Ph.D. Qualifying Examination

Materials

Spring 2011

Notes:

• There are a total of 4 problems.
• Time allowed: 2 hours.
• Exam is closed book and closed notes
• Problems count 25 points each (total=100 points).
• Show your work on these exam sheets. (Add additional sheets, if needed.)
• You may use a calculator.
• Laptops and cell phones are not allowed.
Problem 1

Below, atomic radius, crystal structure, electronegativity, and the most common valence are tabulated, for several elements; for those that are nonmetals, only atomic radii are indicated.

<table>
<thead>
<tr>
<th>Element</th>
<th>Atomic Radius (nm)</th>
<th>Crystal Structure</th>
<th>Electronegativity</th>
<th>Valence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni</td>
<td>0.1246</td>
<td>FCC</td>
<td>1.8</td>
<td>+2</td>
</tr>
<tr>
<td>C</td>
<td>0.071</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0.046</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>0.060</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ag</td>
<td>0.1445</td>
<td>FCC</td>
<td>1.9</td>
<td>+1</td>
</tr>
<tr>
<td>Al</td>
<td>0.1431</td>
<td>FCC</td>
<td>1.5</td>
<td>+3</td>
</tr>
<tr>
<td>Co</td>
<td>0.1253</td>
<td>HCP</td>
<td>1.8</td>
<td>+2</td>
</tr>
<tr>
<td>Cr</td>
<td>0.1249</td>
<td>BCC</td>
<td>1.6</td>
<td>+3</td>
</tr>
<tr>
<td>Fe</td>
<td>0.1241</td>
<td>BCC</td>
<td>1.8</td>
<td>+2</td>
</tr>
<tr>
<td>Pt</td>
<td>0.1387</td>
<td>FCC</td>
<td>2.2</td>
<td>+2</td>
</tr>
<tr>
<td>Zn</td>
<td>0.1332</td>
<td>HCP</td>
<td>1.6</td>
<td>+2</td>
</tr>
</tbody>
</table>

Which of these elements would you expect to form the following with nickel:

(a) A substitutional solid solution having complete solubility
(b) A substitutional solid solution of incomplete solubility
(c) An interstitial solid solution
**Problem 2**

Construct the hypothetical phase diagram for metals A and B between room temperature (20°C) and 700°C given the following information:

- The melting temperature of metal A is 480°C.
- The maximum solubility of B in A is 4 wt% B, which occurs at 420°C.
- The solubility of B in A at room temperature is 0 wt% B.
- One eutectic occurs at 420°C and 18 wt% B–82 wt% A.
- A second eutectic occurs at 475°C and 42 wt% B–58 wt% A.
- The intermetallic compound AB exists at a composition of 30 wt% B–70 wt% A, and melts congruently at 525°C.
- The melting temperature of metal B is 600°C.
- The maximum solubility of A in B is 13 wt% A, which occurs at 475°C.
- The solubility of A in B at room temperature is 3 wt% A.
Problem 3

(a) Lithium fluorite (LiF) has the so-called “rock salt” crystal structure, which may be thought of as two interpenetrating FCC lattice, one composed of the cations, the other of anions. Draw the atomic arrangement in a single unit cell shown below, using “O” for F and “•” for Li. Also, what type of the atomic bond does this LiF possess?

(b) Silicon carbide (SiC) has the so-called “zinc blende” crystal structure, in which one type of atom forms an FCC-like structure while the other occupying certain interior tetrahedral positions. Draw the atomic arrangement in a single unit cell shown below, using “O” for Si and “•” for C. Also, what type of the atomic bond does this SiC possess?

(c) Determine the angle between two adjacent Si-C bonds in (b). Show your calculation step by step.
Problem 4

From the tensile stress-strain behavior for the specimen of a steel alloy shown in the figure below, determine the following:

1) The modulus of elasticity
2) The yield strength at a strain offset of 0.005
3) The maximum load that can be sustained by a cylindrical specimen having an original cross-sectional diameter of 10 mm
4) The change in length of a specimen originally 500 mm long that is subjected to a tensile load of 140,000 N.

![Stress-Strain Curve](image-url)