Materials Science/Structure of Matter

Crystallography

- Body-Centered Cubic (BCC)
- Face-Centered Cubic (FCC)
- Hexagonal Close-Packed (HCP)
Materials Science/Structure of Matter  12-1b
Crystallography

Atoms per cell

- BCC: 2
- FCC: 4
- HCP: 6
Crystallography

Packing Factor

- BCC: 0.68
- FCC: 0.74
- HCP: 0.74

Coordination Number

- The number of the closest (touching) atoms
- FCC, HCP: 12
- BCC: 8
Miller Indices
- Specify planes in crystalline lattices
- Calculated as the reciprocals of the plane intercepts

The following ARE NOT valid Miller indices:
\( \left(\frac{1}{4}, \frac{1}{4}, \frac{3}{4}\right) \quad (026) \quad (-111) \)

The following ARE valid Miller indices:
\( (113) \quad (013) \quad (\bar{1}11) \)

Example (FEIM):
What are the Miller indices of the series of planes shown?

The intercept on the \( a \) axis is \( 1/2 \), so the \( a \) Miller index is 2.
The intercept on the \( b \) axis is 1, so the \( b \) Miller index is 1.
The plane intercepts the \( c \) axis at \( \infty \), so the \( c \) Miller index is 0.
The Miller indices are (210).
Atomic Bonding

- Ionic
- Covalent
- Metallic

Example (FEIM):
Which of the following has a bond that is the least ionic in character?
(A) NaCl
(B) CH₄
(C) H₂
(D) H₂O

The NaCl is entirely ionic. In the CH₄ and H₂O, the hydrogen shares a pair of electrons with both the carbon and the oxygen in covalent bonds, but the carbon and oxygen have a larger share of the probability distribution than the hydrogen. In the H₂, the two hydrogen have equal pull on the two shared electrons, so this bond is entirely covalent and the least ionic.
Therefore, (C) is correct.
Corrosion

Anode reaction (oxidation):
\[ M^0 \rightarrow M^{n+} + n e^- \]

Cathode reaction (reduction):
\[ \frac{1}{2} O_2 + 2e^- + H_2O \rightarrow 2OH^- \]
\[ \frac{1}{2} O_2 + 2e^- + 2H_3O^+ \rightarrow 3H_2O \]
\[ 2e^- + 2H_3O^+ \rightarrow 2H_2O + H_2 \]

Oxidation potential
- If two metals have oxidation potentials that are close, corrosion will be very slow or negligible.
- If two metals have very dissimilar oxidation potentials, corrosion will occur much faster.
Diffusion

Movement of defects through a crystal is governed by the diffusion coefficient:

\[ D = D_0 e^{-Q/RT} \]
• Show the equilibrium phase concentrations.
### Table 42.3 Types of Equilibrium Reactions

<table>
<thead>
<tr>
<th>reaction name</th>
<th>type of reaction upon cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>eutectic</td>
<td>liquid $\rightarrow$ solid $\alpha +$ solid $\beta$</td>
</tr>
<tr>
<td>peritectic</td>
<td>liquid $+$ solid $\alpha \rightarrow$ solid $\beta$</td>
</tr>
<tr>
<td>eutectoid</td>
<td>solid $\gamma \rightarrow$ solid $\alpha +$ solid $\beta$</td>
</tr>
<tr>
<td>peritectoid</td>
<td>solid $\alpha +$ solid $\gamma \rightarrow$ solid $\beta$</td>
</tr>
</tbody>
</table>

Lever Rule

\[
\text{fraction solid} = \frac{x_2 - x}{x_2 - x_1} = \frac{n}{w} = 1 - \text{fraction liquid} \quad 42.3
\]

\[
\text{fraction liquid} = \frac{x - x_1}{x_2 - x_1} = \frac{m}{w} = 1 - \text{fraction solid} \quad 42.4
\]
Materials Science/Structure of Matter  12-4c1

Binary Phase Diagrams

Figure 42.5 Iron-Carbon Diagram
Example (FEIM):
An alloy at 800°C is 2% carbon by weight. What are the compositions and fractions of austenite (\(\gamma\)) and cementite (iron carbide) in the mixture?

Follow the 800°C line to the left until it intersects the (\(\gamma\)) phase line; the austenite is about 1% carbon.
Follow the 800°C line to the right until it intersects the carbide line; the cementite is about 6.67% carbon.

\[
\text{wt}\%_{\gamma} = \left( \frac{x_{\text{carbide}} - x}{x_{\text{carbide}} - x_{\gamma}} \right) \times 100\% = \left( \frac{6.67 - 2}{6.67 - 1} \right) \times 100\% = 82.4\%
\]

\[
\text{wt}\%_{\text{carbide}} = \left( \frac{x - x_{\gamma}}{x_{\text{carbide}} - x_{\gamma}} \right) \times 100\% = \left( \frac{2 - 1}{6.67 - 1} \right) \times 100\% = 17.6\%
\]
If rapid changes are made to the temperature of some alloys, they will not come to the new equilibrium state and will end up with properties that are different and perhaps useful.
Materials Science/Structure of Matter  12-6

Testing Methods

- Standard Tensile Test

- Endurance Test

- Impact Test