MLL 100

Introduction to Materials Science and Engineering

Lecture-17 (February 12, 2022)

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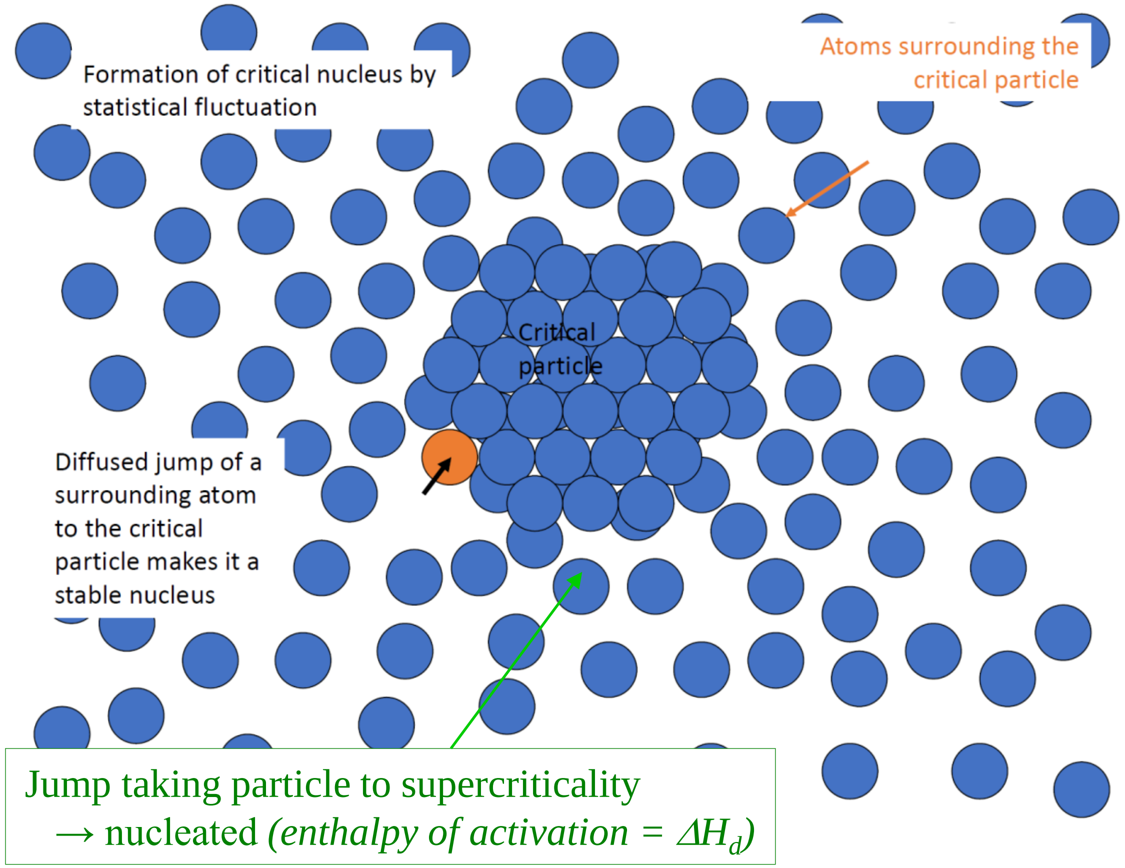
What have we learnt in Lecture-16?

- Heterogeneous nucleation
- Wetting property

Parameters influencing nucleation rate



- Potential atoms capable of jumping to make a critical nucleus supercritical are the atoms which are just 'adjacent' to the liquid, say $\boldsymbol{s^*}$.

- If the ***lattice vibration frequency is*** ν and the ***activation barrier*** for an atom facing the nucleus (i.e. atom belonging to s*) to jump into the nucleus (to make in supercritical) is $\boldsymbol{\Delta H_d}$, the frequency with which nuclei become supercritical due atomic jumps into the nucleus

$$\nu' = s^* \nu \, e^{\left(-\frac{\Delta H_d}{kT}\right)}$$

Rate of nucleation = No. of critical sized particles × Frequency with which they become supercritical

$$I = \frac{dN}{dt}$$

$$N^* = N_t \, e^{\left(-\frac{\Delta G^*}{kT}\right)}$$

No. of particles/volume

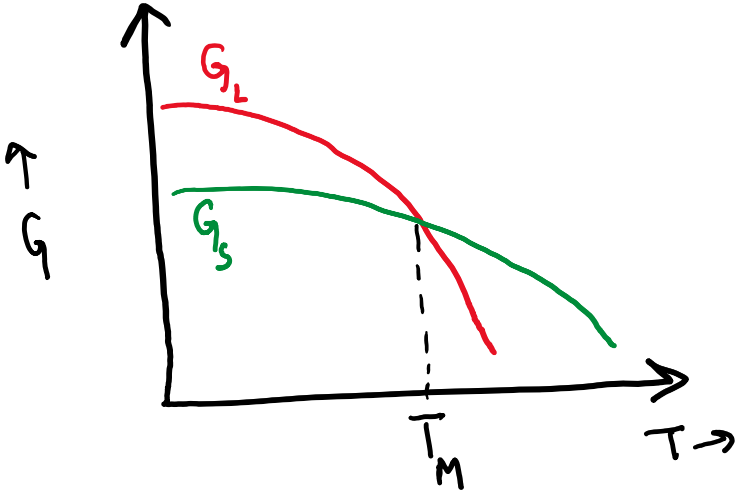
$$\nu' = s^* \nu \, e^{\left(-\frac{\Delta H_d}{kT}\right)}$$

ν → lattice vibration frequency (~10^{13} /s)

Dependence of Nucleation rate on Temperature

$$\Delta G^* = \frac{16\pi\gamma_{sl}^3}{3.(\Delta G_v)^2}$$

- How does the plot of nucleation rate vary with temperature?
  - At T_m , ΔG^* is $\infty \Rightarrow I = 0$ *(if there is no undercooling there is no nucleation).*
  - At T = 0 K again I = 0
- This implies that the function should reach a maximum between $T = T_m$ and T = 0.
- Nucleation rate is not a monotonic function of undercooling.

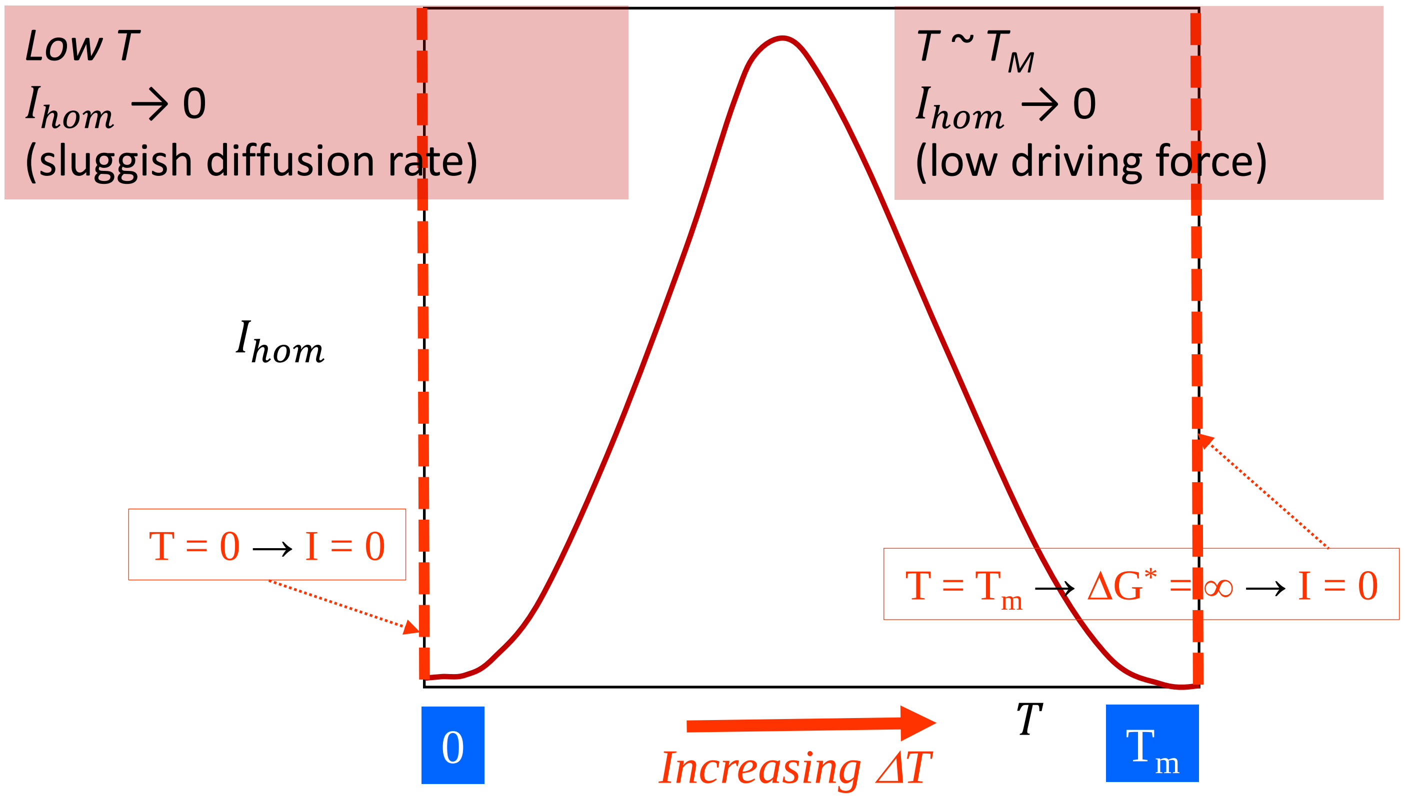


$$I = N_t\, s^*\, \nu\, e^{-\left(\frac{\Delta G^* + \Delta H_d}{kT}\right)}$$

- $\Delta G^* \uparrow \;\Rightarrow I \downarrow$

Note: ΔG^* is a function of T

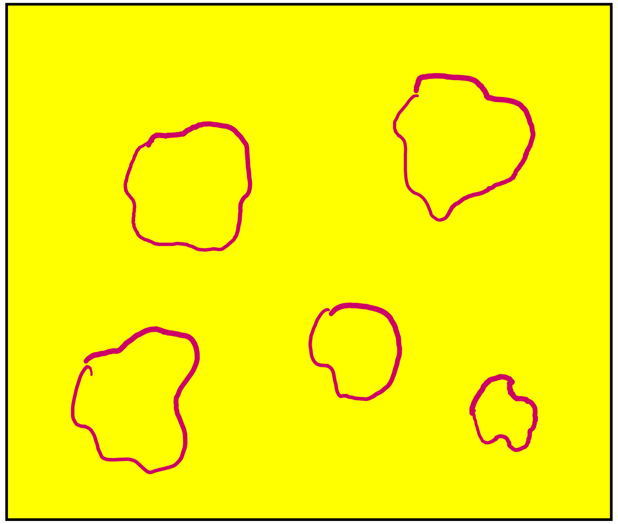
- $T \uparrow \;\Rightarrow I \uparrow$

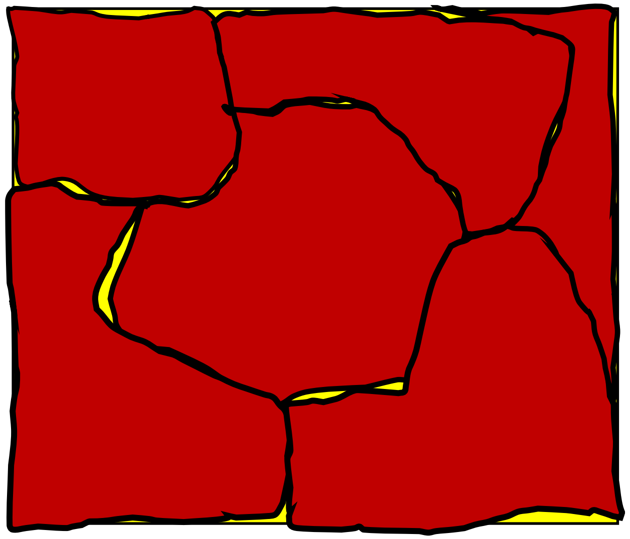


Growth rate

- Fraction of the product phase (solid phase) forming with time

$\rightarrow$ the sigmoidal growth curve





- **Overall transformation rate,** $\frac{dX}{dt}(\mathrm{s}^{-1})$: Fraction transformed (X) per second.
- **Nucleation Rate, I (in m^{-3}s^{-1}):** No of nucleation events per unit volume per second.
- **Growth Rate,** $G = \frac{dR}{dt}(\mathrm{ms}^{-1})$: Rate of increase of the size of growing particle.

$$\frac{dX}{dt} = f(I, G)$$

$$X = 1 - \exp(-\frac{\pi}{3} I G^3 t^4)$$

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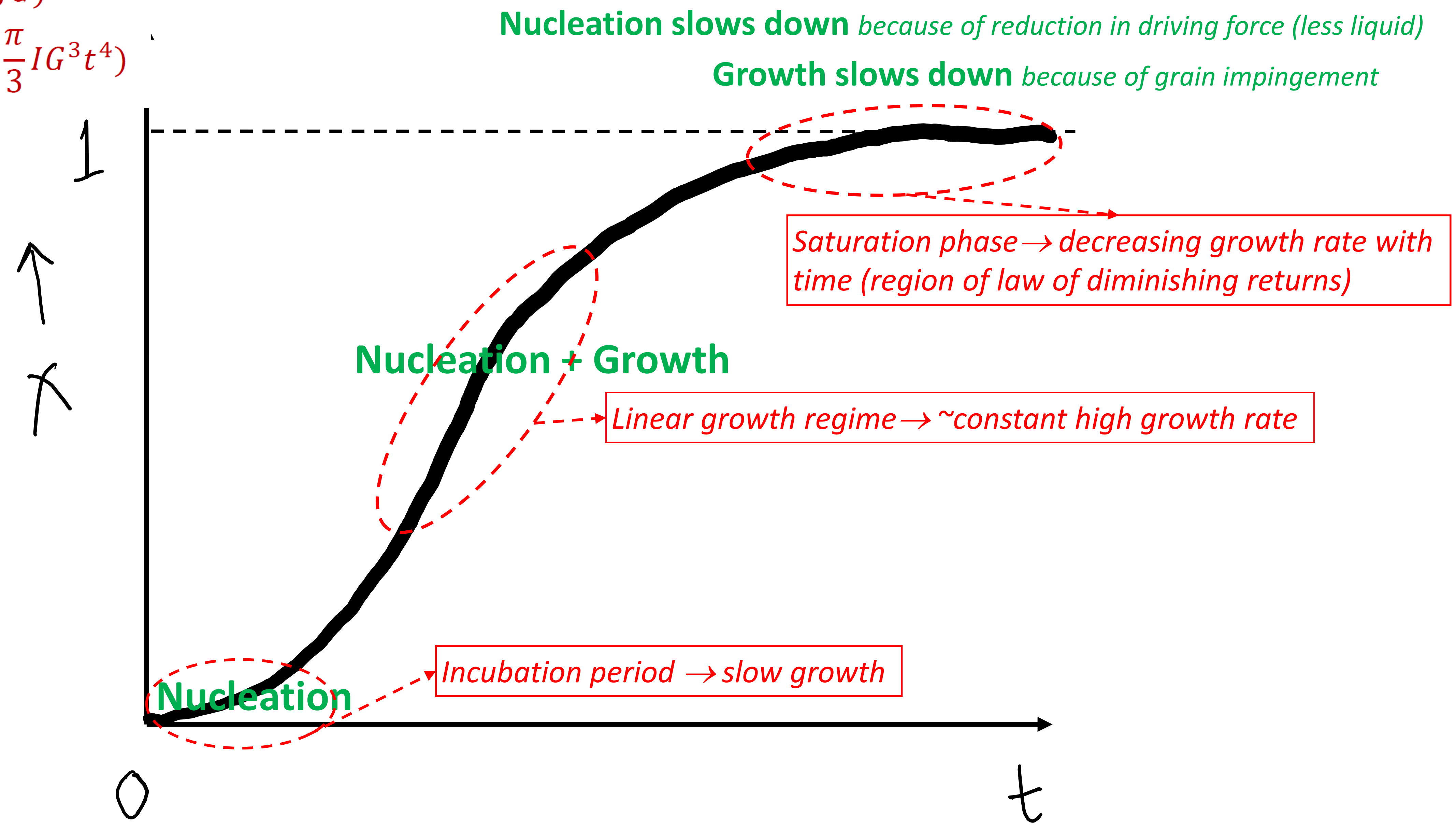
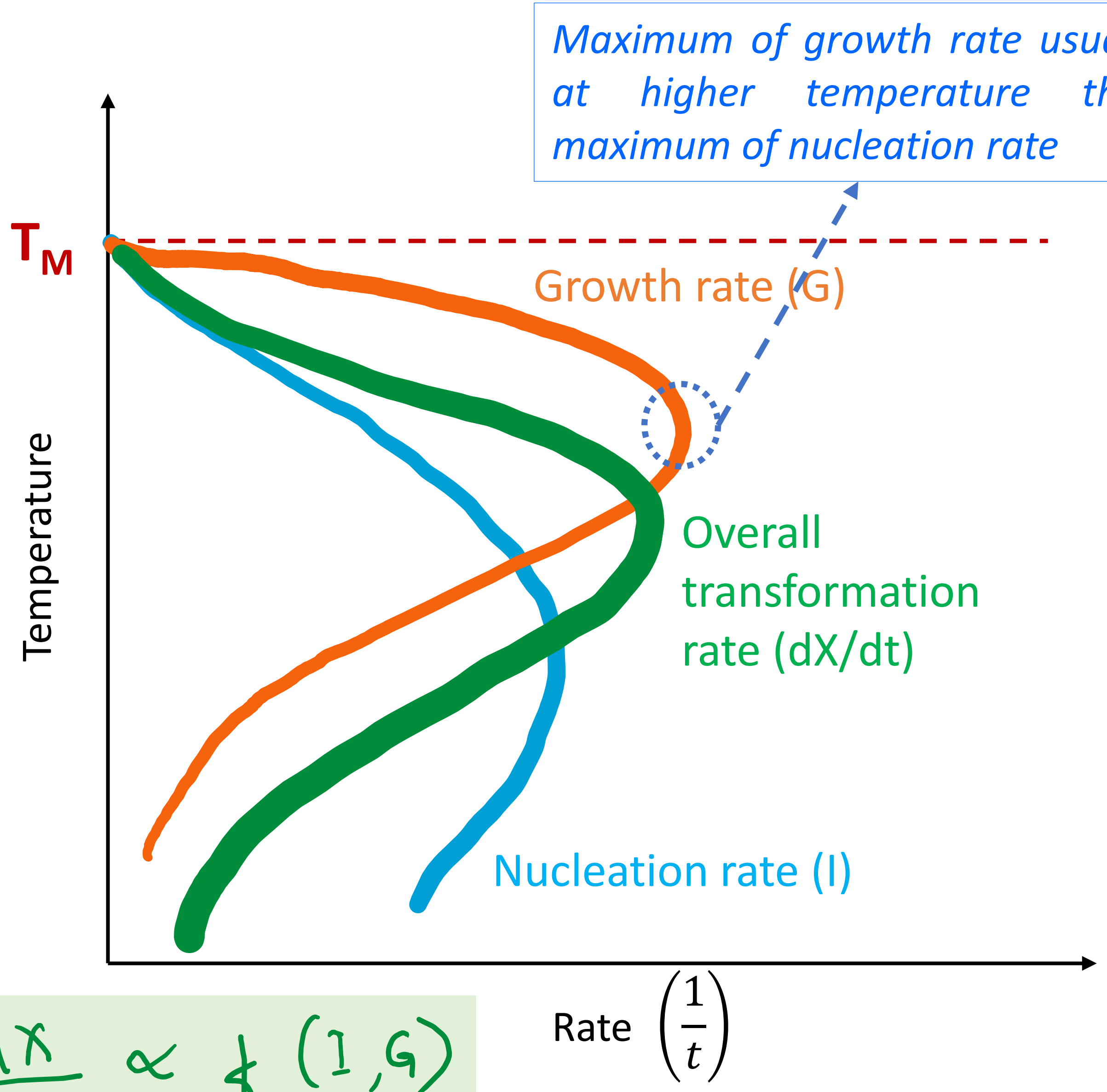
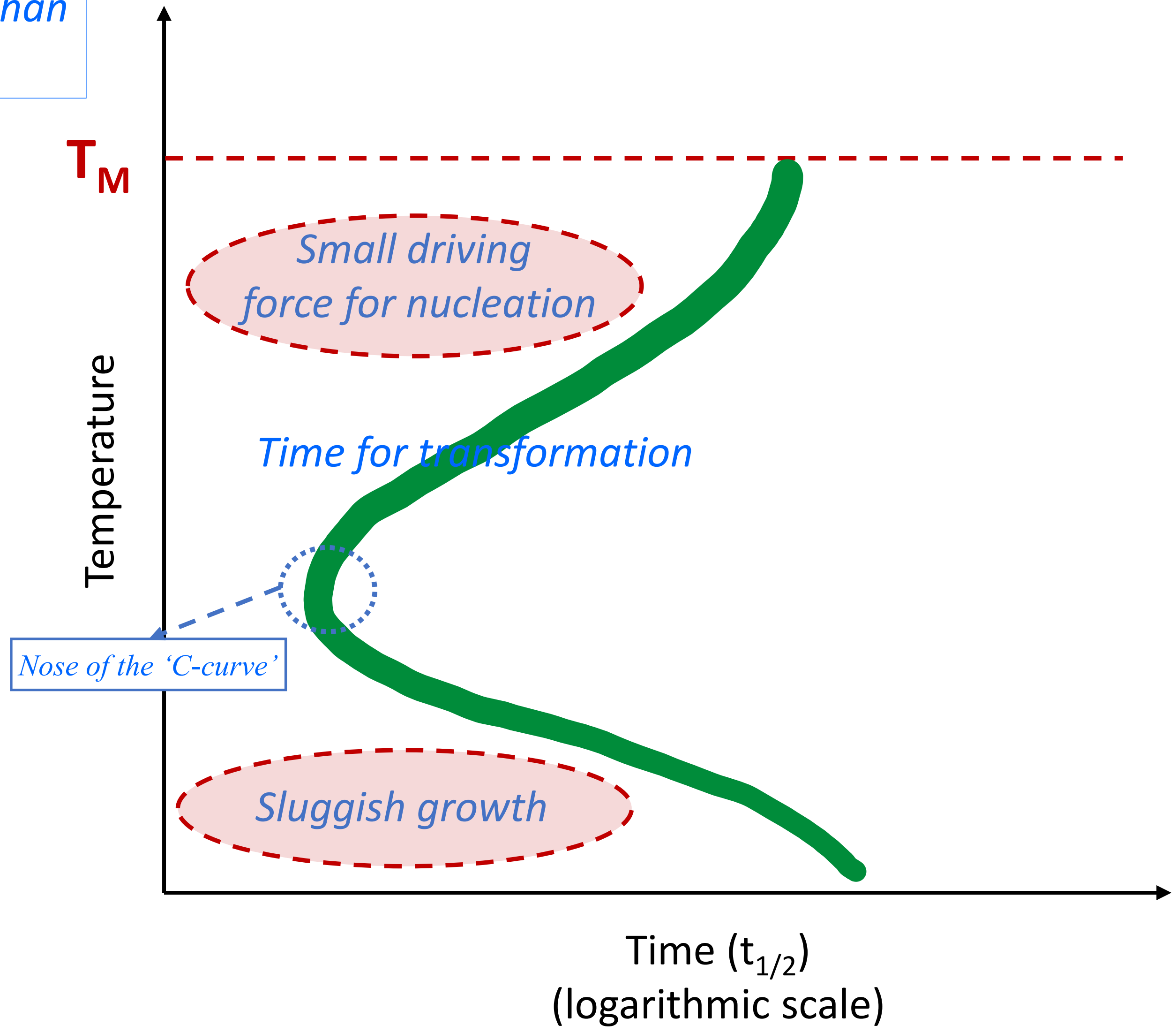


Transformation rate





$$\frac{dx}{dt} \propto f(I, G)$$