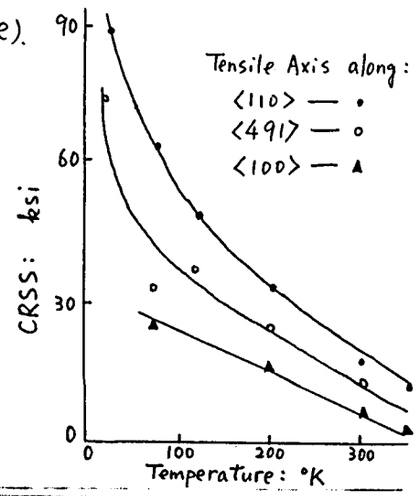
INSTRUCTIONS: 1. Answer the questions in consecutive order.
請按題號之順序答題。
2. Your answers can be in Chinese and/or in English; but not in others.
答題方式僅限於中文及/或英文。

1. Briefly and specifically answer the following three questions:
(a). Ceramic materials are usually more brittle than metals. Why? (6%)
(b). Some precipitation-hardened aluminum alloys are used in high temperature fatigue conditions. These alloys are sometimes softened during service. Name the possible softening mechanism(s). (7%)
(c). When dynamic strain aging occurs, the ductility of a material is deteriorated. Why? (6%)

2. The following questions are related in sequence. Answer each of the questions concisely.
(a). What is meant by slip system? (6%)
(b). Name all the possible slip systems for face-centered cubic (fcc) materials and body-centered cubic (bcc) materials. (6%)
(c). Derive an equation to show the resolved shear stress of a slip system upon tension. (6%)
(d). What is meant by critical resolved shear stress (CRSS) of a slip system? (6%)
(e).



The CRSS of (110)⟨111⟩ slip as a function of test temperature and tensile axis direction is shown in the figure for pure molybdenum. The crystal structure of molybdenum is bcc. The data in the figure do not fall on a single curve, whereas those for fcc materials do fall on a single curve. Why? (7%)

3. (a) Which of the following directions are in the $(21\bar{3})$ plane in a cubic crystal?
$[1\bar{2}0]$ $[302]$ $[\bar{1}\bar{3}1]$ $[212]$ (3%)

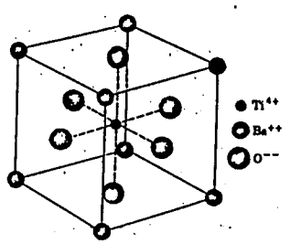
(b) The unit cell of barium titanate ($BaTiO_3$) is shown below. The crystal structure is cubic.

(i) What is the Bravais lattice? (2%)

(ii) How many ions are there in the unit cell? (2%)

(iii) What are the number and type of nearest neighbors for each type of ion? (2%)

(iv) What ions lie along the <310> directions? (2%)



4. (a) Assume that nuclei of β form in α as cubes with edge length X. Derive an expression for the critical cube size X^* and activation energy ΔG^* in terms of γ and ΔG_V. (γ: surface energy & ΔG_V: Volume energy) (6%)

(b) How would small additions of either Na^+ or Ca^{++} to Li^+F^- modify the diffusion rate of Li^+? Provide an answer for each case. (3%)

(c) Give Fick's first law and identify the terms. Is it correct to interpret this law as follows – the jump rate of individual solute atoms increases as the concentration gradient increases and thus the flux increases? (3%)

5. The phase diagram for Pb-Sn is given below. Note that $T_E = 183°C$.

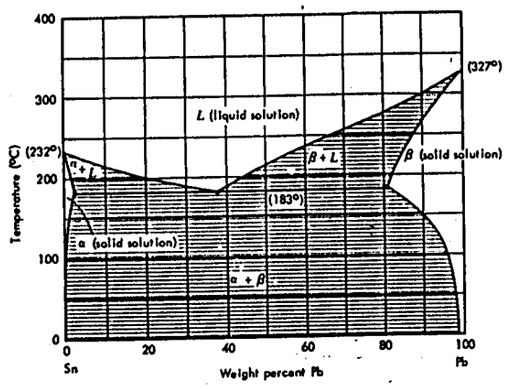
(a) Neatly sketch the microstructures of a 60 wt% Pb alloy at $T = 182°C$ and $T = 184°C$. Label all phases and give their compositions. (3%)

(b) For the alloy in part (a), what percentage of the total β phase present at $T = 184°C$ is in the $\alpha + \beta$ eutectic phase mixture? (3%)

5, cont'd:

(c) How many phases are in equilibrium for the alloy in part (a) if it is held exactly at the eutectic temperature $T_E = 183°C$? (3 %)

(d) Why can we expect small additions of Sn to pure Pb to increase the entropy? (3 %)



6. Pure iron transforms on heating from the BCC phase (ferrite) to the FCC (austenite) at 910°C. The heat (enthalpy) required for the transformation is 215 cal/mole. Calculate the entropy change during the transformation. (4 %) Assume that the atomic diameter is unchanged during the transformation and compute the work done by the atmospheric pressure as 1 mole of iron undergoes the transformation. (3 %) Compute the change in internal energy and compare it with the enthalpy change. (3 %) Is it accurate to say that the enthalpy change and internal energy change are almost the same? (2%) Would they be significantly different if the transformation were to take place at 100 atm ? (3 %) The atomic diameter of iron is 2.48 Å.