Birla Institute of Technology & Science, Pilani

First Semester 2022-2023

Mid-Semester Test - Regular

Course No.	: ME/MF F216
Course Title	: MATERIAL SCIENCE AND ENGINEERING
Nature of Exam	: CLOSED BOOK
Weightage	: 25% of 200 Marks
Duration	: 90 minutes
Date of Exam	: Friday, 04/11/2022 (AN)

No. of Pages = 5
No. of Questions = 9

Note:
1. Please follow all the *Instructions to Candidates* given on the cover page of the answer book.
2. All parts of a question should be answered consecutively. Each answer should start from a fresh page.
3. Assumptions made if any, should be stated clearly at the beginning of your answer.

Answer Part A and Part B in separate answer sheets

Part A

1. (a) Calculate the surface energy of copper for the surfaces {1 0 0}, {1 1 1} of the copper, given the bond energy per mole = 56.4 kJ mol^{-1}. [3 Marks]

   (b) Calculate the energy per vacancy for copper and the number of vacancies per million atoms. [2 Marks]

2. The diffusivity of silver atoms in solid silver metal is 1.0 x 10^{-17} m^2/s at 500^oC and 7.0 x 10^{-13} m^2/s at 1000^oC. Calculate the activation energy (in units of kJ/mol) for the diffusion of Ag in Ag. [5 Marks]

3. Austenite is an FCC phase of iron and has maximum solubility of carbon of approximately 2 wt%. Ferrite is a BCC phase of iron and has maximum solubility of less than 0.08 wt%. We also know that the packing efficiency of the BCC lattice is 68% compared to 74% of the FCC lattice. Explain the reason why the solubility of carbon is higher in the FCC phase than in the BCC phase with justification. [5 Marks]

4. Calculate the maximum radius of an interstitial atom that can be just fit in an FCC lattice of lattice parameter 4 Angstroms. [5 Marks]

5. If gallium is diffused into a silicon wafer with no previous gallium in it at a temperature of 1100 ^{o}C for 3 h, what is the depth below the surface at which the concentration is 1.09×10^{-1} mol/m^3 if the surface concentration is 10 mol/m^3? Diffusivity of Ga in Si at 1100 ^{o}C = 7.0×10^{-17} m^2/s. [5 Marks]

z	erf (z)	z	erf (z)
0.000	0.0000	0.85	0.7707
0.025	0.0282	0.90	0.7970
0.05	0.0564	0.95	0.8209
0.10	0.1125	1.0	0.8427
0.15	0.1680	1.1	0.8802
0.20	0.2227	1.2	0.9103
0.25	0.2763	1.3	0.9340
0.30	0.3268	1.4	0.9523
0.35	0.3794	1.5	0.9661
0.40	0.4284	1.6	0.9763
0.45	0.4755	1.7	0.9838
0.50	0.5205	1.8	0.9891
0.55	0.5633	1.9	0.9928
0.60	0.6039	2.0	0.9953
0.65	0.6420	2.2	0.9981
0.70	0.6778	2.4	0.9993
0.75	0.7112	2.6	0.9998
0.80	0.7421	2.8	0.9999

Part B

Q.1. For the binary system of Copper-Nickel, Cu-Ni the following data are available from a cooling experiment as shown in Table 1 [10 Marks]

Table. 1

Temp, T(°C)	Weight % of Ni in the binary system at the start of solidification	Weight % of Ni in the binary system at the end of Solidification
1085	2	5
1180	10	35
1250	20	55
1350	40	80
1410	60	90
1453	90	95

a) From these data and information provided in Table.1, construct the phase diagram (Temperature vs Concentration) on the graph sheet provided. [4 Marks]

b) Use the phase diagram constructed by "you" in Q.1. (a), find the percentage of solid and liquid phases present in the binary system of Cu-Ni for the temperature and composition shown in the Table. 2. [6 Marks]

Table. 2

Weight % Ni	T(°C)
15	1120
55	1200
60	1300

Q.2. On an Iron-carbide diagram as shown in Figure 1.

a) Calculate the amounts of α-ferrite and cementite (Fe_3C) phases in the pearlite mixture of the eutectoid alloy exactly at the eutectoid temperature (727 °C). [2 Marks]

b) Determine and calculate the amounts of phases in Fe-1.25% C alloy "JUST ABOVE" and "JUST BELOW" the eutectoid temperature (727 °C). [4 Marks]

Hints: You are allowed to assume reasonable values of percentage of Carbon for solving part (b)

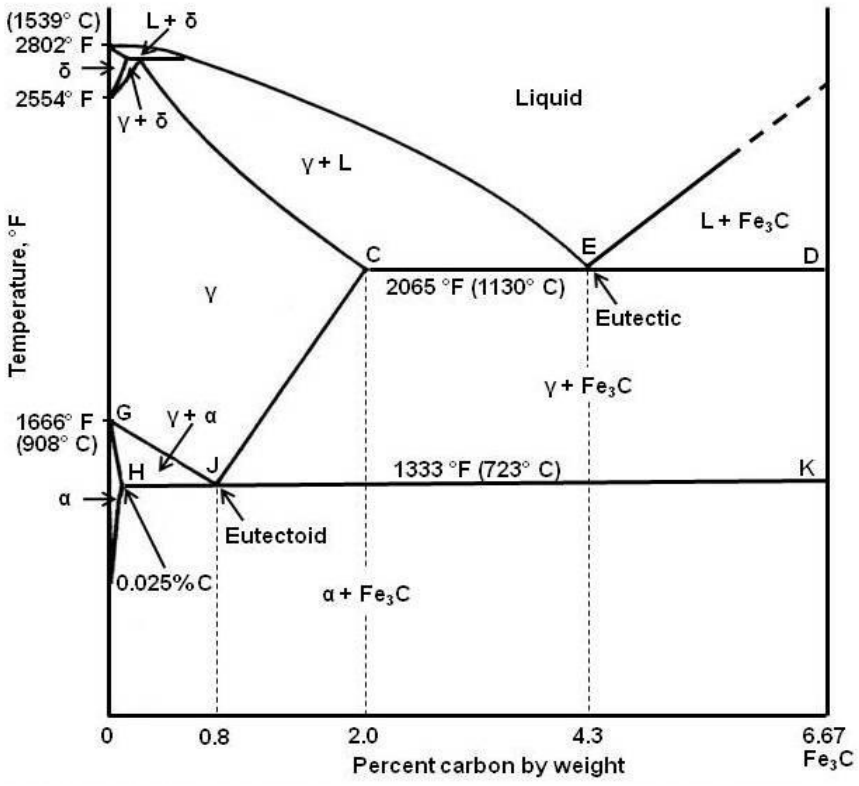

Figure 1

Q.3. A binary phase Ni-Cu phase diagram is shown in Figure 2. If the alloy composition 70wt% Ni-30wt% Cu is slowly heated at a temperature of 1300°C. [4x1 = 4 Marks]

a) At what temperature does the first liquid phase form?
b) What is the composition of this liquid phase?
c) At what temperature does complete melting of the alloy occur?
d) What is the composition of the last solid remaining before complete melting?

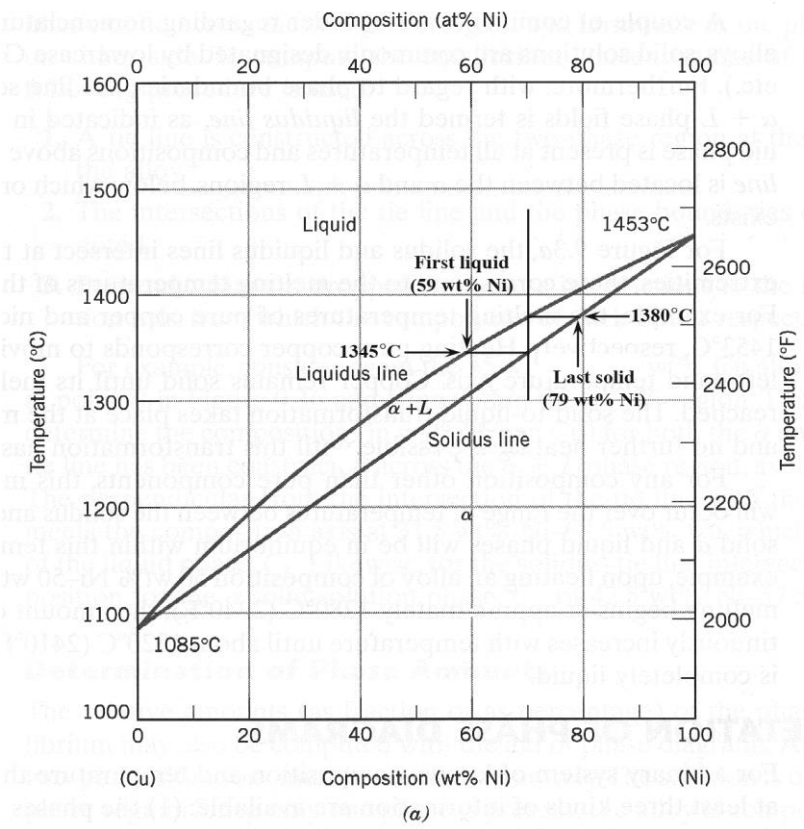

Figure 2.

Q.4. For alloys of two hypothetical metals A and B, there exist an α, A-rich phase and a β, B-rich phase. From the mass fractions of both phases for two different alloys provided in the table 3, (which are at the same temperature), determine the composition of the phase boundary (or solubility limit) for both α and β phases at this temperature. [5 Marks]

Table. 3

Alloy Composition	Fraction of α Phase	Fraction of β Phase
60 wt% A – 40 wt% B	0.57	0.43
30 wt% A – 70 wt% B	0.14	0.86

**** The End ****