BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, Pilani
Pilani Campus
Instruction Division

CHE F243
Materials Science and Engineering

II Semester 2012-13 Comprehensive
Max total time: 180 min Total max marks:90+70

This question paper is divided in two parts; A & B. part A open book and part B closed book. You need to finish the part A first, and then ask for the part B. Attach both parts at the end of the exam before hand it over to the invigilator.

PART A (Open Book)

1. **Read the questions carefully and understand. If you have any questions talk to me.**
2. **Answer to the point and precisely.**
3. **Show every step clearly, Do not jump the steps.**
4. **no marks will be awarded for the answers only.**
5. **Unnecessary vague wordings will deduct mark**
6. **Write unit in every step. violation may deduct marks.**
7. **Show all of your work, assumptions, and reasoning in detail (If I can see your thought process I can give you more credit)**
8. **Box your final answer**
9. **Label all answers with UNITS.**
10. **Be neat and clean.**

1. For an ideal HCP crystal show that the

   a) c/a ratio is 1.633, and
   b) atomic packing factor is 0.74. [10]

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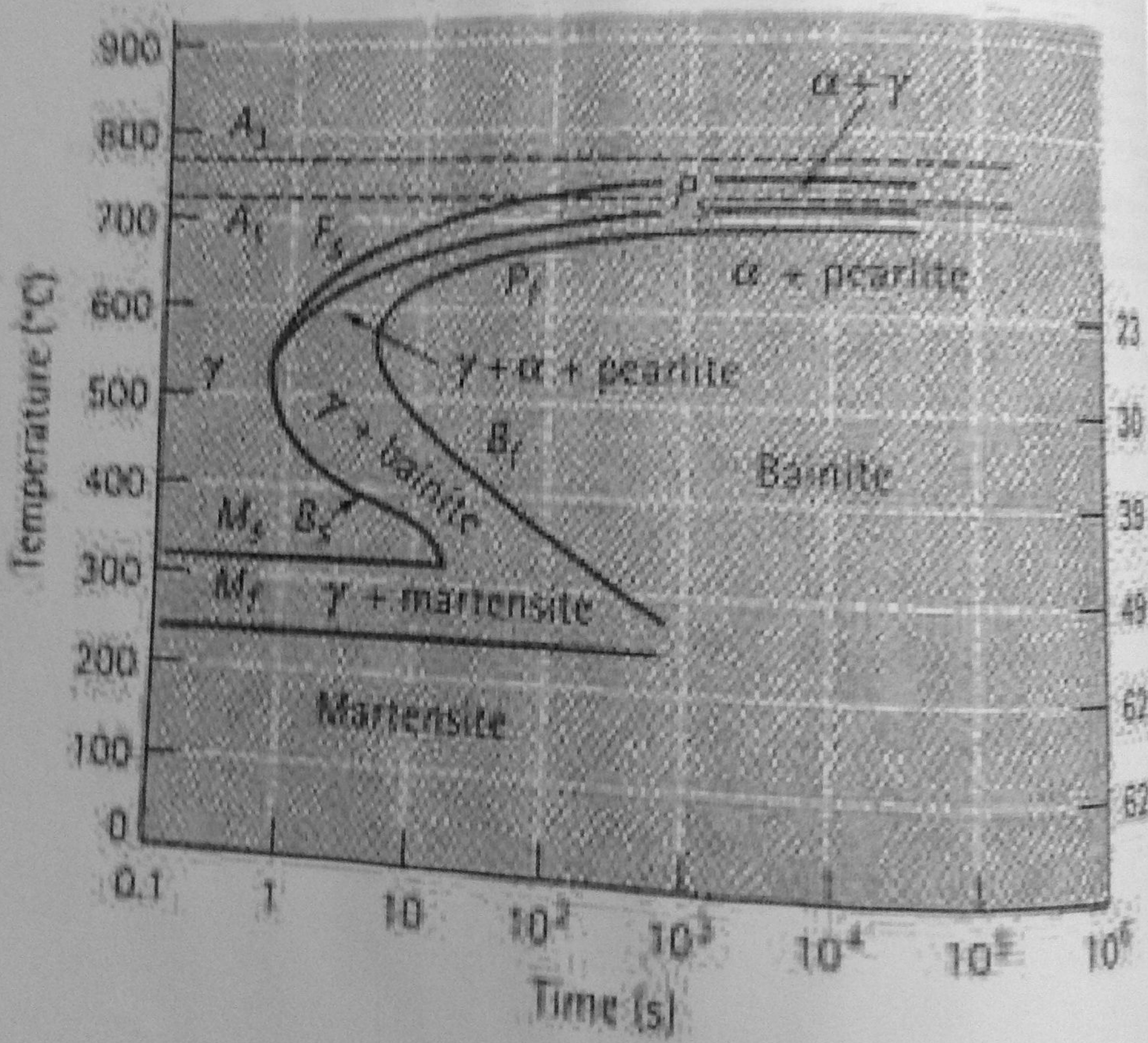
2. Describe the phase(s) present (and draw the corresponding microstructure(s)) in a 0.5% plane C steel after each step in the following heat treatment. [6x2]
(a) fully austenized at 900C, quenched to 650C and hold for 90s, and quenched at 25C
(b) fully austenized at 850C, quenched to 450C, hold there for 90s and quenched to 25C.
(c) fully austenized at 850C, and quenched to 25C
(d) fully austenized at 900C, quenched to 700C and hold for 100s, and quenched at 25C
(e) fully austenized at 850C, quenched to 700C and hold for 100s, quenched to 400C and hold for 50s and quenched at 25C
(f) fully austenized at 900C, quenched to 700C and hold for 100s, quenched to 400C and hold for 10s and quenched at 25C



3. One way to m
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4. Derive expre
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6. Calculate d
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SHORT QUES

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3. One way to manufacture transistors, which amplify electrical signals, is to diffuse impurity atoms into a semiconductor material such as Si. Suppose a Si wafer of 1 mm thick, which originally contains 1 P atom per every 10^7 Si atoms, is treated so that there is 400 P atoms per every 10^7 atoms at one surface. Calculate the concentration gradient (a) in atomic % m^{-1} and (b) in atoms. m^{-3}. m^{-1}. The lattice parameter of Si is 0.54307 nm [8].

4. Derive expressions for r* and ΔG^* considering a hexagonal unit cell shaped nucleation. Compare the ΔG^* with the same of spherical nucleation. [10].

5. A cylindrical rod of brass originally 0.35 in diameter is to be cold worked by drawing. The circular cross section will be maintained during deformation. A cold-worked tensile strength in excess of 55,000 psi (380 MPa) and a ductility of at least 15 %EL are desired. Furthermore, the final diameter must be 0.27 in. Explain step wise how this may be accomplished. [10].

6. Calculate density of iron(II) and cerium(IV) and corresponding oxides using respective crystal structure, atomic, and ionic radius. Show that the stability of the oxide layers on both of them are similar. Ce is FCC structure, and r_{Ce} = 185 pm and $r_{Ce^{4+}}$ = 115 pm. [10]

SHORT QUESTIONS

1. What is shape memory effect? how the shape memory alloy can be used in biomedical implantation? explain with at least 2 different examples. [2]
2. Mention two probable simultaneous function of bioimplants. Where these bioimplants could be used?. [2]
3. Ni is a metal highly susceptible to corrosion and harmful for human body. Why Ni is used in alloys at the first place? [2]
4. What is octane number? Mention a procedure for increasing octane number of petrochemical product. [2]
5. What is catalytic regeneration? explain with proper equation. Where is it used generally? [2]
6. Explain three possible mechanism of how catalysts help to increase rate of a reaction. [2]
7. Calculate the direction of the zone axis of the planes (102) and (211). [2]
8. Calculate the wavelength of electrons when the transmission electron microscope is operated at 250 keV. Show the steps and mention units. [2]
9. What is quantum confinement effect? How this effect could be helpful in cancer treatment? what material generally used for this purpose? [2]
10. What is photolithography? Explain with major steps and proper images. [2]
11. For galvanic cell small anode and large cathode should be avoided-why? explain with proper equation(s). [2]

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12. Is it possible to replace FCC lattice by BCT lattice or vice versa? why or why not? [2]

13. As degree of super cooling increases, number of n* increase, but frequency of attachment decreases- explain with proper equation and schematics. What is the physical significance of this statement? [2]

14. What is glass transition (T_g) temperature? For what kind of materials we expect and don't expect to ha T_g? why? [2]

15. Show comparative stress vs. strain behaviour for LDPE, HDPE and a HDPE annealed sample (after annealed for a long time (10 hours) at 90 °C and then cooled very slowly). Explain these behaviors. [2

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PART B (Closed Book)

1. **Read the questions carefully and understand. If you have any questions talk to me.**
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5. **Unnecessary vague wordings will deduct mark**
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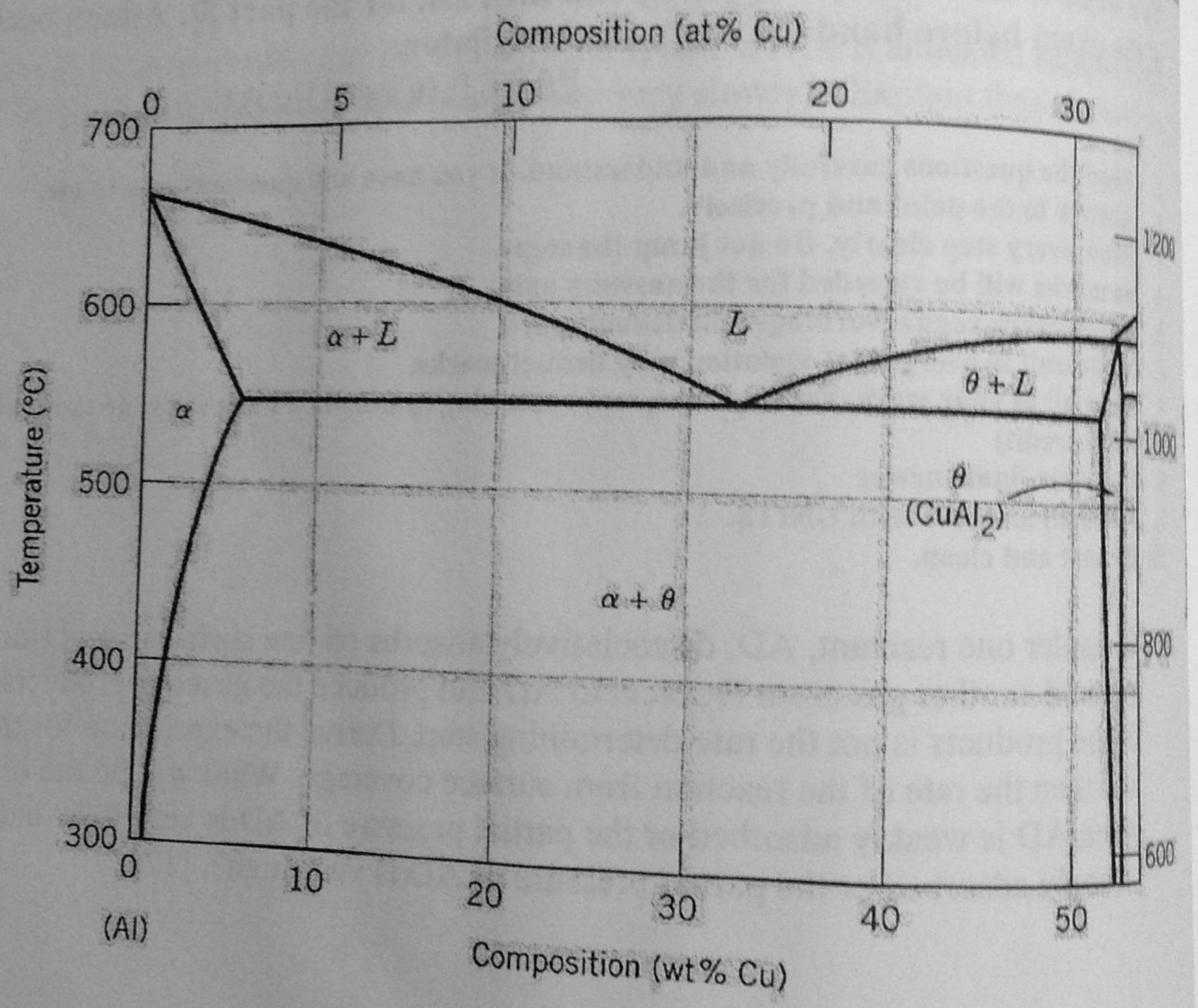
1. Consider one reactant, AD, dissociatively adsorbs on one surface metal (mostly selective to AD) site and another gas atom B reacts to AD and produce the gaseous products C and E. Desorption of the products is not the rate determining step. Derive the expression for the surface coverage and then the rate of the reaction from surface coverage. What will be the order of the reaction when AD is weakly adsorbed or the partial pressure of AD is very low? and when AD is strongly adsorbed or the partial pressure of AD is very high?. [12]

2. A binary Al–8.5 wt % Cu alloy is slowly cooled from 700°C to just below the eutectic temperature. [6]
   (a) Calculate the wt % proeutectic α present just above the eutectic temperature.
   (b) Calculate the wt % eutectic α present just below the eutectic temperature.
   (c) Calculate the wt % θ phase present just below the eutectic temperature.
   (d) Draw the microstructures (and label) of the alloys just above and below the isother



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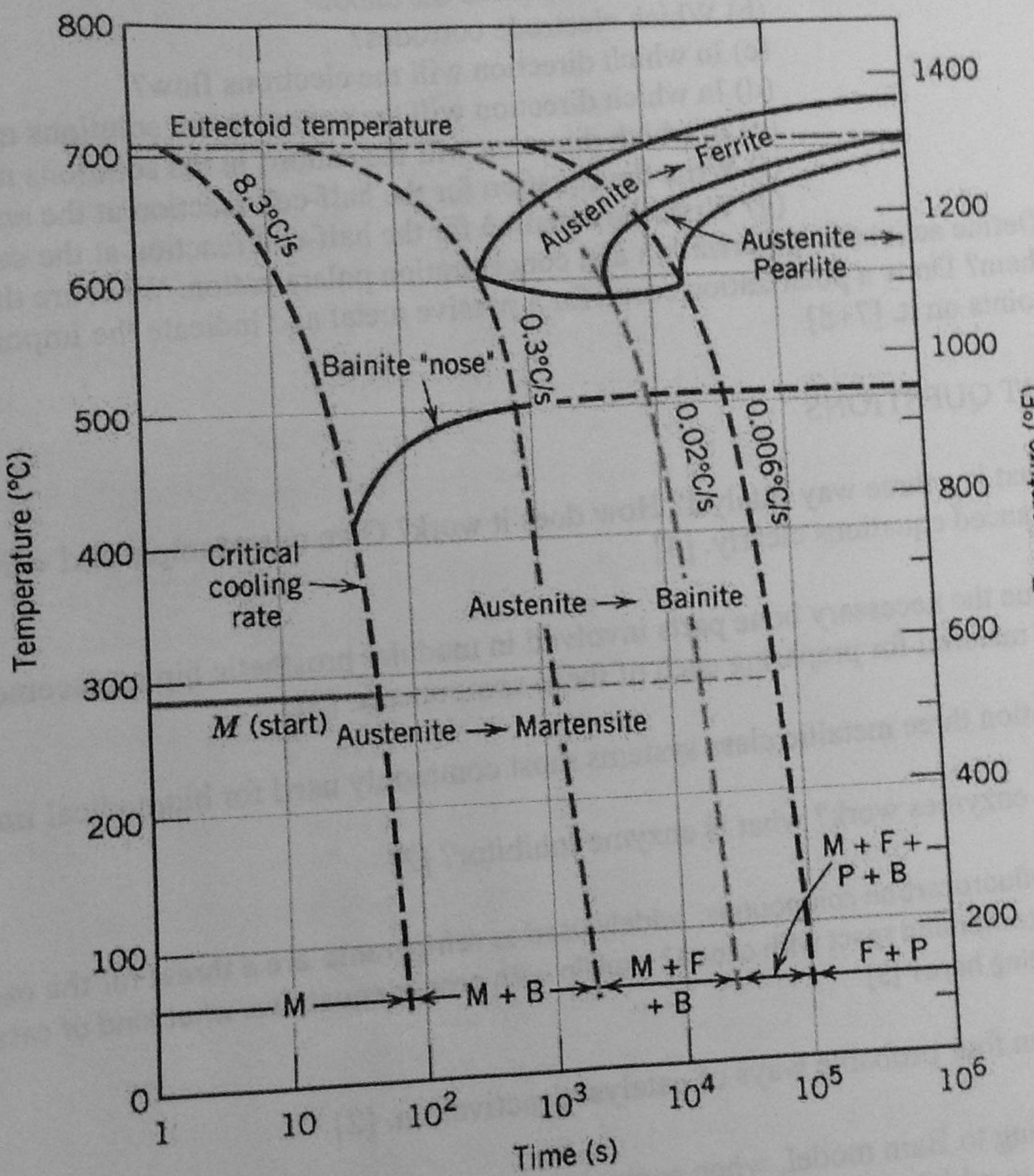
3. Consider the following CCT diagram for 4340 alloy steel. This steel is 1st completely transformed to austenite and then cooled to room temperature at the following rates;
(a) 15C/h,
(b) 180C/h,
(c) 1800C/h, and
(d) 18000C/h. Name the phases and draw each of the microstructure clearly. [8]



4. Consider a magnesium-iron galvanic cell consisting of a magnesium electrode in a solution of 1 M $MgSO_4$ and an iron electrode in a solution of 1 M $FeSO_4$. Each electrode and its electrolyte are separated by a porous wall, and the whole cell is at 25°C. Both electrodes are connected by a copper wire.
   (a) Which electrode is the anode?
   (b) Which electrode corrodes?
   (c) In which direction will the electrons flow?
   (d) In which direction will the anions in the solutions move?
   (e) In which direction will the cations in the solutions move?
   (f) Write the equation for the half-cell reaction at the anode.
   (g) Write the equation for the half-cell reaction at the cathode.

   Define activation polarization and concentration polaraization. What are the differences among them? Draw a polarization curve for a passive metal and indicate the important regions and points on it. [7+8]

SHORT QUESTIONS

1. What is a three way catalyst? How does it work? Give one example and write the relative balanced equations clearly. [3]

2. Name the necessary bone parts involved in modular prosthetic hip replacement. Suggest at least one material for preparing each of these components. [3]

3. Mention three metallic class systems most commonly used for biomedical implantation. [2]

4. How enzymes work? what is enzyme inhibitor? [2]

5. chlorofluorocarbon compounds; widely used as refrigerants are a threat for the ozone layer. How do these compound react with ozone? explain with proper equations. what kind of catalytic reaction we are seeing here? [3]

6. Mention four probable ways of catalyst deactivation. [2]

7. According to Bain model, when austenite converts to martensite, which directions and planes convert to which directions and planes? mention one plane and one direction. consider only one unit cell of martensite and positive directions. [2]

8. What is the length of Burger vector in Cr? Mention geometric relation of the Burger vector with corresponding dislocation line for two kinds of most common linear defects. $r_{Al} = 0.125nm$ [3]

9. Role of microstructure in diffusion; explain effect of temperature on self diffusivity for a single crystalline vs. polycrystalline metal. [2]

10. What is hydrogen over potential? What is the relation between hydrogen overpotential and corresponding exchange current density? [2]

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11. What is the difference between cathodic and anodic protection for metal? What happen electrochemically? explain with proper electrochemcial equations. [3]

12. What is the difference between homogeneous and heterogeneous nucleation? when these two are same? explain with proper equations. [2]

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Materials Science and Engineering

II Semester 2012-13 **Mid sem (Closed Book)**
Max Time: 90 min **Total Max Marks:90**

This question paper is divided in two sections A & B. Write answers on the question paper for section A. For section B use separate sheet.

SECTION A

Q1: True or false? [0.5 point each]

A. As the miller indices of planes increase interplanner spacing increase
B. At room temperature polystyrene will deform less than polyethylene under a constant force.
C. Diffusivity increase in polymer as the % of crystallinity decrease.
D. For optical microscope, working distance increases with the numerical aperture.
E. X-ray diffraction occurs when atoms of a parallel plane family d_{hkl} in a crystal can produce destructive interference of the scattered rays at specific angles.
F. The closed pack stacking sequence for a defect free FCC crystal can be expressed as ABCABCABBABBABC
G. It is possible to determine the angle between two grains, if the burger vector of the crystal and the spacing between the dislocations are known.
H. Diffusion is faster in a single crystal materials compared to a polycrystalline material.
I. Compared to isotactic polymers, atactic polymers crystallize easily.
J. Considering the annealing of a heavily cold worked brass sample, recrystallization influences the mechanical properties less than the grain growth stage.

Q2: Multiple choice: cross the right one(s) [1 point each].

1. In a BCC unit cell one atom is in contact of following number of the identical atoms
   a) Ten
   b) Eight
   c) Twelve
   d) None of the above
2. The volume of atoms in a selected unit cell divided by the volume of the unit cell is known as
   a) Volume ratio of the unit cell
   b) Volume density of the unit cell
   c) Planer density of the unit cell
   d) Atomic packing factor of the unit cell
3. Vacancies are
   a) Planner defects
   b) Volume defects
   c) Line defects

d) Point defects

4. The migration of atoms in a pure material is called
   a) Substitutional diffusion
   b) Interstitial diffusion
   c) Self-diffusion
   d) None of the above

5. Poisson's ratio refers to
   a) Modulus of rigidity to modulus of elasticity
   b) Longitudinal strain to lateral strain
   c) Engineering strain to true strain
   d) Lateral strain to longitudinal strain

6. Crosslinks between the chains in an elastomer have the effect of
   a) Reducing the elastic modulus
   b) Preventing softening on heating
   c) Increasing crystallinity
   d) Preventing diffusion of gas molecules

7. Like optical microscope in TEM lenses are used for
   a) Magnifying the image
   b) Magnifying the image and confining the incoming beam
   c) Increasing resolution
   d) Decreasing working distance

8. A bar of length l is considered to be semi-infinite when
   a) $l>10dt$
   b) $l> 10(dt)^{1/2}$
   c) $l< 10(dt)^{1/2}$
   d) $l=10dt$

where d is the diffusivity of a material through the bar and t is the time for diffusion.

9. Polycrystalline materials are stronger than the single crystal materials, because
   a) Grain boundaries prevent dislocations to move.
   b) Slip planes and directions don't change from one grain to another.
   c) Resolved shear stress doesn't vary from one grain to another.
   d) None of the above is true.

10. Elastic modulus, E for a material depends on the
   a) Magnitude of the applied tensile force
   b) Rate of the deformation
   c) Interatomic distance
   d) Interatomic potential energy

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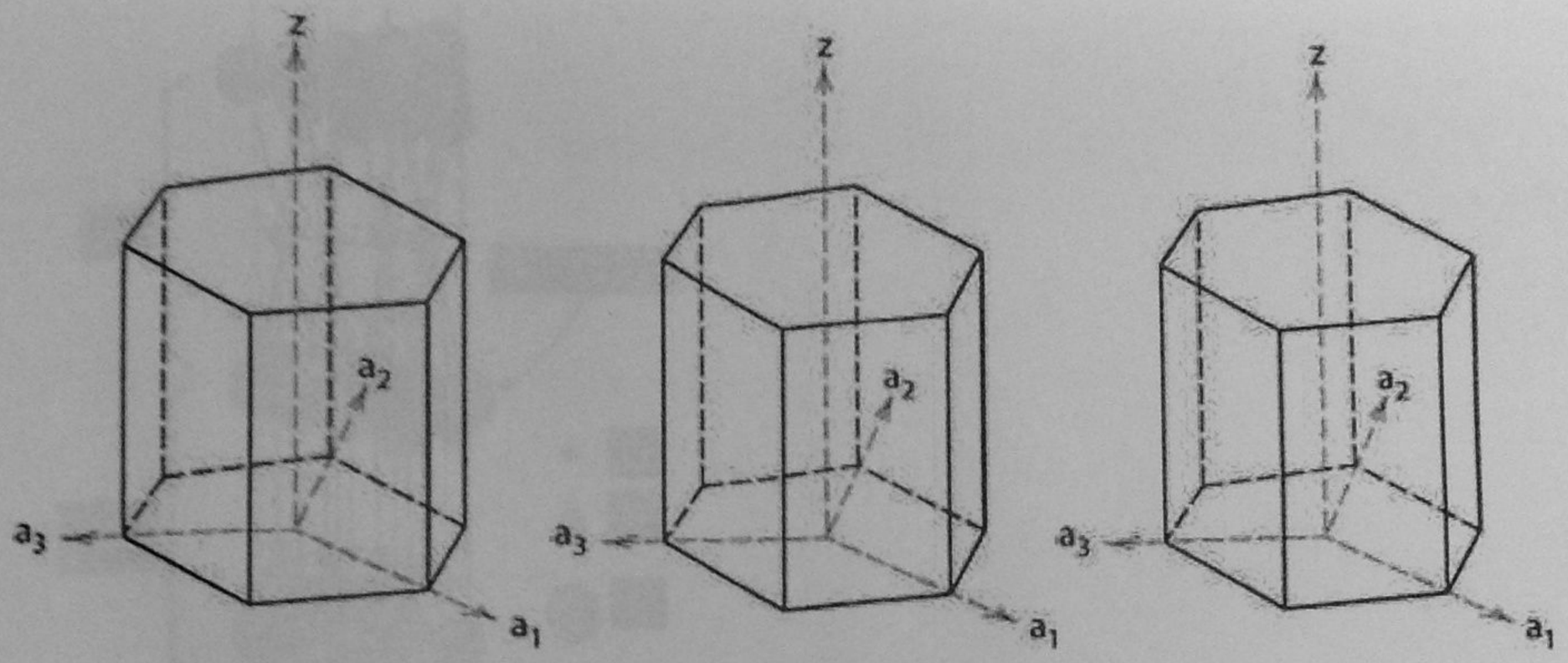
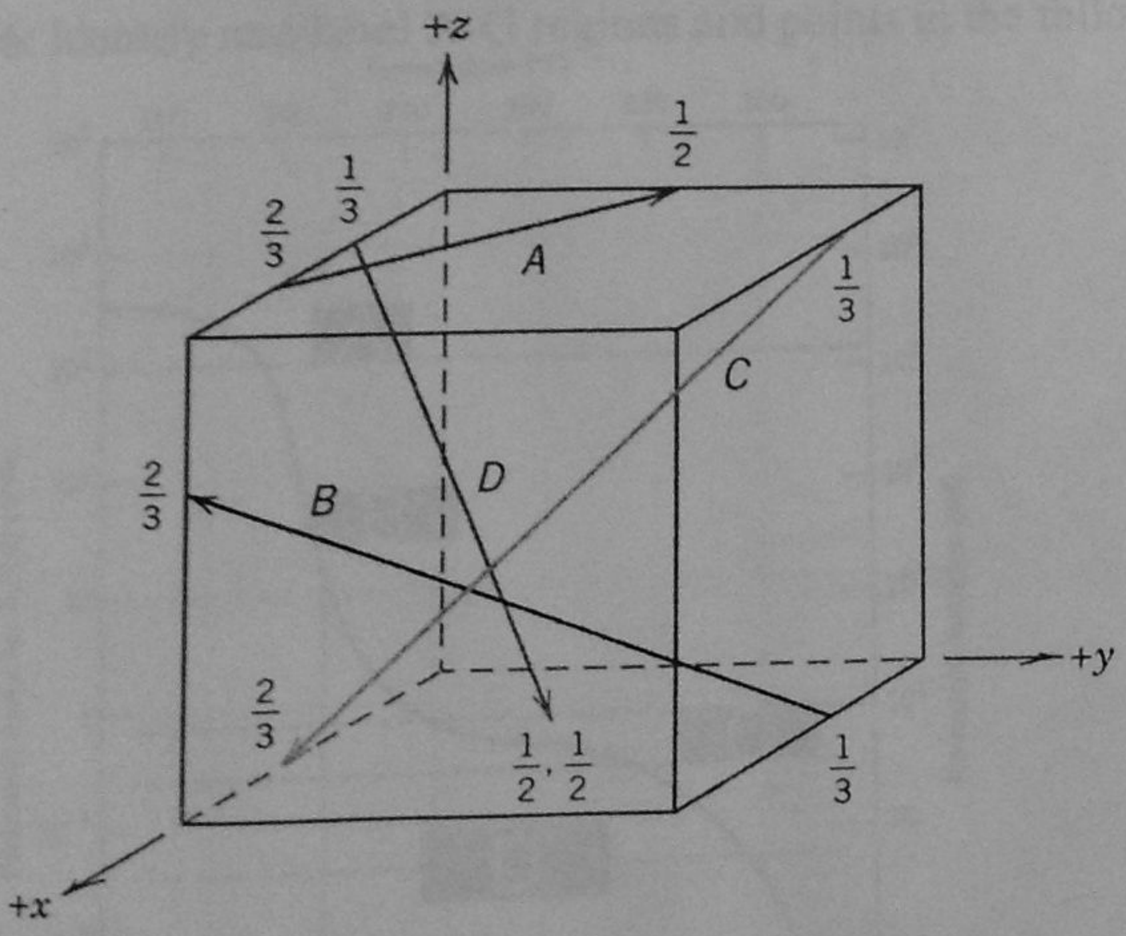
Q3: Draw the planes $(10\bar{1}0)$, $(\bar{1}101)$ and $(\bar{2}112)$ in the hexagonal unit cells below [3]



Q4: Determine the Miller indices of the directions in the unit cell below [4]



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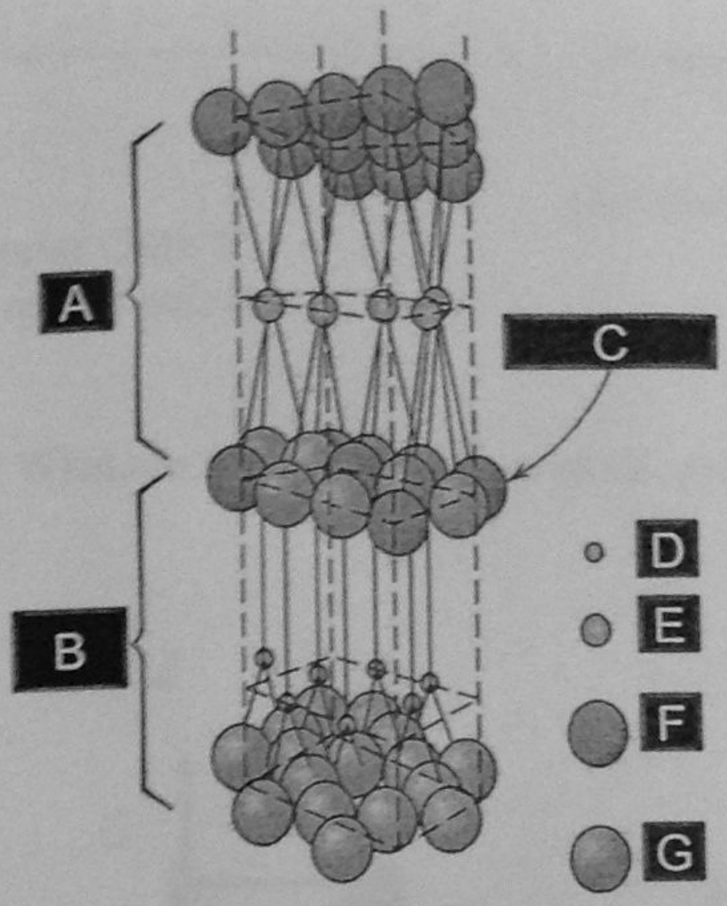
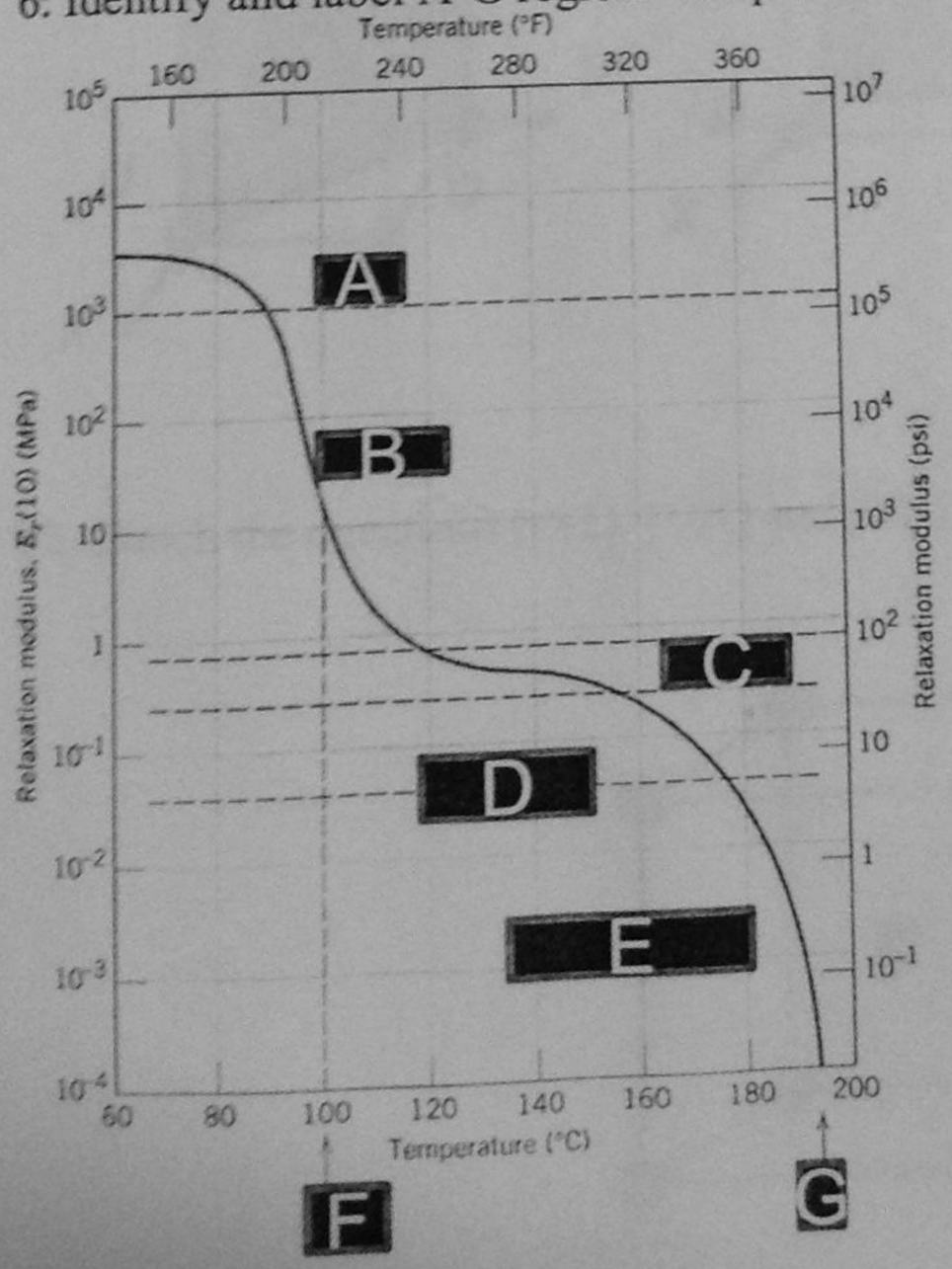
Q5: Identify the following structure. What is the name of this mineral? Label A-G accordingly. [4.5]



6: Identify and label A-G regions and points in the following diagram. [3.5]



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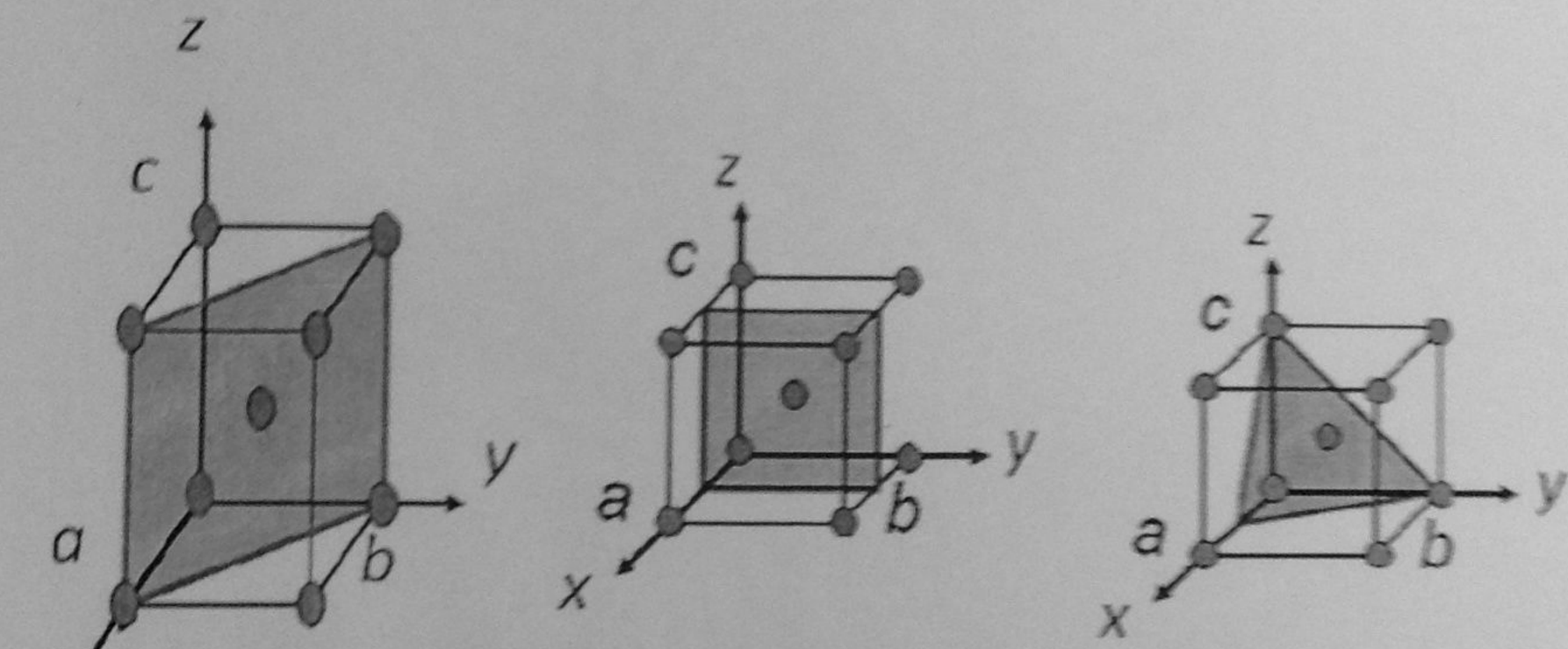
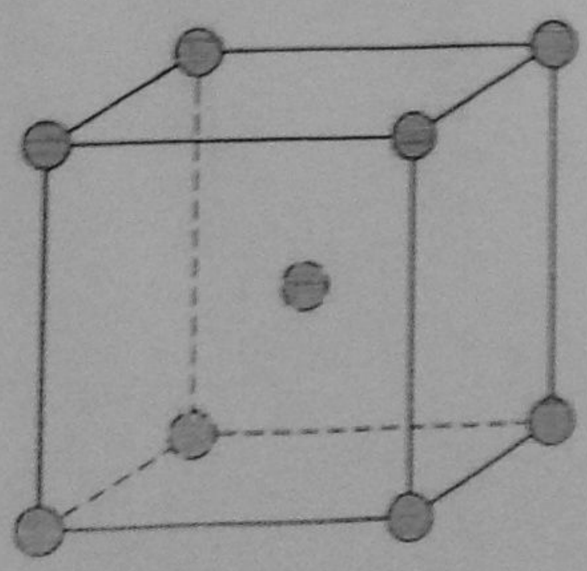
Surprise Quiz 1
10 min, 6 points

15/01/13

Q1. What are the miller indices of the planes shown in the crystals below? Pt 3



Q2. Sketch the directions [111], [101] and [001] in the following crystal Pt 3



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Surprise Quiz 2
Name:
ID:

22/01/13
Time 10 m

Q1. The corundum crystal Al_2O_3 has an HCP arrangement of O^{2-}. What site(s) will be occupied by Al^{3+}, octahedral or tetrahedral and what fraction? Pt 3

Q2. Calculate theoretical density of CaO. Consider it has a rock salt structure Pt 3

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Surprise Quiz 4 (CLOSED BOOK)
15 min, 10 points

07/03/13

NAME:

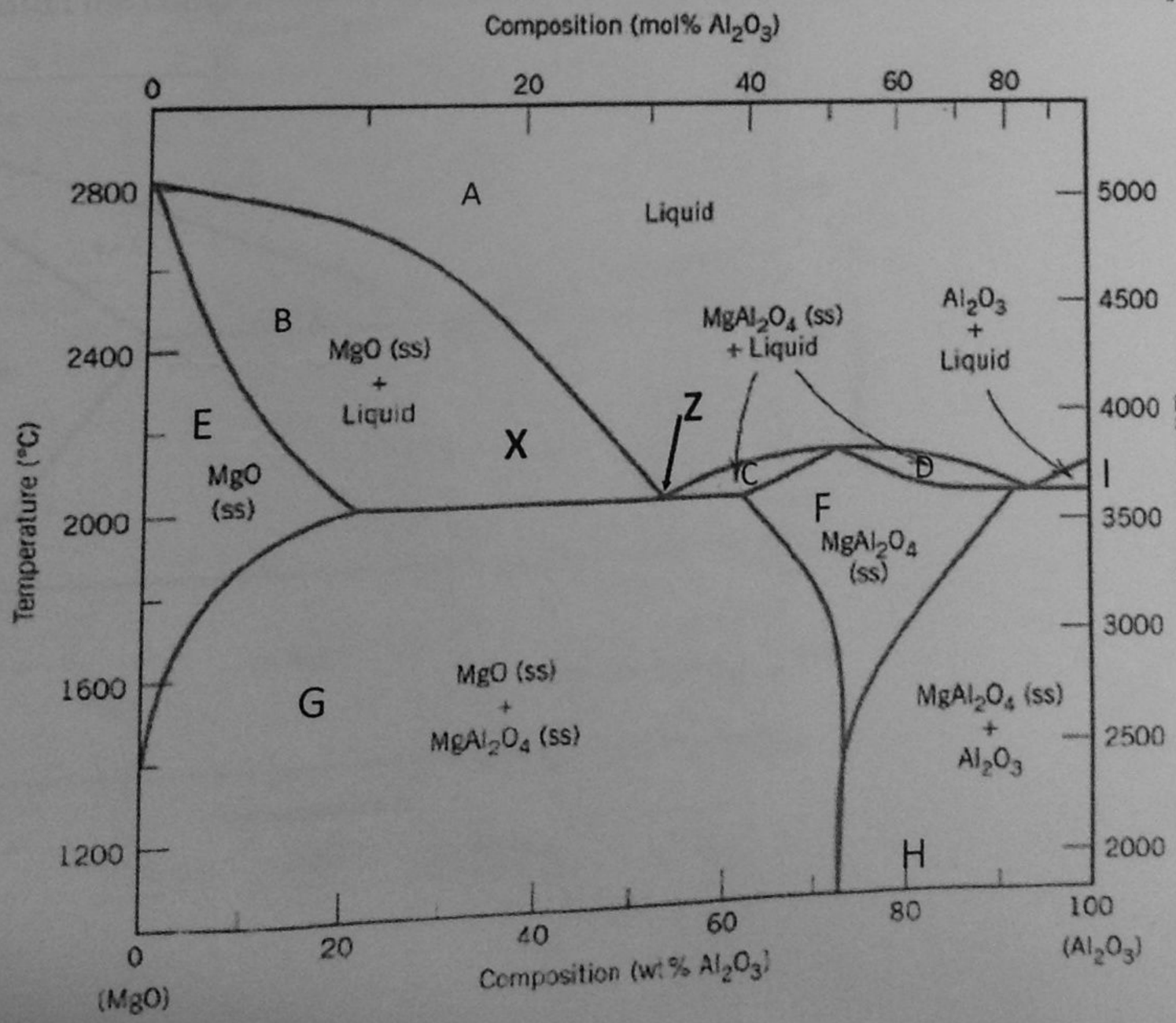
ID:

Show every steps clearly, no marks will be awarded for the answers only.
Unnecessary vague wordings will deduct mark

Q1: Mention all rules for an isomorphous phase diagram to create clearly, precisely, and separately. [2]

Q2. Consider the following phase diagram. Calculate the degree of freedom* for the areas from A to I. What will be the composition and weight fractions of the phases present at the points X and Z. [4 +4]

* and mention them



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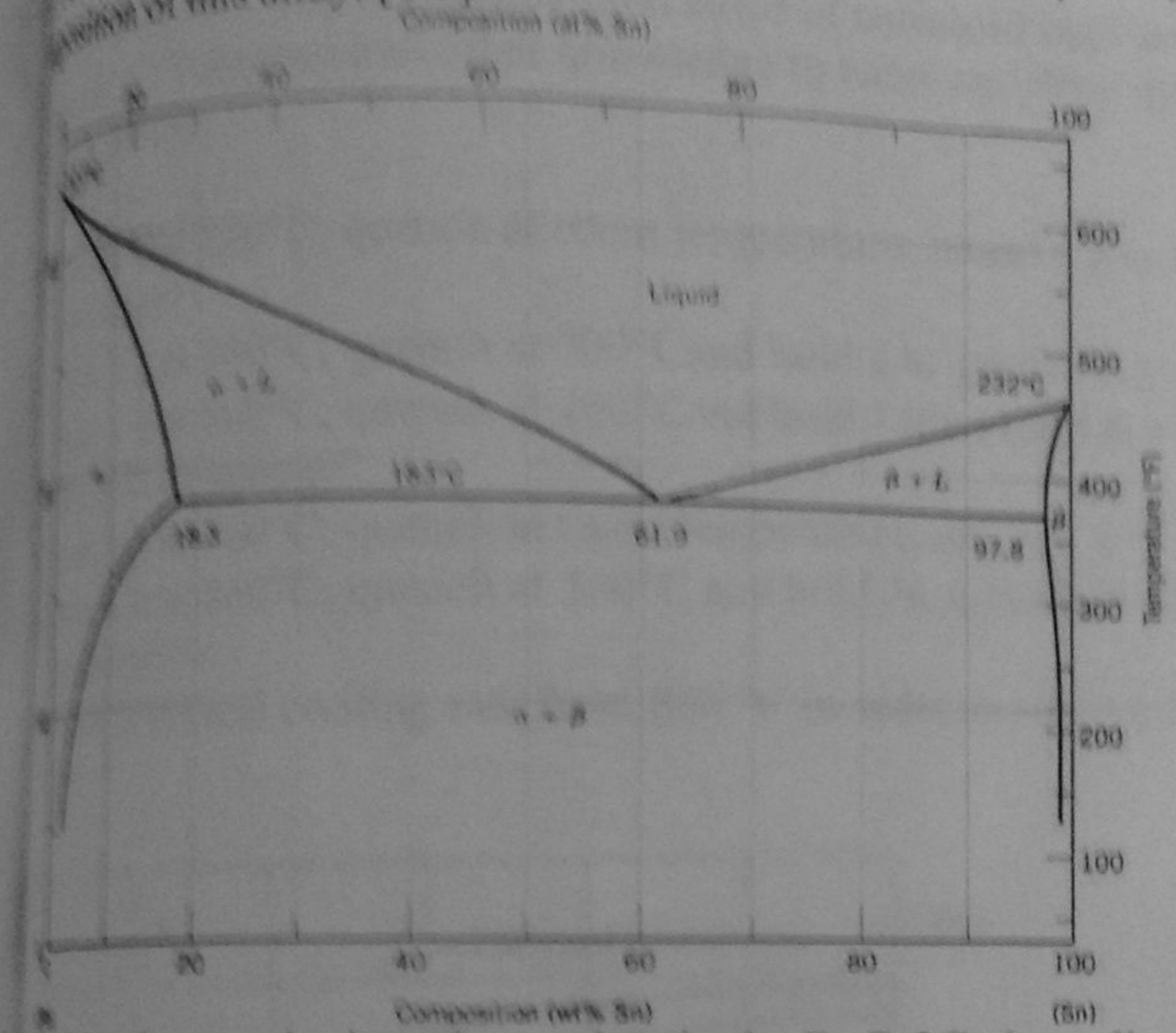
09/04/13

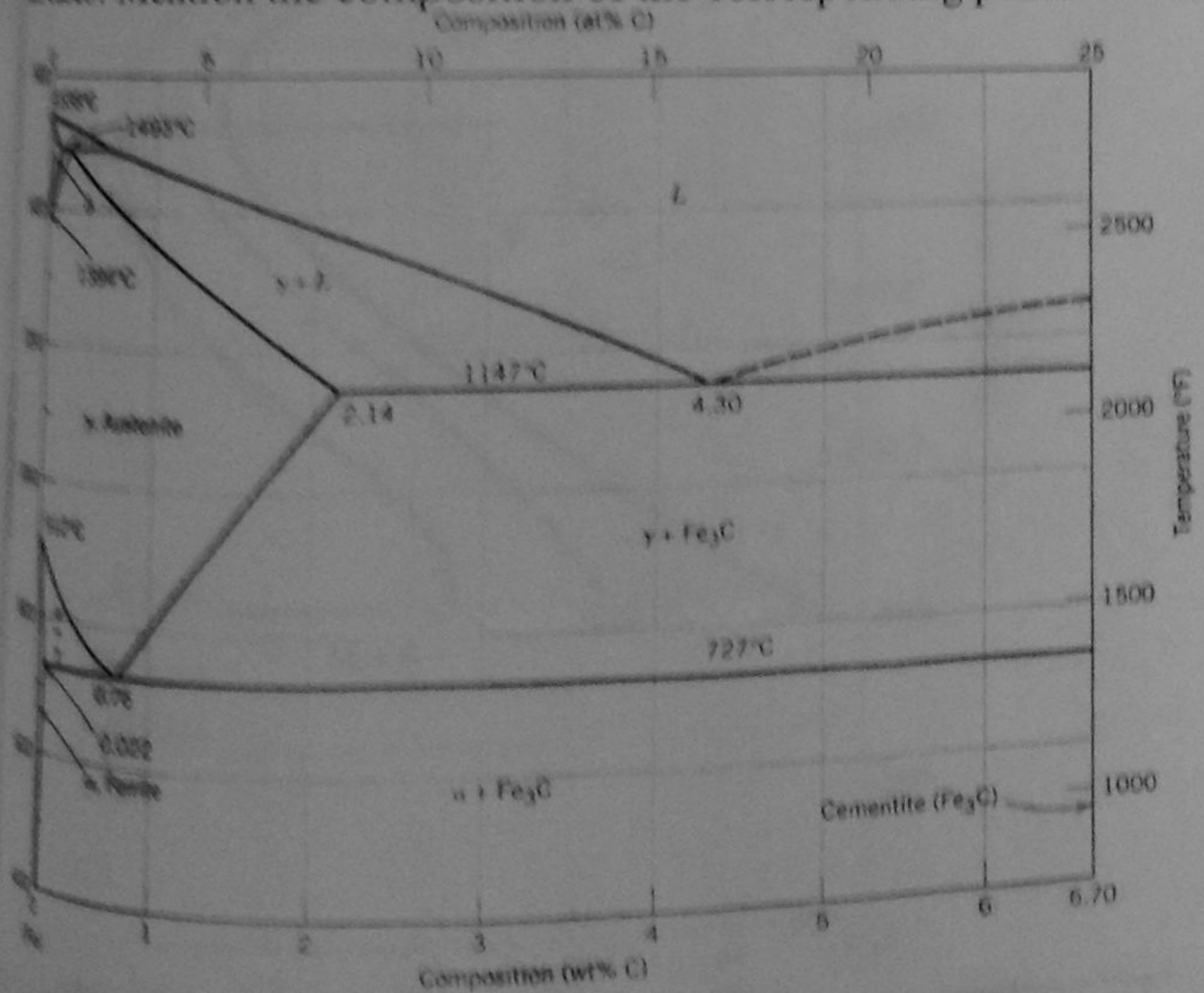
ID:

...steps clearly, no marks will be awarded for the answers only. Unnecessary vague wordings will deduct mark

...-tin (Pb-Sn) alloy consists of 60 wt % proeutectic β at 183°C - ΔT. Calculate the average ...position of this alloy. [1.5]



...cle and name the invariant points in the Fe-Fe3C phase diagram below. What reactions are happening in ...ases? Mention the composition of the corresponding phases at each invariant points. [4.5]



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Materials Science and Engineering

09/04/13

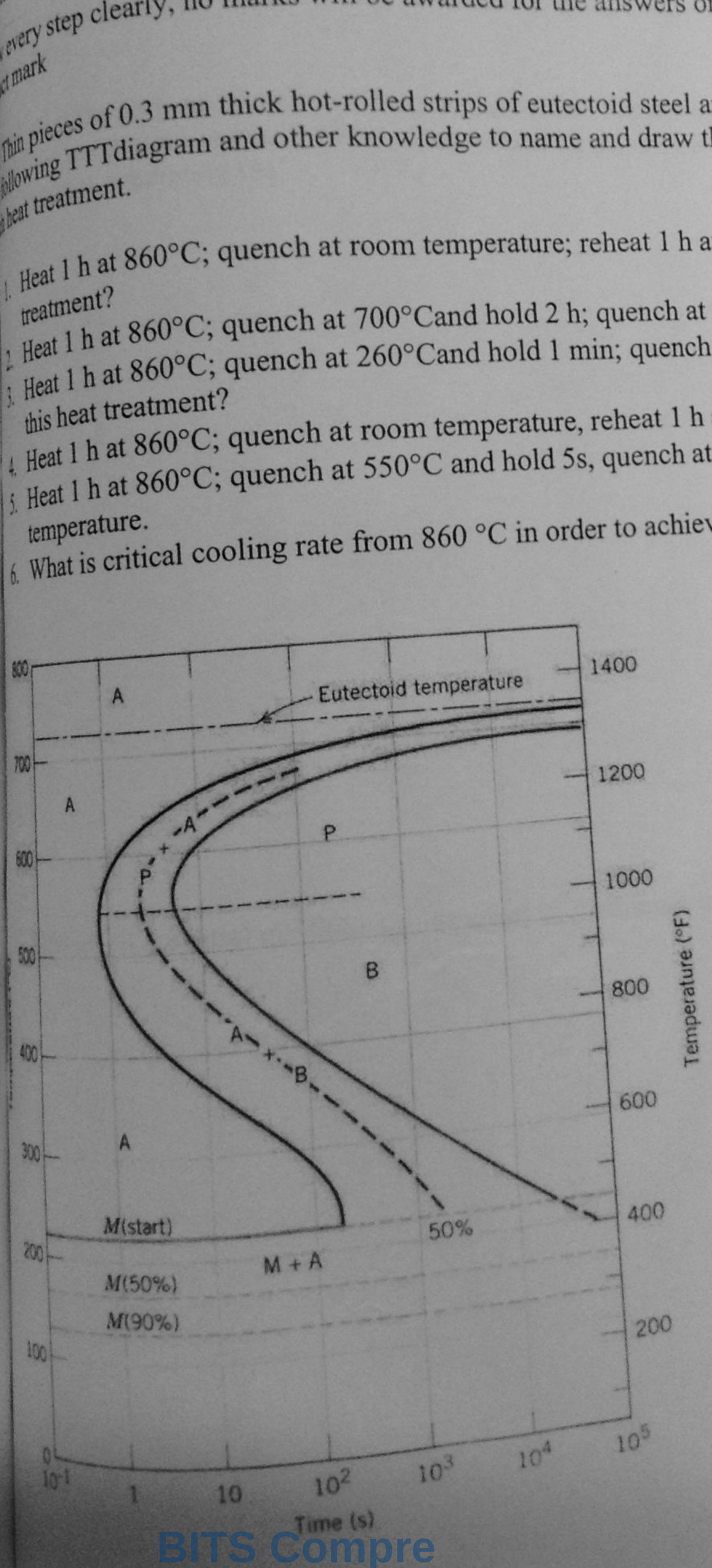
ise Quiz 6
in, 6points

ME: ID:

w every step clearly, no marks will be awarded for the answers only.Unnecessary vague wordings will
ct mark

Thin pieces of 0.3 mm thick hot-rolled strips of eutectoid steel are heat-treated in the following ways. Use following TTTdiagram and other knowledge to name and draw the microstructures of the steel samples after heat treatment.

1. Heat 1 h at 860°C; quench at room temperature; reheat 1 h at 350°C. What is the name of this heat treatment?
2. Heat 1 h at 860°C; quench at 700°Cand hold 2 h; quench at room temperature.
3. Heat 1 h at 860°C; quench at 260°Cand hold 1 min; quench at room temperature. What is the name of this heat treatment?
4. Heat 1 h at 860°C; quench at room temperature, reheat 1 h at 700°C.
5. Heat 1 h at 860°C; quench at 550°C and hold 5s, quench at 400°C and hold 60s, quench at room temperature.
6. What is critical cooling rate from 860 °C in order to achieve 100% martensite?



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...se Quiz 7
..., 6 points

16/04/13

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...every step clearly, no marks will be awarded for the answers only.Unnecessary vague wordings will ...mark

1. What is the purpose of adding Cr in stainless steel? What electrochemical reactions are expected for rusting ...Cr is not present in steel? What electrochemical reaction is expected when Cr is present in steel? Show ... equation separately [4].

2. Mention all essential qualities (point wise) of a biomaterial attributed for orthopedic applications [2].

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Surprise Quiz 8
15 min, 6points

23/04/13

NAME:

ID:

Show every step clearly, no marks will be awarded for the answers only.Unnecessary vague wordings will deduct mark

Q1: "Use of catalyst DOES NOT vary ΔG & K_{eq} values of the reaction concerned"-true or false? explain with proper equation and schematic. What FCC stands for in a petroleum refining industry?. [4]

Q2:. Mention use of zeolites in petrochemical industry. Explain shortly pointwise the mechanism of how zeolites work there.[2]

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Re Quiz 1
15 min, 6 points

29/04/13

NAME:

ID:

Show every step clearly, no marks will be awarded for the answers only.Unnecessary vague wordings will deduct mark

Q1: Explain the technique/approach generally used for preparation of nanomaterials [2 x 2]

Q2:. What is "Moore's Law," ? What is the prime reason limiting the transistor miniaturization? [2]