1) Fill in the blanks in the following table. (6 Points)

<table>
<thead>
<tr>
<th>Elements</th>
<th>Applications</th>
<th>Crystal Structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pb</td>
<td>Pb-Sn Alloy Electronic Packaging</td>
<td><strong>FCC</strong></td>
</tr>
<tr>
<td>Sn</td>
<td>Interconnect</td>
<td><strong>HCP</strong></td>
</tr>
<tr>
<td>Au</td>
<td>Structural Fabrication</td>
<td><strong>FCC</strong></td>
</tr>
<tr>
<td>Fe (Room Temperature)</td>
<td>Aerospace Material</td>
<td><strong>BCC</strong></td>
</tr>
<tr>
<td>Ti</td>
<td></td>
<td><strong>HCP</strong></td>
</tr>
<tr>
<td>Ni</td>
<td>High Temperature Material</td>
<td><strong>FCC</strong></td>
</tr>
</tbody>
</table>

2) Match the information between the two columns. Note that some of the information may be used more than once while others may not be needed at all. (6 Points)

- Covalent bonding
  - Presence of electron cloud
  - Bond directionality
- Metallic bonding
  - Characterized by coulombic forces
  - Exhibits good electrical conductivity
  - Implies high melting temperature
- Ionic bonding
  - Implies in good formability
  - High molecular weight
  - High degree of softening

3) Fill in the following table with your answers. (4 Points)

<table>
<thead>
<tr>
<th>Crystal system</th>
<th>Coordination number</th>
<th>Number of atoms per unit cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>FCC</td>
<td>12</td>
<td><strong>4</strong></td>
</tr>
<tr>
<td>BCC</td>
<td>8</td>
<td><strong>2</strong></td>
</tr>
</tbody>
</table>

Note: Answer 5 out of 6 Questions.
4) Calculate the atomic packing factor for the BCC unit cell, assuming the atoms to be hard spheres. (Let $a_o$ be the lattice parameter and $r$ be the atomic radius. You will also need to determine the relationship between $a_o$ and $r$ for the calculation. Show work!) (6 Points)

$$\begin{align*}
D = \text{cube diagonal} \\
\delta = \text{face diagonal} \\
a = 2r \\
= \text{atomic diameter}
\end{align*}$$

$$\begin{align*}
a_o^2 + a_o^2 &= \delta^2 & (1) \\
\delta^2 + a_o^2 &= D^2 & (2) \\
D &= 4r & (3) \\
V_{\text{cell}} &= \frac{4}{3} a_o^3 & (4) \\
3a_o^2 &= (4r)^2 \\
a_o^2 &= \frac{16}{3} r^2 \\
r^2 &= \frac{3}{16} a_o^2 \\
\text{# atoms/cell} &= 2 \\
\therefore \text{Vol atoms} &= 2 \times \frac{4}{3} \pi (\frac{\sqrt{3}}{2} a_o)^3 & (5) \\
V_{\text{cell}} &= a_o^3 & (6) \\
\text{APF} &= \frac{\frac{8}{3} \pi (\frac{\sqrt{3}}{2} a_o)^3}{a_o^3}
\end{align*}$$

5) Calculate the diffusivity $D$ in square meters per second for the diffusion of zinc in copper at 400°C. Use values of $D_0 = 3.4 \times 10^{-5}$ m$^2$/s, $Q = 45.7$ kcal/mol and $R = 1.987$ cal/(mol-K). Show work! (4 Points)

$$D = D_0 \exp\left[-\frac{Q}{RT}\right]$$

$$\begin{align*}
D &= 3.4 \times 10^{-5} \text{ m}^2/\text{s} \exp\left[-\frac{45700 \text{ kcal/mol}}{1.987 \text{ cal/mol} \cdot 673 \text{ K}}\right] \\
D &= 3.4 \times 10^{-5} \text{ m}^2/\text{s} \left[-34.17\right] \\
D &= 4.89 \times 10^{-20} \text{ m}^2/\text{s}
\end{align*}$$

Low T, small $D$
G) Considering 500 g of an alloy with 30 wt. pct. Ag and 70 wt. pct. Cu that is cooled from 1000°C, how many grams of liquid and proeutectic alpha are present at 850°C? What are the liquid and proeutectic alpha compositions? Trace the composition and temperature on the phase diagram. Show Work! (8 Points)

\[ \text{At 850°C:} \]

- **30% Ag, 70% Cu**

\[ \text{Phase:} \]

- \( L + \alpha \) at 850°C

\[ \text{Amount of} \ \alpha: \]

\[ \% = \frac{53 - 30}{53 - 8} \times 100 \]

\[ \% = 51.1 \]

\[ \text{For 500 g:} \]

\[ 500 \times \frac{51.1}{100} \]

\[ \alpha \rightarrow = 255.6 \text{ g} \]

\[ \text{Amount of} \ \text{L:} \]

\[ \% = \frac{30 - 8}{53 - 8} \times 100 \]

\[ \% = 48.9 \]

\[ \text{For 500 g:} \]

\[ 500 \times \frac{48.9}{100} \]

\[ L \rightarrow = 244.4 \text{ g} \]