using $[A]_0$, $[B]_0$, k_1, and k_2 when the equilibrium is achieved.

Question 3

Fill in the blanks (A)–(M) with the most suitable word, term, numerical value, alphabet, and so on.
The hydrogen atomic wave functions are expressed as follows.

$$\psi_{nlm}(r,\theta,\phi) = R_{nl}(r)Y_l^m(\theta,\phi)$$

This equation tells us that the hydrogen atomic wave functions depend on three quantum numbers, n, l, and m. The n is called the (A) quantum number and has the values of (B). The energy of a hydrogen atom depends on only the (A) quantum number. The l is called the (C) quantum number and has the values of (D). The value of l is customarily denoted by a letter, with $l = 0$ being denoted by (E), $l = 1$ by (F), $l = 2$ by (G), $l = 3$ by (H), and so on. A wave function with $n = 1$ and $l = 0$ is called a (I) wave function; one with $n = 2$ and $l = 0$ a (J) wave function, and so on.
The m is called the magnetic quantum number and has the values of (K). The energy of a hydrogen atom in a magnetic field depends on m. In the absence of a magnetic field, each energy level has a degeneracy of (L). In the presence of a magnetic field, these levels split, and the energy depends on the particular number of m. This splitting is called the (M) effect and that of the 2p state is illustrated in Fig. 1. Illustrate the splitting of the 2p state in a magnetic field in Fig. 1. The m values should be included.

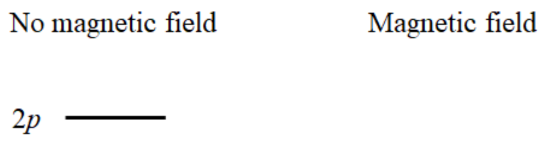

Fig. 1 The splitting of the 2p state of a hydrogen atom in a magnetic field.

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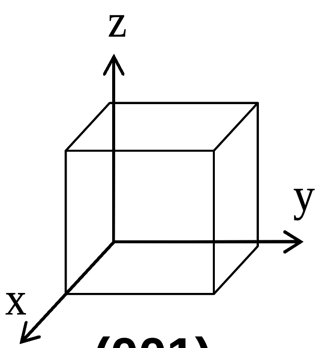
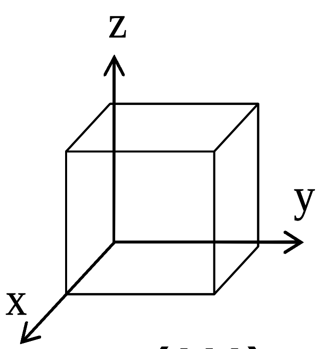
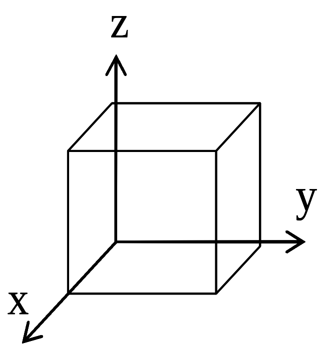
Question 1 Draw the lattice plane of each Miller index.



(001)

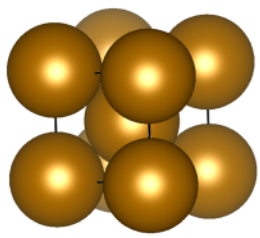


(111)



(110)

Question 2 This figure shows a cubic unit cell of a metal.
Answer the following questions.



2-1 How may atoms are there in the unit cell?

2-2 When the X-ray (wavelength : 0.15418 nm) is irradiated to this metal, the 110 diffraction line is observed at $2\theta = 44.0$ degree in the powder X-ray diffraction pattern. Calculate the lattice parameter of this metal.

2-3 When the atomic weight of this metal is 56.0, Calculate the density of this metal. Avogadro number is 6.02×10^{23}.

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Question 3

Calculate the molar conductivity Λ_m of 1.00×10^{-2} mol dm^{-3} KCl aqueous solution with the conductivity of 0.140 S m^{-1}. Draw a graph for the relation between the Λ_m and the square root of concentration c ($c^{1/2}$) for the KCl solution. Explain the reason of such a dependency.

Question 4

Answer the following questions for an electrochemical cell Pt | H_2 (1 atm) | H^+ ‖ Ag^+ | Ag at 25 °C where the standard electrode potentials at 25°C are given as Ag^+ | Ag 0.80 V.

(1) What are (a) the anode reaction, (b) cathode reaction, and (c) the overall cell reaction?

(2) Can we expect the overall cell reaction to be spontaneous? Describe the reason.

(3) Write down the Nernst equation for the right hand side electrode potential E as a function of $a(Ag^+)$ and a(Ag). For the left hand side electrode, write down E as a function of pH.

If necessary, use the following constant: R = 8.314 J K^{-1} mol^{-1}, F = 96500 C mol^{-1}