**Problem 1**

Nitrogen from a gaseous phase is to be diffused into pure iron. If the surface concentration is maintained at 0.2 wt.% N, what will be the concentration at 0.3 mm from the surface after 5 hours? The diffusion coefficient for N in Fe is $2.5 \times 10^{-11}$ $m^2/sec$.

**Tabulation of Error Function Values**

| $z$ | $erf(z)$ | $z$ | $erf(z)$ | $z$ | $erf(z)$ |
|---|---|---|---|---|---|
| 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 |

1) $C_s = 0.2$ wt% N  $C_0 = 0$  $x = 0.3$ mm  $t = 5$ hrs

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

$$\frac{C_x}{0.2} = 1 - erf\left[\frac{0.3 \times 10^{-3}\ m}{2\sqrt{2.5 \times 10^{-11}\ m^2/sec \cdot 5\ hrs \cdot 3600\ sec/hr}}\right]$$

$$\frac{C_x}{0.2} = 1 - erf(0.22)$$

From table

| $z$ | $erf(z)$ |
|---|---|
| 0.20 | 0.2227 |
| 0.22 | x |
| 0.25 | 0.2763 |

$$\frac{C_x}{0.2} = 1 - 0.2441$$

$$\Rightarrow \boxed{C_x = 0.15 \text{ wt\% N}}$$

Linear interpolation

$$\frac{x - 0.2227}{0.22 - 0.20} = \frac{0.2763 - 0.2227}{0.25 - 0.20}$$

**Problem 2**
The fraction of vacancies in a metal at 800˚C is 2.86 x $10^{-4}$. What is the fraction of vacancies at 1100˚C?

$n_v = 2.86 \times 10^{-4}$ at $800°C = 1073K$

$n_v = \exp\left(\frac{-Q}{RT}\right) = 2.86 \times 10^{-4} = \exp\left(\frac{-Q}{8.62 \times 10^{-5} \frac{eV}{atom\,K} \cdot 1073K}\right)$

$Q = 0.75$ eV/atom

At $1100°C = 1373K$

$n_v = \exp\left[\frac{-0.75}{8.62 \times 10^{-5} \cdot 1373}\right] \Rightarrow \boxed{n_v = 1.7 \times 10^{-3}}$

**Problem 3**
An alloy contains 30 wt.% zinc and 70 wt.% copper. What is the concentration of Zn (in atoms of Zn/$m^3$) in the alloy?
DATA: $A_{Cu}$ = 63.55 gm/mole, $A_{Zn}$ = 65.41 gm/mole, $\rho_{Cu}$ = 8.94 gm/$cm^3$, $\rho_{Zn}$ = 7.13 gm/$cm^3$

30 wt% Zn  70 wt% Cu

$$N_{Zn} = \frac{N_A C_{Zn}}{\frac{C_{Zn} A_{Zn}}{\rho_{Zn}} + \frac{A_{Zn}}{\rho_{Cu}}(100 - A_{Zn})}$$

$$N_{Zn} = \frac{6.02 \times 10^{23} \frac{atoms}{mole} \cdot 30 wt\%}{\frac{(30 wt\%)(65.41 \frac{gm}{mole})}{7.13 gm/cm^3} + \frac{(65.41 gm/mole)(70 wt\%)}{8.94 gm/cm^3}} = \boxed{2.29 \times 10^{22} \frac{atoms}{cm^3} = 2.29 \times 10^{28} \frac{atoms}{m^3}}$$

**Problem 4**
Lithium has an atomic radius of 0.152 nm, a density of 0.534 gm/cm$^3$ and atomic weight, $A_{Li}$ = 6.94 gm/mole. Determine if the structure is BCC or FCC.

$r = 0.152\ nm \qquad \rho = 0.534\ gm/cm^3 \qquad A_{Li} = 6.94\ gm/mole$

$$\rho = \frac{n A_{Li}}{V_c N_A}$$

$$V_{c_{FCC}} = a_{FCC}^3 = (2r\sqrt{2})^3 \qquad n = 4$$

$$V_{c_{BCC}} = a_{BCC}^3 = \left(\frac{4r}{\sqrt{3}}\right)^3 \qquad n = 2$$

For FCC

$$\rho = \frac{4\,(6.94\ gm/mole)}{(2 \times 0.152 \times 10^{-7}\ cm\ \sqrt{2})^3 \cdot 6.02 \times 10^{23}\ \frac{atoms}{mole}} = 0.58\ \frac{gm}{cm^3}$$

For BCC

$$\rho = \frac{2\ atoms\ (6.94\ gm/mole)}{\left(\frac{4 \times 0.152 \times 10^{-7}\ cm}{\sqrt{3}}\right)^3 \cdot 6.02 \times 10^{23}\ \frac{atoms}{mole}} = 0.533\ \frac{gm}{mole}$$

$\Rightarrow$ **BCC**

**Problem 5**
Put your answer in the boxes to the right.

| | **(answer)** |
|---|---|
| An x-ray diffraction pattern from a FCC crystal has a peak at 2θ = 45˚ that is indexed to the (111) plane. What is the lattice parameter? The x-ray wavelength = 0.154 nm.<br>(a) 0.201 nm<br>(b) 0.348 nm<br>(c) 0.189 nm<br>(d) none of the above | b |
| The grain size of a material can be determined by:<br>(a) optical microscopy<br>(b) x-ray diffraction<br>(c) the density<br>(d) all of the above | a |
| A metallic bond forms by the:<br>(a) formation of an electron cloud surrounding the atoms<br>(b) sharing of electrons between the atoms<br>(c) transfer of an electron from one atom to the other<br>(d) none of the above | a |
| A close packed plane in the BCC structure is the:<br>(a) $(\bar{1}01)$<br>(b) (001)<br>(c) $(\bar{1}11)$<br>(d) none of the above | a |
| T/F Steady state diffusion occurs when the concentration gradient changes with the diffusion time. | F |

$$2d_{hjl}\sin\theta_{hkl} = n\lambda \qquad n = 1$$

$$d_{hjl} = \frac{a}{\sqrt{h^2 + k^2 + \ell^2}}$$

$$\frac{2a}{\sqrt{1^2 + 1^2 + 1^2}}\sin(22.5^\circ) = 0.154\ nm$$

$$a = 0.348\ nm$$