

DIFFUSION IN SOLIDS

- 1) (a) Compare interstitial and vacancy (substitutional) diffusion mechanisms.
 (b) Which type of diffusion is more rapid and why?
 (c) What is the driving force in steady-state diffusion?

- 2) (a) Compare the self-diffusion activation energies of following pure metals:

<i>Metal</i>	<i>Melting point (°C)</i>	<i>Crystal Structure</i>
Nickel	1452	FCC
Zinc	419	HCP
Molbdenum	2600	BCC

- (b) Compare the diffusion coefficient values;

- i) At a constant temperature

- Interdiffusion of carbon in α -iron (BCC) , (impurity diffusion)
- Interdiffusion of carbon in γ -iron (FCC) (impurity diffusion)
- Iron in α -iron (BCC) (self-diffusion)
- Iron in γ -iron (FCC) (self-diffusion)

- ii) Interdiffusion of carbon in α -iron (BCC) at $T=500^{\circ}\text{C}$ and $T=900^{\circ}\text{C}$

- 3) The diffusivity of silver in solid silver metal is $1.0 \times 10^{-17} \text{ m}^2/\text{s}$ at 500°C and $7.0 \times 10^{-13} \text{ m}^2/\text{s}$ at 1000°C . Calculate the diffusivity (diffusion coefficient) of Silver in silver at 800°C .
- 4) A sheet of steel 2.5 mm thick has nitrogen atmospheres on both sides at 900°C and is permitted to achieve a steady-state diffusion condition. The diffusion coefficient for nitrogen in steel at this temperature is $1.2 \times 10^{-10} \text{ m}^2/\text{s}$, and diffusion flux is found to be $1.0 \times 10^{-7} \text{ kg}/\text{m}^2\text{s}$. Also it is known that the concentration of nitrogen in steel at the high pressure surface is $2 \text{ kg}/\text{m}^3$. How far into the sheet from this high-pressure side will the concentration be $0.5 \text{ kg}/\text{m}^3$? Assume a linear concentration profile.
- 5) Consider the gas carburizing of a gear of 1020 steel:
 - (a) Calculate the time in minutes necessary at 927°C to increase the carbon content to 0.4 % at 0.50 mm below the surface.
 - (b) What will be the carbon concentration at a depth of 0.4 mm after 2 hours at 927°C ?
 - (c) Calculate the diffusion coefficient at 500°C , if the carbon content at 0.5 mm beneath the surface of the gear after 5 hour is reached to 0.21% at 500°C

Assume that the carbon content at the surface is 0.9% and $D_{927^{\circ}\text{C}} = 1.28 \times 10^{-11} \text{ m}^2/\text{s}$.

- 6) Nitrogen from a gaseous phase is to be diffused into pure iron at 675°C. If the surface concentration is maintained at 0.2 wt. % N, what will be the concentration 2 mm from the surface after 25 hours? The diffusion coefficient for nitrogen in iron at 675°C is $1.9 \times 10^{-11} \text{ m}^2/\text{s}$

- 7) The diffusion coefficients for nickel in iron are given at two temperatures:

T (K)	D (m^2/s)
1473	2.2×10^{-15}
1673	4.8×10^{-14}

(a) Determine the values of D_0 and the activation energy Q_d

(b) What is the magnitude of the D at 1300°C (1573K)?

- 8) The outer surface of a steel gear is to be hardened by increasing its carbon content; the carbon is to be supplied from an external carbon-rich atmosphere which is maintained at an elevated temperature. A diffusion heat treatment at 600°C (873K) for 100 min. increase the carbon concentration to 0.75 wt. % at a position 0.5 mm below the surface. Estimate the diffusion time required at 900°C to achieve this same concentration also 0.5 mm position. Assume that the surface carbon content is the same for both heat treatments, which is maintained constant. (For diffusion of C in α -iron, $Q_d=80,000 \text{ J/mol}$ and $D_0=6.2 \times 10^{-7} \text{ m}^2/\text{s}$)

z	$\text{erf}(z)$	z	$\text{erf}(z)$	z	$\text{erf}(z)$
0	0	0.55	0.5633	1.3	0.9340
0.025	0.0282	0.60	0.6039	1.4	0.9523
0.05	0.0564	0.65	0.6420	1.5	0.9661
0.10	0.1125	0.70	0.6778	1.6	0.9763
0.15	0.1680	0.75	0.7112	1.7	0.9838
0.20	0.2227	0.80	0.7421	1.8	0.9891
0.25	0.2763	0.85	0.7707	1.9	0.9928
0.30	0.3286	0.90	0.7970	2.0	0.9953
0.35	0.3794	0.95	0.8209	2.2	0.9981
0.40	0.4284	1.0	0.8427	2.4	0.9993
0.45	0.4755	1.1	0.8802	2.6	0.9998
0.50	0.5205	1.2	0.9103	2.8	0.9999