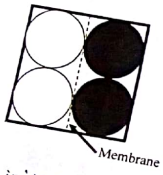
APL 102: Introduction to Materials Science and Engineering – Minor 2 Exam

Name: **Entry No.:**

Question 1 [15]

a) Below diagram shows two sets of balls, initially separated so that the white balls are to the left and the black balls to the right. Write down how many distinguishable possible ways there are for this initial configuration. Now the membrane is removed and the balls can be placed anywhere in the four possible positions. Determine with the help of sketches the number of distinguishable possible ways in which the balls can now be placed. Hence determine the entropy of mixing, ΔS_{mix}, associated with the change from the initial to the mixed configuration. [10]



Membrane

~~No~~ number of sites = N = 4

~~number of~~ n = 2

$\therefore W = {}^{N}C_n = {}^{4}C_2 = \frac{4!}{2!\,2!} = \frac{4\times3\times2\times1}{2\times2} = 6$

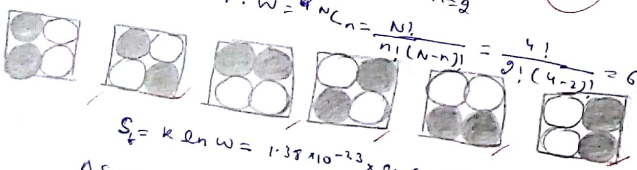
for the initial configuration ~~two ways~~ only one ~~way~~ way is possible in which the white balls can be at right and the black balls at right.

~~The upper~~ $S_i = k \ln W = k \ln(1) = 0$

When the membrane is removed

number of sites = N = 4 n = 2

$\therefore W = {}^{4}C_n = \frac{N!}{n!(N-n)!} = \frac{4!}{2!(4-2)!} = 6$



$S_f = k \ln W = 1.38 \times 10^{-23} \times \ln 6 = 2.473 \times 10^{-23}$

$\Delta S_{mix} = S_f - S_i = 2.473 \times 10^{-23}$ ~~units~~!

the entropy of the mixture has increased, which means that the randomness has increased.

9.5

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b) The cable of a hoist has a cross section of 80 mm^2. The hoist is used to lift a crate weighing 500 kg. What is the stress in the cable? The free length of the cable is 3 m. How much will it extend if it is made of: (i) Steel (E = 200 GPa); (ii) Polypropylene (E = 1.2 GPa)? [5]

$A = 80\ mm^2 = 80 \times 10^{-6}\ m^2$

wt. of crate = 500 kg

force = wt. of crate × 9.81

= 500 × 9.81 = 4905 N

$\therefore$ stress = $\frac{\text{force}}{\text{Area}} = \frac{4905}{80\times10^{-6}} = 61.3125 \times 10^6$ Pa

3.5

$L_o = 3m$

i) for steel → stress = E (strain) $= 200 \times 10^9 \times \frac{\Delta L}{L_o}$

$61.3125 \times 10^6 = 200 \times 10^9 \times \frac{\Delta L}{L_o}$

ΔL = extension in cable

$\Rightarrow \Delta L = \frac{61.3125 \times 10^6 \times 3}{200 \times 10^9} = 9.197\ m$

ii) for poly propylene → stress = E (strain)

$\Rightarrow 61.3125 \times 10^6 = 1.2 \times 10^9 \times \frac{\Delta L}{L_o}$

$\Rightarrow \Delta L = \frac{61.3125 \times 10^6 \times 3}{1.2 \times 10^9} = 153.2.8125\ m$

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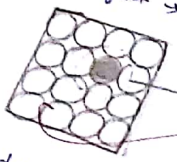
Question 2

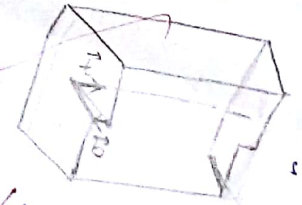
a) Schematically show one each in point defect, line defect, area defect and volume defect. Name the sketched defects. [15]



[6]

① Point defect → effect a region of 1-2 atomic diameter.

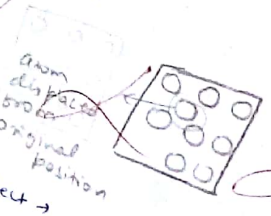
② Line defect →



Substitutional defect.

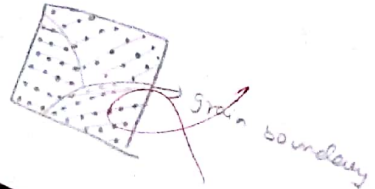
Screw dislocation defect.

③ Area defect



Frenkel defect.

④ Volume defect →



Grain boundary

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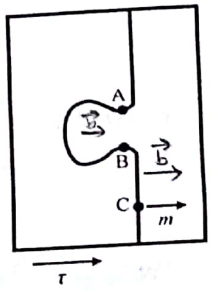
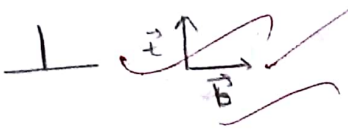
b) Shown in the below diagram is a dislocation line on its slip plane. The direction of slip motion, under the influence of the resolved shear stress (τ), is shown by arrow *m* at segment C. The segment C of the dislocation line is a positive edge dislocation. Sketch the characteristics of the segment C. Find the nature and character of segments A and B of the dislocation line and sketch them as well. Also show the direction of slip of these segments. [9]



② C is a positive edge dislocation → how will direction of $\vec{b}$ change??

∴ dislocation line ($\vec{t}$) is perpendicular to burger's vector ($\vec{b}$)



slip plane is in the plane of $\vec{t}$ and $\vec{b}$

1.5 the nature at segment A is screw dislocation → what character?

here $\vec{b}$ is parallel to $\vec{t}$ → there is no slip plane in screw dislocation

the nature at segment B is also screw dislocation

$\vec{b}$ is antiparallel to $\vec{t}$

1.0 → what character?

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Question 3 **[15]**

a) At 937 °C, what is the time required to carburize a steel with an initial composition of 0.3% C to 0.6% C at a depth of 0.25 *mm*? Assume a constant surface concentration of 1% C due to the carburizing atmosphere. Given the following:

Diffusion Process	D_0, 10^{-4} $m^2 s^{-1}$	Q, $kJ\ mol^{-1}$
C in α-Fe	0.008	83
C in γ-Fe	0.7	157

You may assume $erf(\theta) = 0$.

$C_1 = 0.3\%\ C$ $C_2 = 0.6\%\ C$

$C(x,t) = 1\%\ C$ $x = 0.25mm$

① for α-fe

$D = D_0 e^{-\frac{Q}{RT}}$

$= 0.008 \times e^{-\frac{83\times10^3}{8.314\times1210}}$

$= 2.089 \times 10^{-6}$

$C(x,t) = A - B\,erf\left(\frac{x}{2\sqrt{Dt}}\right)$

$1 = \frac{C_1+C_2}{2} - \frac{C_2-C_1}{2}\,erf\left(\frac{x}{2\sqrt{Dt}}\right)$

$= \frac{0.3+0.6}{2} - \frac{0.6-0.3}{2}\left(\frac{x}{2\sqrt{Dt}}\right)$

$1 = 0.45 - 0.15 \times \frac{0.25\times10^{-3}}{2\sqrt{2.089\times10^{-6}\times t}}$

$0.55 = \frac{0.15\times0.25\times10^{-3}}{2\sqrt{2.089\times10^{-6}\times t}}$ $= \frac{0.01875}{1.44\times10^{-3}\sqrt{t}}$

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$\sqrt{t} = \frac{13.02}{0.55} = 23.674$

2) $t = 560.45$ s

② for C in γ-fe

$D = 0.7\,e^{-\frac{157\times10^3}{8.314\times1210}}$

$= 0.7 \times 1.669 \times 10^{-7}$

$= 1.16 \times 10^{-7}$

$C(x,t) = A - B\,erf\left(\frac{x}{2\sqrt{Dt}}\right)$

$1 = \frac{0.3+0.6}{2} - \frac{0.6-0.3}{2}\left(\frac{x}{2\sqrt{Dt}}\right)$

$0.55 = 0.15\left(\frac{0.25\times10^{-3}}{2\sqrt{1.16\times10^{-7}\,t}}\right)$

$t = 99.$

5

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Name:

Question 4 **Entry No.:**

a) From the $Cu-Zn$ alloy phase diagram provided below: [15]

[1 + 2 + 3.5 + 1.5 + 2]

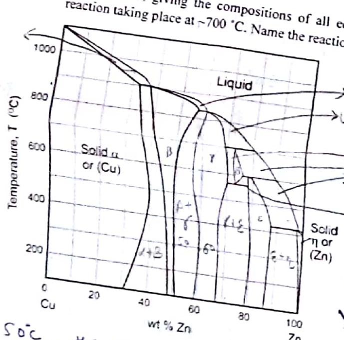
i) Find the approximate composition of the liquid which is in equilibrium with α at 950 °C.

ii) Determine the temperature (approximately) at which solidification begins and is completed for an alloy of 90 wt.% Zn slowly cooled from the liquid phase.

iii) Determine the phases present and their compositions and estimate the phase fractions in an alloy of 55 wt.% Zn held in equilibrium at 300 °C.

iv) List all the thermodynamic variables for an alloy having liquid and α phases in equilibrium.

v) Write in full, giving the compositions of all equilibrium phases, the invariant reaction taking place at ~700 °C. Name the reaction.



iv)

v) peritectic

0.5

i) at 950°C, the composition of liquid which is in equilibrium with α is 30 wt%. Zn

1

ii) The temperature at which solidification begins is slightly above 400°C (around 410-420°C) and is completed for an alloy of 90 wt%. Zn slowly cooled from liquid phase.

iii) the phases that are present at 55 wt% Zn in equilibrium at 300°C is β, γ composition of β is 50 wt%. Zn and composition of γ is 60 wt%. Zn

$f_\beta = \frac{C_\gamma - C_0}{C_\gamma - C_\beta} = \left|\frac{0.6 - 0.55}{0.6 - 0.5}\right| = \frac{0.05}{0.1} = 0.5$

$f_\alpha = \frac{C_0 - C_\beta}{C_\alpha - C_\beta} = \frac{0.55 - 0.5}{0.6 - 0.5} = \frac{0.05}{0.1} = 0.5$

3.5

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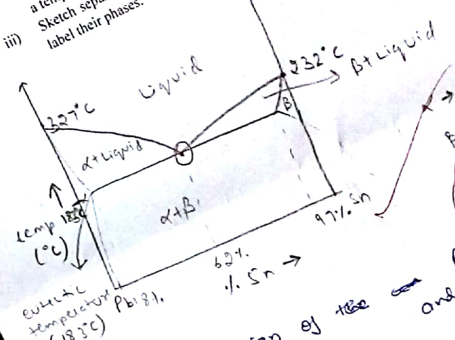
b) Consider a hypo-eutectic alloy composition in the $Pb-Sn$ phase diagram. [2 + 3]

i) Mention the composition of the considered alloy.

ii) Mention the different phase fields, including the initial and the final one, the considered alloy passes through when cooled from high temperature (~350 °C) to a temperature below the eutectic temperature.

iii) Sketch separately the microstructure of the alloy in each of the phase fields and label their phases.

iii)



1.5

i) the composition of Pb is 18 wt%. Sn and the composition of Sn is 97 wt%. Sn

ii) initial phase when the temperature is 350°C is liquid

final phase when the temperature is below eutectic temperature is a mixture of Pb and Sn

iii)