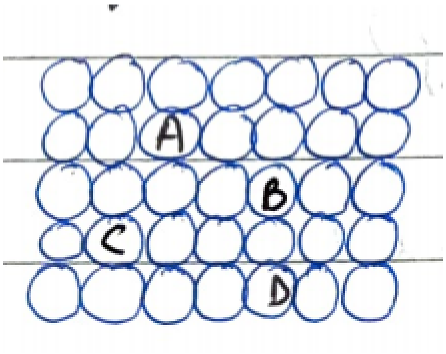
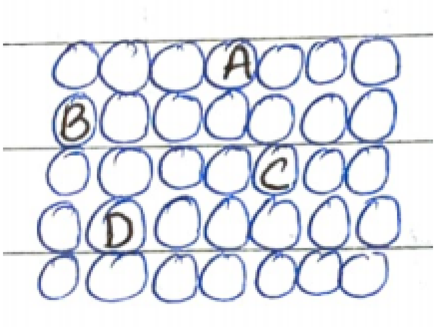
Draw self-diffusion, inter diffusion, vacancy diffusion, grain boundary diffusion, surface diffusion, and pipe diffusion.

ANSWER>>>

SELF DIFFUSION

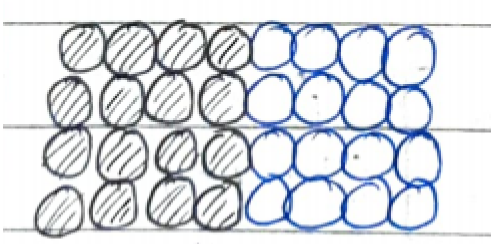


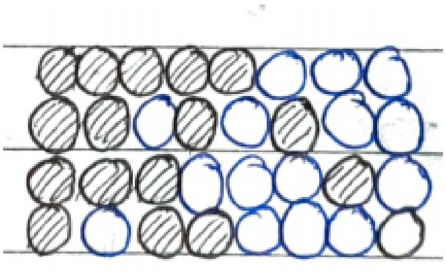


Atoms at time t = 0

at time t = t0

INTER DIFFUSION

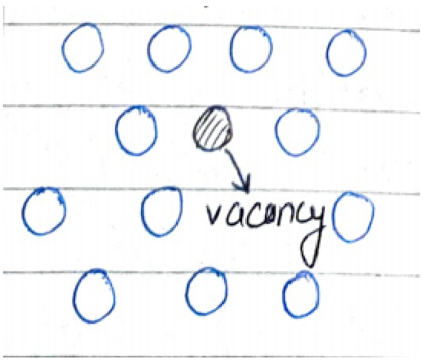


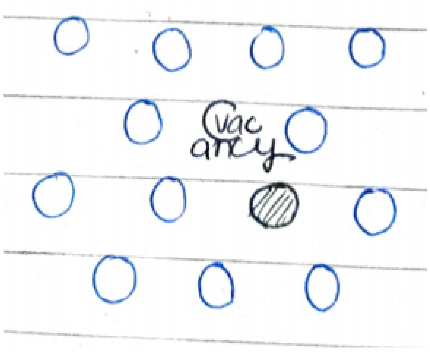


Initially

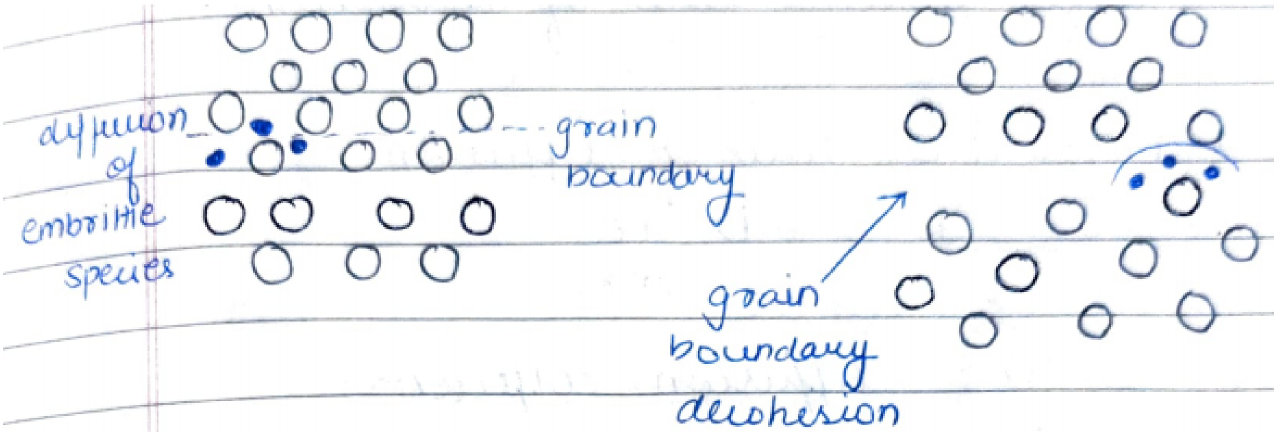
finally

VACANCY DIFFUSION

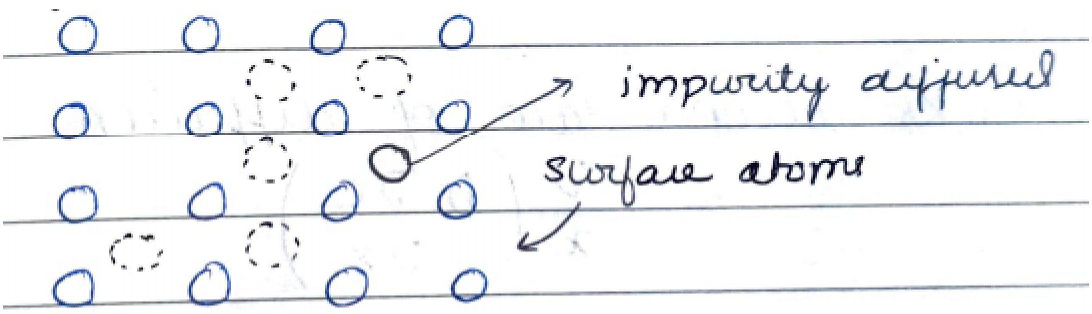




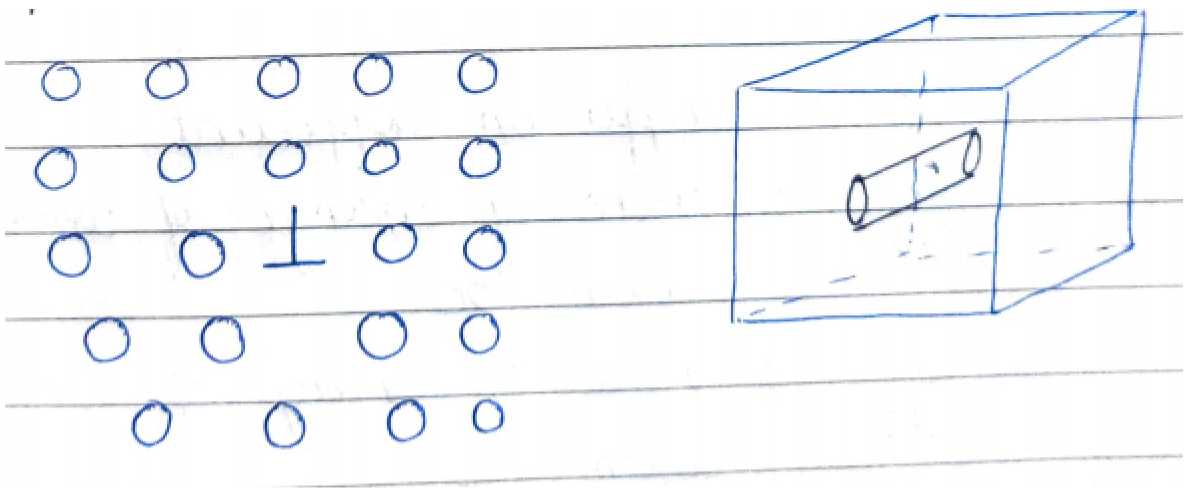
GRAIN BAUNDARY DIFFUSION



SURFACE DIFFUSION



PIPE DUSSION



Q2) Write expression of Fick’s First and Second Laws of diffusion and state all parameters involved.

ANSWER>>>

Fick’s First Law of diffusion

$$J = -D \frac{dC}{dx}$$

dC / dx is Concentration gradient.

The constant of proportionality D is the diffusion coefficient.

J is the steady-state diffusion.

Fick’s Second Law of diffusion

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2}$$

The left side term denotes rate of change of Concentration.

The constant of proportionality D is the diffusion coefficient

Q3) Discuss in short the solution of Fick’s Second Law of diffusion using Gaussian error function.

ANSWER>>>>

Solutions to this Second Fick’s Law (concentration in terms of both position and time) are possible when physically meaningful boundary conditions are specified.

1. Before diffusion, any of the diffusing solute atoms in the solid are uniformly distributed with concentration of C0.

2. The value of x at the surface is zero and increases with distance into the solid.

3. The time is taken to be zero the instant before the diffusion process begins.

These boundary conditions are simply stated as

For t = 0, C = C0 at 0 <= x <= infinity

For t = 0, C = Cs (the constant surface concentration) at x = 0

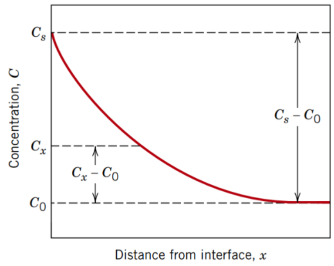
C = C0 at x = infinity.

Application of these boundary conditions to Equation 5.4b yields the solution

$$\frac{C_x - C_0}{C_s - C_0} = 1 - \operatorname{erf}\left(\frac{x}{2\sqrt{Dt}}\right)$$

where Cx represents the concentration at depth x after time t. The expression erf(x/2 sqrt(D t)) is the Gaussian error function.

$$\operatorname{erf}(z) = \frac{2}{\sqrt{\pi}}\int_0^z e^{-y^2}dy$$



where has been replaced by the x/2 sqrt (Dt).

On supposing that it is desired to achieve some specific concentration of solute, C1, in an alloy; the left-hand side of Equation Ficks Second Law becomes.

$$\frac{C_1 - C_0}{C_s - C_0} = \text{constant} \qquad \frac{x}{2\sqrt{Dt}} = \text{constant} \qquad \frac{x^2}{Dt} = \text{constant}$$

Q4) Note any five applications of the diffusion.

ANSWER>>>

Applications of Diffusion:

i) Diffusion is fundamental to phase changes e.g. -iron to α-iron.
ii) Joining of materials by diffusion bonding e.g. welding, brazing soldering galvanizing and metal cladding.
iii) Important in heat treatment like homogenizing treatment of casting, recovery, recrystallization and precipitation of phases.
iv) Production of strong bodies by powder metallurgy.
v) Surface treatment of steels e.g. case hardening.

Q5) List the factors affecting diffusivity.

ANSWER>>>

FACTORS THAT INFLUENCE DIFFUSION

a) Diffusing Species

b) Temperature

c) Activation Energy

d) Diffusion Mechanism

e) Microstructure

Q6) Compute number of kg of hydrogen that pass per hour through a 5 mm thick sheet with an area of 0.20 m^2 at 500°C. Let, diffusion coefficient of 1.0 x 10^8 m^2/s, conc. at the high and low pressure sides are 2.4 and 0.6 kg of hydrogen per m^3 and the steady-state conditions. **[Ans. 2.592 x 10^{-3} kg/h]**

ANSWER>>>

Ans 6. $D \frac{dC}{dx} = J$

where J = diffusion flux mass / Area x Time

$$1 \times 10^{-8} \left[\frac{2.4 - 0.6}{5 \times 10^{-3}} \right] = \frac{\cancel{mass}}{\cancel{0.2}} \quad \frac{mass}{0.2}$$

$$\therefore 10^{-8} (1.8)(0.2)(0.2) 10^{3} \text{ kg/sec} = mass/h$$

$$\therefore mass/h = 2.592 \times 10^{-3} \text{ kg/hour}$$

Ans = 2.592×10^{-3} (Ans)

Q7) Steel sheet, 1.5 mm thick has nitrogen atmospheres on both sides at 1200°C with steady-state condition. D is 6 x 10^{-11} m^2/s, and J is 1.2 x 10^{-7} kg/m^2-s. Concentration of nitrogen in the steel at high-pressure surface is 4 kg/m^3. How far into the sheet from this high-pressure side will the concentration be 2.0 kg/m^3. Assume linear conc. profile. **[Ans. 1 m]**

Ans 7.

$J = 1.2 \times 10^{-7}$ kg/m^{2}s

$D = 6 \times 10^{-11}$ m^{2}s

$$J = D \left[\frac{C_H - C_L}{\text{length}} \right]$$

$$1.2 \times 10^{-7} = 6 \times 10^{-11} \left[\frac{9 - 2}{x} \right]$$

$\boxed{x = 1\,\text{mm}}$ (Ans)

Q8) Nitrogen from a gaseous phase is to be diffused into pure iron at 700⚠C. If the surface concentration is maintained at 0.1 wt% N, what will be the concentration 1 mm from the surface after 10 h? The diffusion coefficient for nitrogen in iron at 700⚠C is 2.5 x 10-11 m2/s. **[Ans. Cx = 0.04564 wt% N]**

Ans8. time = 10 hour

$D = 2.5 \times 10^{-11}\ m^2/s$

it is the problem for unsteady call

$$\frac{C_x - C_0}{C_s - C_0} = 1 - erf\left(\frac{x}{\sqrt{Dt} \times 2}\right)$$

$$\frac{x}{2 \times \sqrt{Dt}} = \frac{1 \times 10^{-3}}{2 \times \sqrt{10 \times 60 \times 60 \times 2.5 \times 10^{-11}}}$$

$= 0.52704$

at z	$= erf(z)$
0.5	0.5205
0.55	0.5633

interpolation

$$\frac{0.5 - 0.55}{0.5205 - 0.5633} = \frac{0.5 - 0.52704}{0.5205 - x'}$$

$1.16822 [0.5205 - x'] = 0.02704$

$x' = 0.54364$

$erf(z) = 0.54364$

$$\frac{C_x - C_0}{C_s - C_0} = 0.45635$$

$C_0 = 0$ concentration at ∞

$C_x = 0.1 \times 0.45635$

$= \underline{\underline{0.045635}}\ N$

Q9) Cite the values of the diffusion coefficients for the inter-diffusion of carbon in both α-iron (BCC) and α-iron (FCC) at 900°C. Which is larger? Explain why this is the case.

Ans 9. $\log D = \log D_0 - Q_d \left(\frac{1}{T}\right) \frac{1}{2.3R}$

For [BCC] : Fe α Carbons

$D_0 = 1.1 \times 10^{-6}$

$Q_d = 87400$

$\log D = \log [1.1 \times 10^{-6}] - \frac{87400}{19.122} \left[\frac{1}{900+273}\right]$

$\log D = -10 + 0.1448600$

$D = 10^{-10} \times 1.3959 \ m^2/sec$

~~log~~ For [~~B~~ FCC]

$\log D = \log 2.3 \times 10^{-5} - (14800) \frac{1}{[1173](8.314)(2.3)}$

$D = 10^{-12} \times 10^{0.76379}$

$D = 5.804 \times 10^{-12} \ m^2/sec$

The diffusion ~~cof~~ co officienct of BCC are more than FCC. This is because BCC has lower density due to ~~to~~ which more intersetial site hence the rate of deflection is more.

P.F. of BCC < P.F. of FCC

Q10) At what temperature will the diffusion coefficient for the diffusion of copper in nickel have a value of 6.5×10^{-17} m^2/s. Use the diffusion data from Table given in book. **[Ans. 879°C]**

ANSWER>>>

Ans 10. $D = 6.5 \times 10^{-17}\ m/s^2$

diffusion of Cu in Nickel

$D_0 = 2.7 \times 10^{-5}$

$Q_0 = 256000$

$$\ln D = \ln D_0 - \frac{1}{RT}(Q_0)$$

$$\log D = \log(2.7 \times 10^{-5}) = \frac{-Q_0}{2.3RT}$$

$$-16.1870 + 4.5686 = \frac{-256000}{2.3 \times 8.314\,T}$$

$$T = \frac{256 \times 10^3}{2.3 \times 8.314} \times \frac{1}{11.6184}$$

$T = 1152.27\ K$

$T = 879°C$ (Ans)

Submitted by-

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ME 2