1. (20%)

Figure 1 shows a binary eutectic phase diagram on which an alloy of overall composition \( X_0 = 0.2 \) is gradually cooled from temperature \( T_1 \) to \( T_5 \). \( T_5 \) is just below the eutectic temperature.

(A) Determine the total fraction of \( \alpha \) phase in the alloy at temperature \( T_5 \). (5 分)

(B) Sketch the microstructure at temperature \( T_5 \) and label all the phases. (5 分)

(C) Sketch equilibrium cooling curve (temperature versus time) for alloy \( X_0 \) and put related temperature points in your drawing. (5 分)

(D) Draw the free energy curves for each of the phases in the above eutectic system at \( T_5 \). Label all the phases. (Plot mole fraction along the ordinate versus free energy along the abscissa.) (5 分)

2. (10%)

(A) Calculate the Atomic Packing Factor (APF) of the face-centered cubic (FCC) crystal structure. (hint: \( \text{APF} = \frac{\text{volume of atoms in the unit cell}}{\text{volume of unit cell}} \)) (5 分)

(B) Determine whether it is possible for a boron atom to fit into a tetrahedral site in FCC aluminum. Atomic radii of boron and aluminum are 0.46 Å and 1.43 Å, respectively. (5 分)

3. (10%)

(A) Which crystal plane will appear as the first X-ray diffraction peak of FCC aluminum? (3 分)

(B) Calculate the diffraction angle of the peak in above question. (Atomic radius of aluminum and is 1.43 Å. The wavelength of X-ray irradiation is 1.54 Å.) (7 分)

4. (20%)

(A) Two silica glasses (SiO\(_2\)) containing 5 wt% and 10 wt% soda (Na\(_2\)O) are studied. How will their glass transition temperature compare? Why? (7 分)

(B) Two amorphous polymers, A and B have the same molecular weight but different glass transition temperatures. How will their elastic modulus values compare? Why? (7 分)

(C) Compare the Degree of Crystallization of polyethylene [C\(_2\)H\(_4\)]\(_n\), polypropylene [C\(_3\)H\(_6\)(CH\(_3\))]\(_n\) and polystyrene [C\(_2\)H\(_5\)(C\(_6\)H\(_5\))]\(_n\). (6 分)

5. (10%)

(A) Suppose a metal, semiconductor and an insulator all have the same resistance at 20°C. Which material will have the highest resistance at 50°C? (5 分)

(B) Plot resistivity versus temperature diagram of a superconductor. (5 分)
6. (10%)
   What is a Light Emitting Diode and how does it work? (10 分)

7. (10%)
   (A) Which of the following dielectric materials will achieve the highest charge density in a simple parallel plate capacitor at room temperature: diamond (C), quartz (SiO₂), barium titanate (BaTiO₃) or HDPE (C₂H₄)n? (4 分)
   (B) What is the polarization mechanism of the dielectric material you just selected? (6 分)

8. (10%)
   Diamond and copper are the best heat conductors in nature. Explain the mechanism of their high thermal conductivity. (10 分)