$$\frac{T_m - T_m^b}{T_m^b} = \frac{2(\gamma_{Lw} - \gamma_{sw})}{\cancel{HP}\; H \rho \Delta_m h} \quad (1)a$$

-8

T_m^b = bulk melting temperature

γ_{Lw} and γ_{sw} = liquid and solid wall

$\rho = N/V$ is the density

$\Delta_m h = h_L - h_s$ is the latent heat of melting per particle.

$$T_m(H) = T_T^b + \frac{2(\gamma_{Lw} - \gamma_{sw})}{\rho_s \Delta_m s H}$$

Given the $V = A_w H$

making use of Clapeyron approach.

$$\Omega = U - TS - \mu N = -PA_wH + 2\gamma A_w$$

with internal energy

$$U = TS - PA_wH + 2\gamma A_w + \mu N,$$

where S is the entropy, P is the pressure and γ is the surface tension. The thermody potentials of the two phases are equation $\Omega_L = \Omega_s$

$$P_L - P_s = \frac{2(\gamma_{Lw} - \gamma_{sw})}{H}$$

$$d\Omega = -SdT - PA_w dH + (2\gamma - PH)\, dA_w - N d\mu \, 6$$

$$\frac{dH}{H^2} = -\frac{dT}{2(\gamma_{Lw} - \gamma_{sw})}\left[(\rho_L s_L - \rho_s s_s) + (P_L - P_s)\frac{d\mu}{dT}\right)$$

$$\frac{d\mu}{dT} = \frac{P_L^b s_L^b - P_G^b s_G^b}{P_L^b - P_G^b} = -s_L^b$$

$$\frac{dH}{H^2} = -\frac{(P_L - P_s)(s_L - s_L^b) + \rho_s(s_L - s_s)\, dT}{2(\gamma_{Lw} - \gamma_{sw})}$$

(1)

For sufficiently large confining distances (and corresponding small shift in the melting $T_m - T_m^b$, one can approximate

$$\frac{dH}{H^2} = -\frac{\rho_s^b \Delta m_s^b}{2(\gamma_{Lw} - \gamma_{Sw})} dT$$

$$\Delta m s^b = S_L^b - S_s^b$$

the final step to recover the CGT equation is to integrate this equation along thermodynamic path connecting the confined system for finit H and corresponding T_m ~~and~~ and unconfined one $H \to \infty$ and bulk melting temperature T_m^b

$$\int_H^\infty \frac{dH}{H^2} = \frac{-\rho_s^b \Delta m s^b}{2(\gamma_{Lw} - \gamma_{Sw})} \int_{T_m}^{T_m^b} dT$$

$$T_m(H) = T_T^b + \frac{2(\gamma_{Lw} - \gamma_{Sw})}{H \rho_s^b \Delta_m s^b}$$

(15) from Confined Claperon (15) approach

$$\Omega = U - TS - \mu N = -PA_w H + 2\gamma A_w$$

with inter energy

$$U = TS - PA_w H + 2\gamma A_w + \mu N$$

-10

Where S = entropy

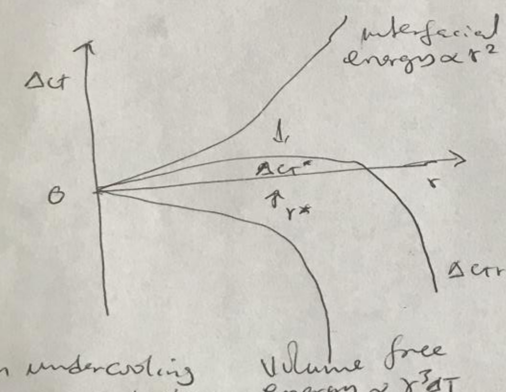
P = pressure

γ = surface tension

Coexistence between the liquid and solid phase thermodynamic potentials of the 2 phase are equal

$$\Omega_L = \Omega_s.$$

(b)



for given undercooling ΔT

$$r^* = \frac{2\gamma_{SL}}{\Delta G_V} = \left(\frac{2\gamma_{SL} T_m}{L_v}\right)\frac{1}{\Delta T}$$

For given undercooling ΔT, r^* correspond to a maximum excess free energy

$r < r^* \rightarrow$ Cluster or embryos

$r > r^* \rightarrow$ nuclei

Below T_m, G_V is positive, so formation of small volume of solid has negative contribution, if γ_{SL} is isotropic

$$\Delta G_r = -\frac{4}{3}\pi r^3 \Delta G_V + 4\pi r^2 \gamma_{SL}$$

c) Kelvin equation $\Rightarrow \ln\left(\frac{P_{Cr}}{P}\right) = \frac{2\gamma V_{molecule}}{k_B T_r}$

$CCE = \frac{dP}{dT} = \frac{PL}{T^2 R}$

Integrating CCE

$\int_1^2 dP = \int \frac{PL}{T^2 R} dT$ gives $\ln\left(\frac{P_2}{P_1}\right) = \frac{L}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

Substituting $\ln\left(\frac{P_2}{P_1}\right)$ gives r from the Kelvin equation

$$r = \frac{2\gamma T}{\rho L (T_1 - T_2)}$$

Good +5

$$\rho L (T_1 - T_2) r = 2\gamma T$$

$$\rho L \Delta T = 2\gamma T \qquad T_1 - T_2 = \Delta T$$

$$\Delta T = \frac{2\gamma T}{\rho L r}$$ Same as Gibbs-Thomson equation

Ostwald-Freundlich equation $(OFE) = x_a = x_a^{\infty} \exp\left[\frac{2 V_a \gamma}{R_s T R_{sg}}\right]$

X_a = mole fraction

V = Molar volume

R_{sg} = radius

γ = Interfacial tension

R_a = Universal gas Constant

T = Temperature.

d) -20

e) -20

2 (b) (b) This eutectic region with 3 phases in equilibrium. This is an invariant point with liquid, Ni and $ZrNi_5$

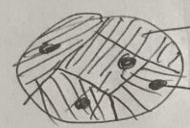
Triple point is eutectic point

OK

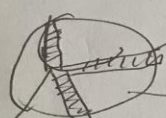
Reaction $\Rightarrow L \rightleftharpoons Ni + ZrNi_5$

$F = C - P + 1$ (at constant pressure of 1 atom)

$F = 2 - 3 + 1 = 0$



(c)



phase fraction of Ni

$$\frac{15-5}{15-0} = \frac{10}{15} = 0.67$$

-5

phase fraction of Zr = 0.33

Composition of Ni = 100% Ni or % Zr

Composition of $ZrNi_5$ = 85% Ni or 15% Zr

(d)

Fast cooling

fraction of Ni = 0.67

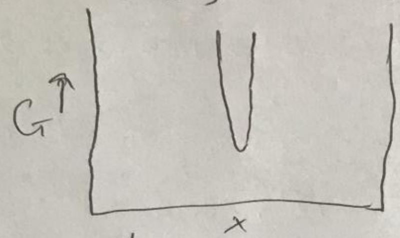
fraction of Zr = 0.33

Composition of Ni = 100% Ni

Composition of $ZrNi_5$ = 85% Ni

e)

d) ~~An is for~~
~~An~~ intermetalic is forme when two metals bond chemically to form a compound with composition and crystalline structure. The Gibbs energy shows that intermetallics are usually narrow



-7

Intermetallics phases

$ZrNi_5$	=> 15% Zr	at room temperature to 1170°C
Zr_2Ni_7	=> 22% Zr	" " " " 1438°C
$ZrNi_3$	=> 25% Zr	" " " " 920°C
Zr_8Ni_{21}	=> 28 ~~%~~ % Zr	" " " " 1180°C
Zr_7Ni_{10}	=> 41% Zr	" " " " 1163°C
Zr_9Ni_{11}	=> 45% Zr	" " " " 975°C–1157°C

e) Ni – 20% Cu is complet solid solution therefore is an isomorphous system.
Lever rule is used to determine phase fractions and compositions OK
Matrix phase is solid solution α (Cu,Ni) which is made up of Cu and Ni at lower temperature below solidus.
There are solid solution α and liquid solution between solidus and liquidus. We hence full solubility above the liquidus.
Mixture of Cu and Ni is the spherical domain
Solid α composition => 84% Ni
liquid composition => 76% Ni

e) -20