The University of Western Ontario
Department of Physics and Astronomy

P2800 Fall 2008

Solution for Homework Assignment #4

1. In the pure CO_2 equilibrium phase diagram (see below), how many components, phases, and degrees of freedom are there at points A, B, C and D (1 point).

   A: C = 1; P = 2, F = 1; B: C = 1; P = 1, F = 2;

   C: C = 1; P = 3, F = 0; D: C = 1; P = 2, F = 1.

2. Determine the weight percents of elements A, B and C for a ternary alloy at points E, F, G, H, I (1 point).

E:	A – 70%,	B – 15%,	C - 15%;
F:	A – 30%,	B – 40%,	C - 30%
G:	A – 25%,	B – 5%,	C - 70%:
H:	A – 2%,	B – 2%,	C -96%
I:	A – 30%,	B – 70%,	C - 0%

3. Consider the aluminum – nickel (Al-Ni) phase diagram below. For this phase diagram:

(a) Determine the coordinates of the **composition** and **temperature** of the invariant reactions. (Hint: there should be 6 of them)

(b) Write the <u>equations</u> for the three-phase invariant reactions and name them.

(c) Label the **two-phase** regions in the phase diagram. For example, two phases Al + Al_3Ni coexist in the region between ~2% -43% Ni and at T=400-639.9°C (2 points).

(a, b) 1. Eutectic reaction at 639°C, 7% Ni

$L(7\%\ Ni) \rightarrow Al\ (0.05\%\ Ni) + Al_3Ni\ (42\%\ Ni)$

2. Peritectic reaction at 854°C, 42% Ni

$L(28\%\ Ni) + Al_3Ni_2\ (55\%\ Ni) \rightarrow Al_3Ni\ (42\%\ Ni)$

3. Peritectic reaction at 1133°C, 59% Ni

$L(44\%\ Ni) + AlNi\ (63\%\ Ni) \rightarrow Al_3Ni\ (59\%\ Ni)$

4. Peritectoid reaction at 700°C, 81% Ni

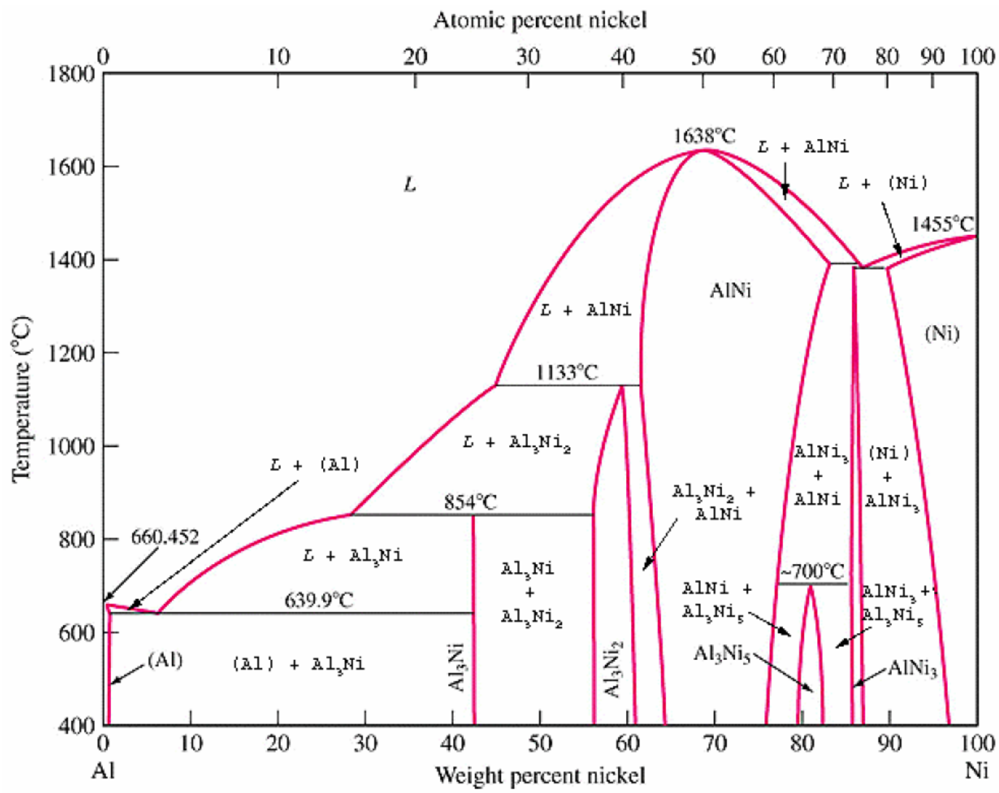
$AlNi(77\%\ Ni) + AlNi_3\ (86\%\ Ni) \rightarrow Al_3Ni_5\ (81\%\ Ni)$

5. Peritectic reaction at 1395°C, 85% Ni

$L(87\%\ Ni) + AlNi\ (83\%\ Ni) \rightarrow AlNi_3\ (86\%\ Ni)$

6. Eutectic reaction at 1385°C, 86% Ni

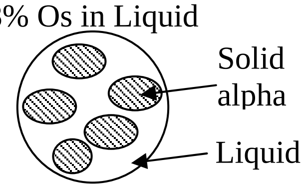
$L(87\%\ Ni) \rightarrow Ni\ (90\%\ Ni) + AlNi_3\ (86\%\ Ni)$



4. Consider the binary peritectic Ir-Os phase diagram below. Make phase analyses of a 70 wt % Ir–30 wt % Os at the T's: (*a*) 2600°C, (*b*) 2665°C + Δ*T*, and (*c*) 2665°C - Δ*T* . In the phase analyses include: (i) The phases present. (ii) The chemical compositions of the phases. (iii) The amounts of each phase. (iv) Sketch the microstructure by using 2 cm diameter circular field. (2 points).

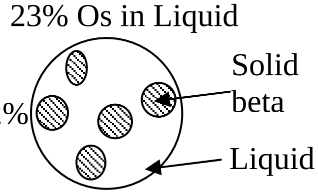
(a) At 2600°C: (i) Liquid and alpha phases; (ii) Compositions of phases: 18% Os in Liquid phase; 39% Os in alpha phases; (iii) Amount of phases

$$Wt\%\ \text{liquid} = \frac{39-30}{39-18} = \frac{9}{21} = 42.8\% \qquad Wt\%\ \text{alpha} = \frac{30-18}{39-18} = \frac{12}{21} = 57.2\%$$



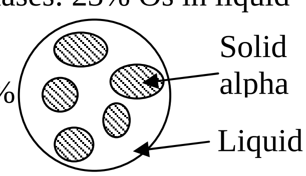
(b) At 2665°C + ΔT: (i) Liquid and beta phases; (ii) Compositions of phases: 23% Os in Liquid phase; 61.5% Os in beta phases; (iii) Amount of phases

$$Wt\%\ \text{liquid} = \frac{61.5-30}{61.5-23.0} = \frac{31.5}{38.5} = 81.8\% \quad Wt\%\ \text{beta} = \frac{30-23}{61.5-23} = \frac{7}{38.5} = 18.2\%$$



(c) At 2665°C - ΔT: (i) Liquid and alpha phases; (ii) Compositions of phases: 23% Os in liquid phase; 43% Os in alpha phases; (iii) Amount of phases

$$Wt\%\ \text{liquid} = \frac{43-30}{43-23.0} = \frac{13}{20} = 65.4\% \quad Wt\%\ \text{alpha} = \frac{30-23}{43-23} = \frac{7}{20} = 34.6\%$$



5. Define the following phases that exist in the Fe-Fe_3C phase diagram: (*a*) austenite, (*b*) α ferrite, (*c*) cementite, (*d*) δ ferrite (1 point).

(a) Austenite, the interstitial solid solution of C in γ Fe, has an *fcc* crystal structure and a relatively high maximum solid solubility of carbon (2.08 %).
(b) An interstitial solid solution of C in the *bcc* Fe crystal lattice, *α* ferrite has a maximum solid solubility of carbon of 0.02 %.
(c) Cementite, Fe_3C, is a hard, brittle intermetallic compound with a carbon content of 6.67 %.
(d) An interstitial solid solution in *δ* iron, *δ* ferrite has a *bcc* crystal structure and a maximum solid solubility of C of 0.09 %.

6. A 0.25 % C hypoeutectoid plain-carbon steel is slowly cooled from 950°C to a T just slightly *below* 723°C. (*a*) Calculate the weight percent proeutectoid ferrite in the steel. (*b*) Calculate the weight percent eutectoid ferrite and weight percent eutectoid cementite in the steel (1 point).

(a) The weight percent proeutectoid ferrite just below 723ºC will be the same as that just above 723ºC. It is therefore calculated based upon a tie line.

$$Wt\%\ \text{proeutectic ferrite} = \frac{0.8 - 0.25}{0.8 - 0.02} \times 100\% = 70.5\%$$

(b) The weight percent total cementite and total ferrite are calculated based on the tie line shown to the right.

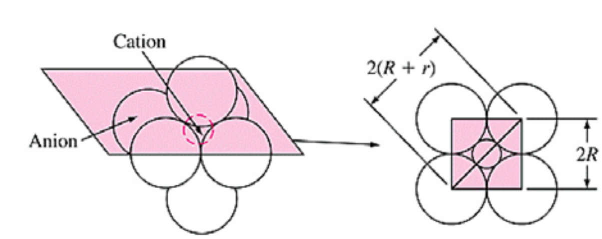
$$Wt\%\ \text{total cementite} = \frac{0.25 - 0.02}{6.67 - 0.02} \times 100\% = 3.46\% \quad Wt\%\ \text{total ferrite} = \frac{6.67 - 0.25}{6.67 - 0.02} \times 100\% = 96.5\%$$

The eutectoid ferrite is equal to the difference between the total ferrite and the proeutectoid ferrite: $Wt\%\ \text{eutectoid ferrite} = 96.5\% - 70.5\% = 26.0\%$

Since the steel contains less than 0.8 percent carbon, no proeutectoid cementite was formed during cooling. Thus, $Wt\%\ \text{eutectoid cementite} = Wt\%\ \text{total cementite} = 3.46\%$

7. Give two composition examples of shape memory alloys (SMA). Using *Temperature vs Load* plot describe the changes in SMA shape and structure under different load and temperature conditions (1 point): (see lecture notes)

8. Calculate the critical (minimum) radius ratio r/R for octahedron coordination (CN = 6) of anions of radii R surrounding a central cation of radius r in an ionic solid (1 point).



$$[2(r+R)]^2 = (2R)^2 + (2R)^2$$
$$(r+R)^2 = 2R^2$$
$$r + R = \sqrt{2}R$$
$$r = \sqrt{2}R - R = 0.414R$$
$$\frac{r}{R} = \mathbf{0.414}$$