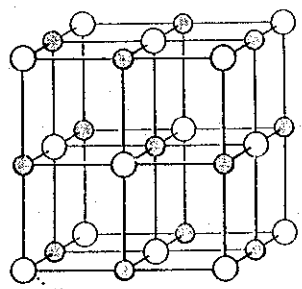
1. Sketch the following planes and directions in a cubic unit cell: (a) (113), (b) [122], (c) $(1\bar{1}2)$, and (d) $[1\bar{1}2]$. (10 points)

2. (a) One homogeneous phase or two separate phases may be formed when two elements are mixed together depending on their mutual affinity. However, when a very small amount of B element is added to the phase of pure A, no second phase is formed usually. Why? (7 points)
(b) A material system approaches equilibrium when its Gibbs free energy G approaches the minimum. Could we use the internal energy U to replace G for the above statement? Why? (8 points)

3. MgO is of the FCC-type structure with lattice constant a=4.2 Å. Calculate its density in unit of g/cm^3. The atomic weights for Mg and O are 24.3 and 16.0 g, respectively. (10 points)



(MgO and NaCl structure)

4. MgO and NaCl are of the same FCC-type structure. Do you expect that NaCl has a lattice constant larger or smaller than that of MgO? Why? The measured surface energy at room temperature for MgO and NaCl are 1000 and 300 erg/cm^3, respectively. Propose possible origins for this difference and explain it. (15 points)

5. Describe the simple equations for the relationships between the flow stress σ and (a) grain size d, (b) dislocation density ρ, (c) shear strain ε, (d) shear strain rate $\dot{\varepsilon}$. Also, describe the relationship between the critical resolved shear stress (CRSS) τ_c and the tensile yield stress σ_y for a single crystal specimen (better to show the drawing). What is the maximum ratio for CRSS/σ_y? (20 points)

6. Describe in your own words the meaning and the different stages occurred during "annealing" for metallic materials? What are the material and processing factors that will affect the characteristics of annealing? What is the driving force for each stage of the annealing process? (15 points)

7. Describe the relationship between resistivity and temperature for metals and insulators. Give explanations as well. (15 points)

國立中山大學九十學年度博士班招生考試試題

科目：高分子科學【材料所乙組】

Please note that (1) *this examination has three subject areas on two separate pages,* and (2) *partial credits will be given only to incomplete answer relevant to the solution of the problem*

A: Polymer Synthesis

A1. Which of the following monomers would you expect to polymerize readily by a free-radical mechanism? Why?
$CH_2=C(CH_3)_2$, $CH_2=CH(CH_3)$, $CH_2=CHCH=CH_2$ (5 pts.)

A2. Explain why if two polyester samples of number-average molecular weights 2,000 and 10,000 respectively are mixed, the melt viscosity decreases while the number-average molecular weight for the entire system remains unchanged. (5 pts.)

A3. Consider the following initiators: (10 pts.)
$(C_6H_5CO_2)_2$; Na + Naphthalene; AIBN; H_2SO_4; $(CH_3)_3COOH + Fe^{2+}$
What is the initiating species from each of these initiators: Show equations.

A4. Which will produce the larger yield of monomer when heated at moderate temperatures: (a) polystyrene, or (b) poly-α-methylstyrene? Why? (5 pts.)

A5. Give the chemical structure for each of the following polymers. (10 pts.)
(1) Poly(vinylidene chloride)
(2) Poly(methyl methacrylate)
(3) Polydimethylsiloxane
(4) Nylon-6,10
(5) Phenol-formaldehyde resins (PF)

A6. Early in 1941, poly(trimethylene terephthalate) (PTT) has been synthesized by Whinfield and Dickson, and it is known that the physical properties of PTT is superior than those of poly(ethylene terephthalate) (PET). At that time, ethylene glycol, which is the starting material of PET, can be commercially prepared, while 1,3-propandiol, which is the starting material of PTT, still cannot be commercially prepared. More recently, PTTs have drawn attention for their application in textile industry due to a great reduction in the manufacturing cost of 1,3-propanediol. If you are assigned to do the research work of PTT, please describe an efficient route to collect all of the related literatures in detail. (5 pts.)

B: Polymer Processing

B1. Show that the *equation of continuity*, which is typically written as

$$\partial\rho/\partial t = -(\vec{\nabla}\bullet\rho\vec{v}) \quad [1]$$

(in which t, ρ, and v are respectively the time, the density, and the velocity of the fluid and the arrows are used to emphasize vectors) can be expressed as

$$D\rho/Dt = -\rho(\vec{\nabla}\bullet\vec{v}), \quad [2]$$

if an operator, the 'substantial derivative' defined as $D/Dt = \partial/\partial t + \vec{v}\bullet\vec{\nabla}$, [3]
is adopted. (3 pts.)

B2. Similarly, show that the *equation of motion*, typically written as

$$\partial[\rho\vec{v}]/\partial t = -[\vec{\nabla}\bullet\rho\vec{v}\vec{v}] - [\vec{\nabla}\bullet\underline{\underline{\pi}}] + \rho\vec{g} \quad [4]$$

can be expressed as $\rho[D\vec{v}/Dt] = -[\vec{\nabla}\bullet\underline{\underline{\pi}}] + \rho\vec{g}$ [5]
(in which g represents gravity and the stress tensor $\underline{\underline{\pi}} = P\underline{\underline{\delta}} + \underline{\underline{\tau}}$, [6]
with P, δ, and τ represent respectively the pressure, the unit (identity) tensor, and the deviatoric stress tensor whereas double-underlines are used to emphasize tensors). (3 pts.)

B3. What is the physical meaning of the *equation of continuity*? (3 pts.)

B4. What is the physical meaning of the *equation of motion*? (3 pts.)

B5. What is the physical meaning of the *substantial derivative*? (3 pts.)

B6. On the basis of Equation 5, Equation 6 can be rewritten as

$$\rho[D\vec{v}/Dt] = -\vec{\nabla}P - [\vec{\nabla} \bullet \underline{\underline{\tau}}] + \rho\vec{g} \,. \qquad [7]$$

Regarding the pressurization of polymer melt during polymer processing (which is an important operation in the molding or extrusion of polymers), what approaches does Equation 7 suggest? Any further comments? Be as imaginative as you can in answering this question. (5 pts.)

C: Physical Properties (5 pts. each)

C1. A polyethylene oxide has a *glass transition temperature* (T_g) of –67°C and a *melting temperature* (T_m) of 67°C. A polypropylene has a T_g of –25°C and a T_m of 185°C.

(1) Please give the definition of *glass transition temperature*.

(2) Differential scanning calorimeter (DSC) measures thermal properties of polymers showing enthalpy response (ΔH) as a function of temperature (T). Please sketch the DSC response (i.e. ΔH versus T) of the polyethylene oxide upon heating from –90°C to 200°C.

(3) If the polyethylene oxide and the polypropylene are mixed in equal weight yielding a transparent film, please sketch the DSC response of the composite film over the same temperature range.

C2. Atactic polystyrene dissolved in cyclohexane has a *theta* (Θ) *temperature* of 36°C.

(1) Please give the definition of *theta* (Θ) *temperature* for a polymer solution.

(2) Please describe the relationship between *end-to-end distance* (R) and *molecular weight* (M_w) of the polystyrene molecule after cyclohexane is *completely removed*.

(3) Please sketch and explain qualitatively that X-ray scattering intensity as a function of scattering angle (θ) for X-ray with 0.154 nm wavelength.

C3. *Conjugated polymers* can have unique opto-electronic properties, such as electrical conductivity, luminescence, and nonlinear optics. Please answer the following two questions.

(1) What is *conjugated polymer*?

(2) What is the necessary process in making *conjugated polymers* become electrically conducting?