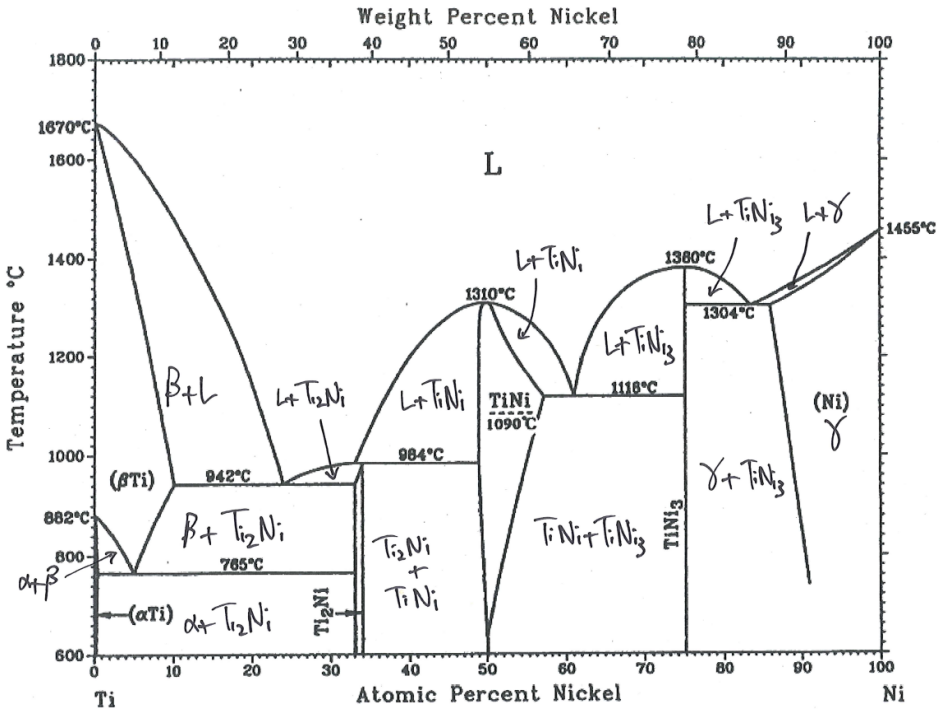
Lecture 1 - introduction to phase diagrams

1. How many phase transformations occur on cooling pure Ti from the melt? State the transformations.

Solution: Two. $L \rightleftharpoons \beta$ and $\beta \rightleftharpoons \alpha$. The latter transformation is an *allotropic* transformation, which involves a change in crystal structure (in this case from BCC to HCP), but no change in composition. A number of metallic elements exhibit allotropy, such as Fe (BCC, FCC), Co (HCP, FCC) and Pu which can exist as 6 different solid forms. For those interested, there is a nice paper about Pu here: (http://link.springer.com/article/10.1007%2Fs11661-007-9373-5)

2. Label the two-phase fields on the diagram. How many *different* two-phase fields are there?

Solution: There are 11 *different* phase fields. There are 13 two-phase fields in total, but L + TiNi and L + $TiNi_3$ appear twice.

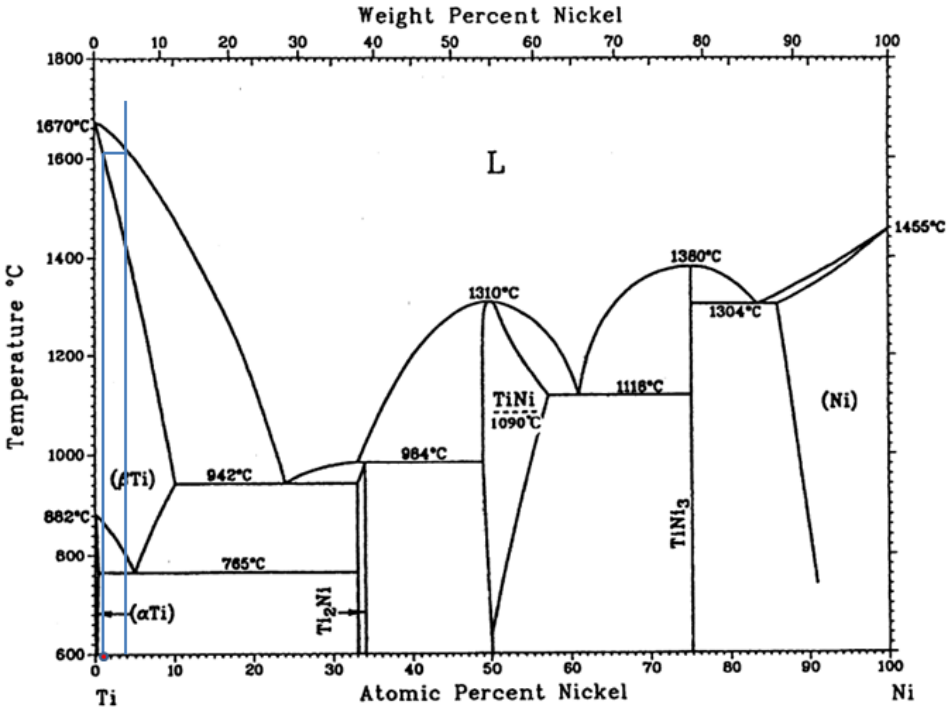


3. To the nearest g, what mass of Ti is needed to make 1 kg of TiNi? The relative atomic mass of Ti is 47.9 and the relative atomic mass of Ni is 58.7.

Solution: The relative atomic mass of Ti is 47.9 and the relative atomic mass of Ni is 58.7. 1 mole of TiNi has a mass of 106.6 g, so in 1000 g we have $\frac{1000}{106.6}$ moles ~ 9.4 moles. So as 1 mole of TiNi contains 1 mole of Ti (i.e. 9.4 moles of TiNi contains 9.4 moles of Ti), then the mass of Ti in 1000 g TiNi is $9.4\,\text{mol} \times 47.9\,\text{g mol}^{-1} = 449\,\text{g}$.

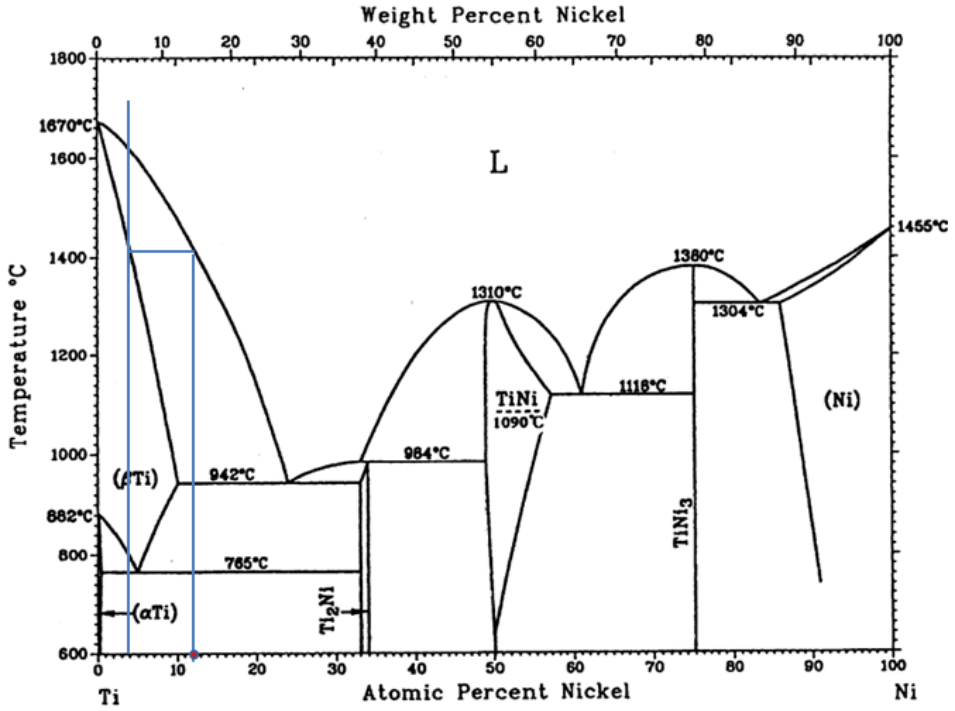
4. For a Ti-4at%Ni alloy, use the phase diagram to determine the composition of the first solid to form? What is this?

Solution: Reading directly from the phase diagram, the value is ~ 1 atomic%Ni.

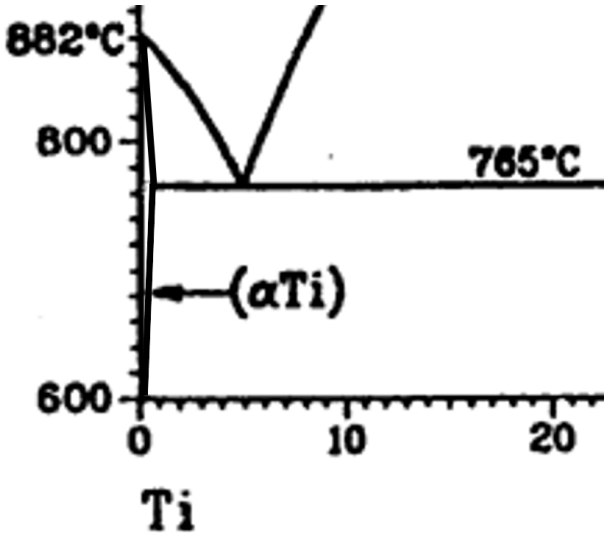


5. For a Ti-4at%Ni alloy, use the phase diagram to determine the composition of the last liquid to solidify? What is this?

Solution: Reading directly from the phase diagram, the value is ~ 12 atomic%Ni.

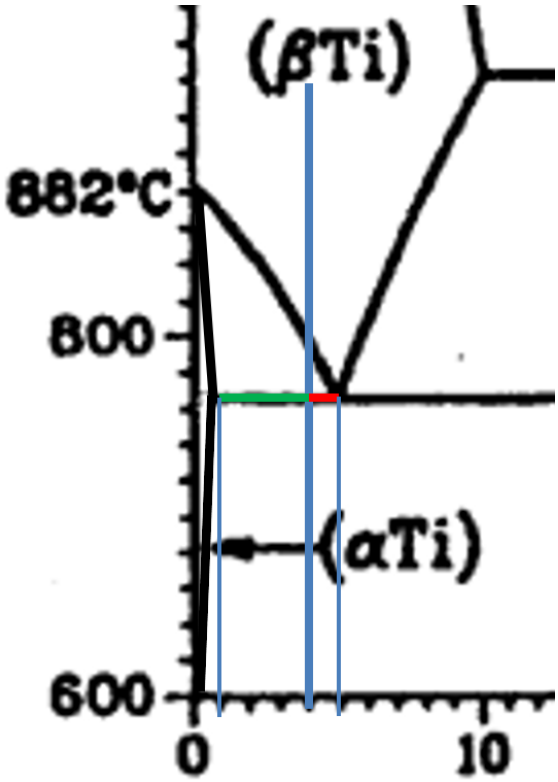


6. For a Ti-4at%Ni alloy at just above 765 °C (see magnified region below), use the lever rule to determine the atomic fractions of α and β.



Solution: We need to use the lever rule. The fraction of α is given by the red line as a fraction of the (red + green line) in the diagram $\sim \frac{5-4}{5-1} = 0.25$, so the fraction

of β is 0.8.



7. What transformation/reaction occurs at 5 atomic%Ni and 765 °C? What sort of reaction is this?

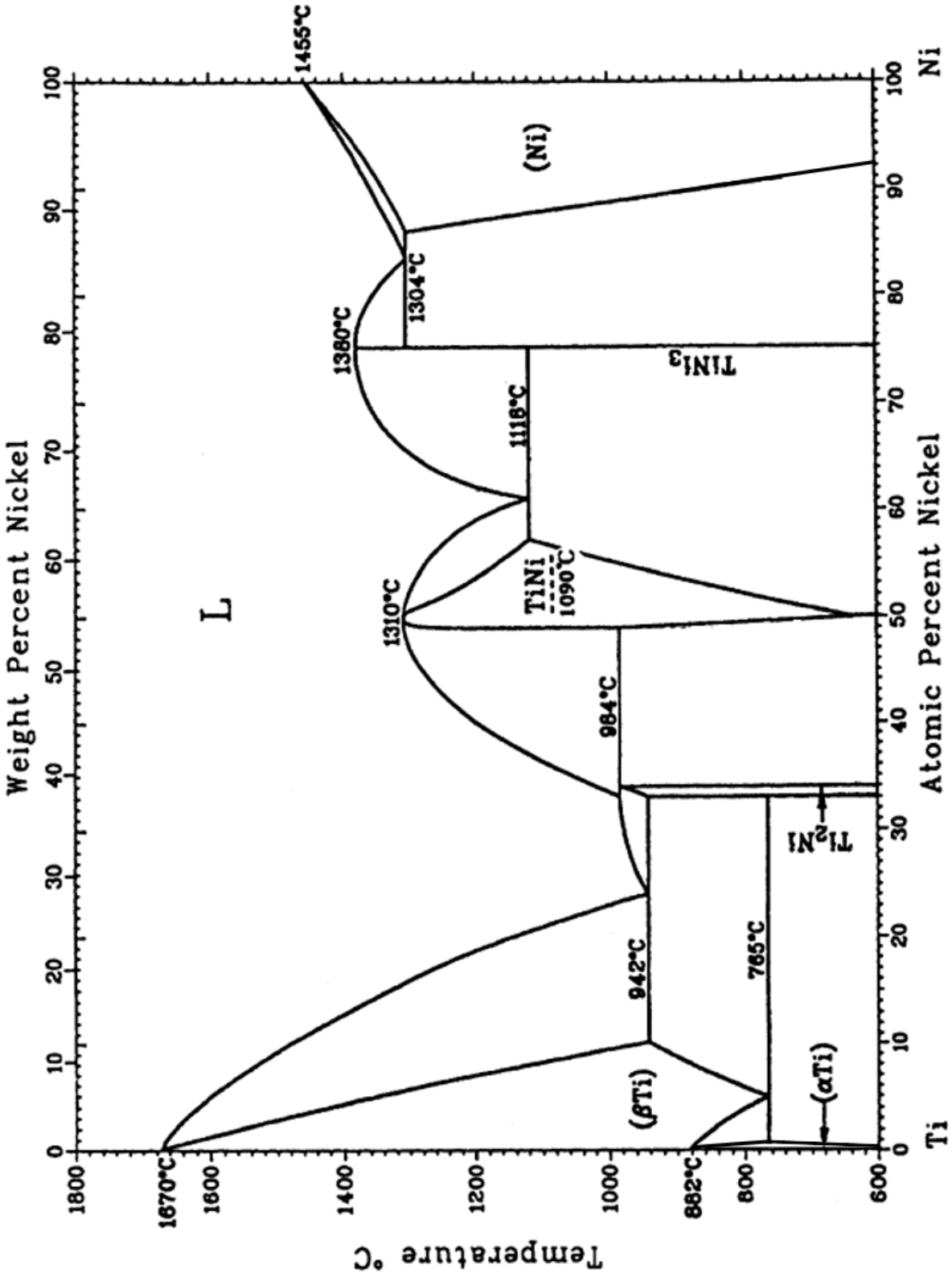
Solution: This is a *eutectoid* reaction where $\beta \rightleftharpoons \alpha +$ Ti_2Ni.

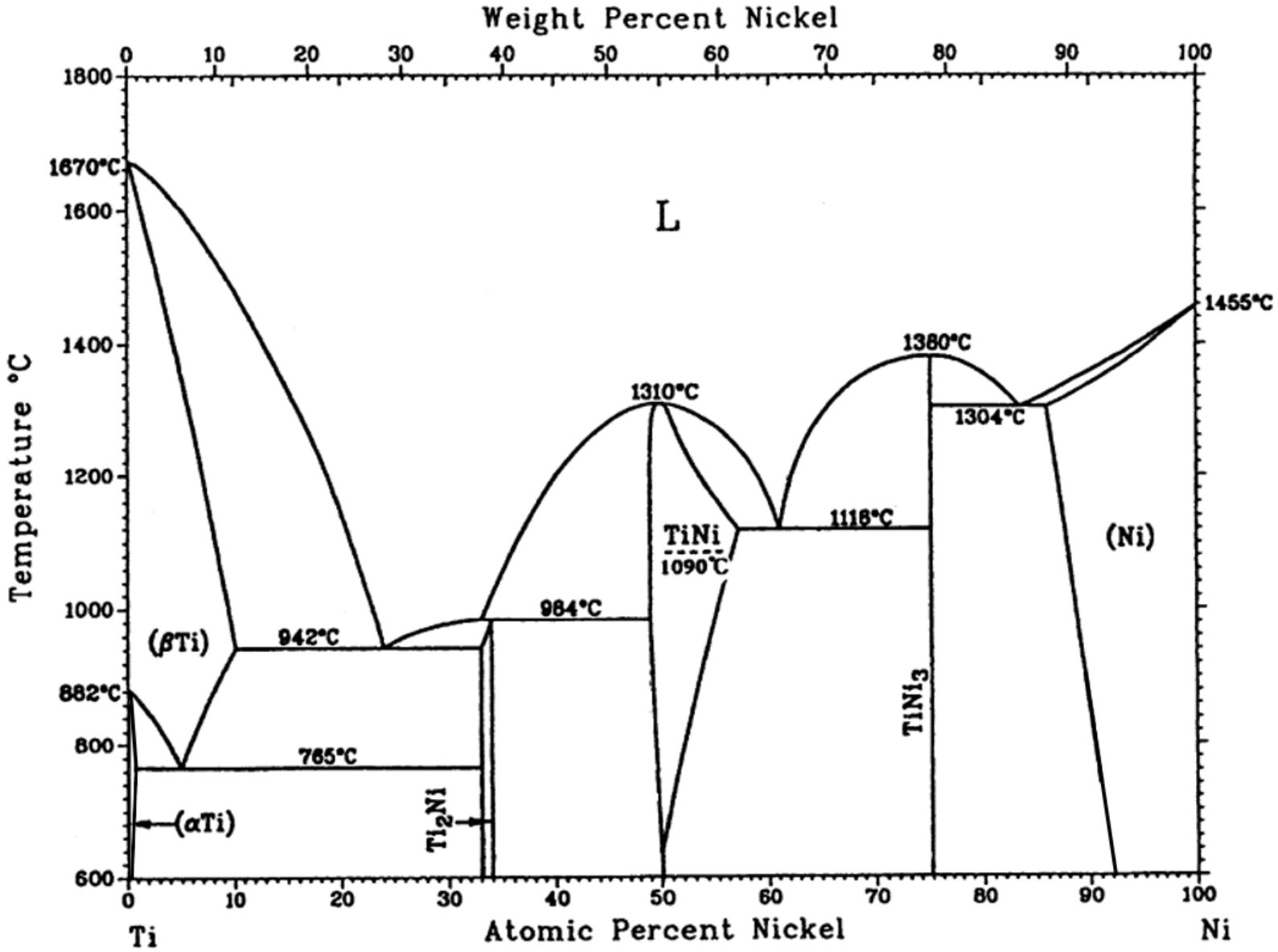
8. At 942 °C and Ti-24at%Ni what phases are in equilibrium?

Solution: This is a eutectic point, so L $\rightleftharpoons \beta +$ Ti_2Ni.

9. How many degrees of freedom does the system have at that point on phase diagram defined in 8? (Assume the condensed phase rule $P + F = C + 1$.)

Solution: Using $P+F = C+1$, we have 3 phases and 2 components so $F = 0$. This means we have invariant equilibrium, so nothing can change (i.e. the composition or the temperature) and maintain equilibrium at this point on the phase diagram.


Weight Percent Nickel
Atomic Percent Nickel
Temperature °C
Ti
Ni
L
(Ni)
(βTi)
(αTi)
1455°C
1380°C
1304°C
1118°C
1310°C
1090°C
984°C
942°C
765°C
882°C
1670°C
TiNi3
TiNi
Ti2Ni


Weight Percent Nickel
0
10
20
30
40
50
60
70
80
90
100
1800
1670°C
1600
1400
1200
1000
882°C
800
600
Temperature °C
L
1455°C
1380°C
1310°C
1304°C
1118°C
TiNi
1090°C
984°C
(Ni)
(βTi)
942°C
765°C
(αTi)
Ti2Ni
TiNi3
Ti
Atomic Percent Nickel
Ni

Dr S C Hogg