MULTI STEADY STATE CSTR - RECAP

ASSUMPTION: SINGLE REACTION in a CSTR

At steady state: the heat generated must be equal to the heat removed

$$\widetilde{\Delta H}_R^{in}\frac{\dot{R}_A V}{\dot{F}_A^{in}} = \widetilde{C}_P^{*}(1+\kappa)(T-T^{*})$$

$$\begin{cases} G(T) = \widetilde{\Delta H}_R^{in}\dfrac{\dot{R}_A V}{\dot{F}_A^{in}} \\ R(T) = \widetilde{C}_P^{*}(1+\kappa)(T-T^{*}) \end{cases}$$

In the exercise considered, the generated heat is

$$\frac{V}{\dot{F}_A^{in}}\left(r_1\Delta\widetilde{H}_{R1} + r_2\Delta\widetilde{H}_{R2}\right)$$

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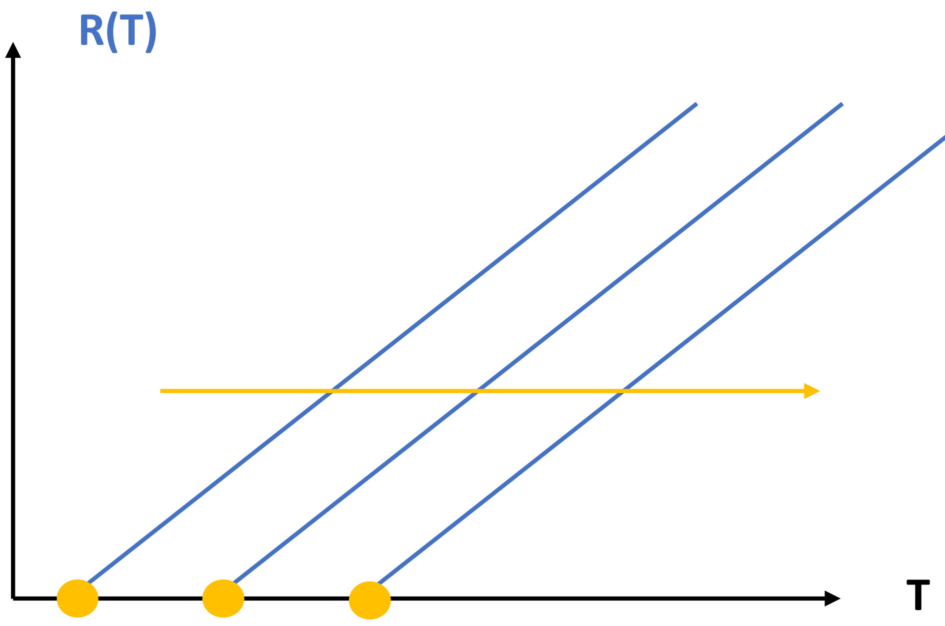

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T* : intercept

Removed heat decreases with increasing T*

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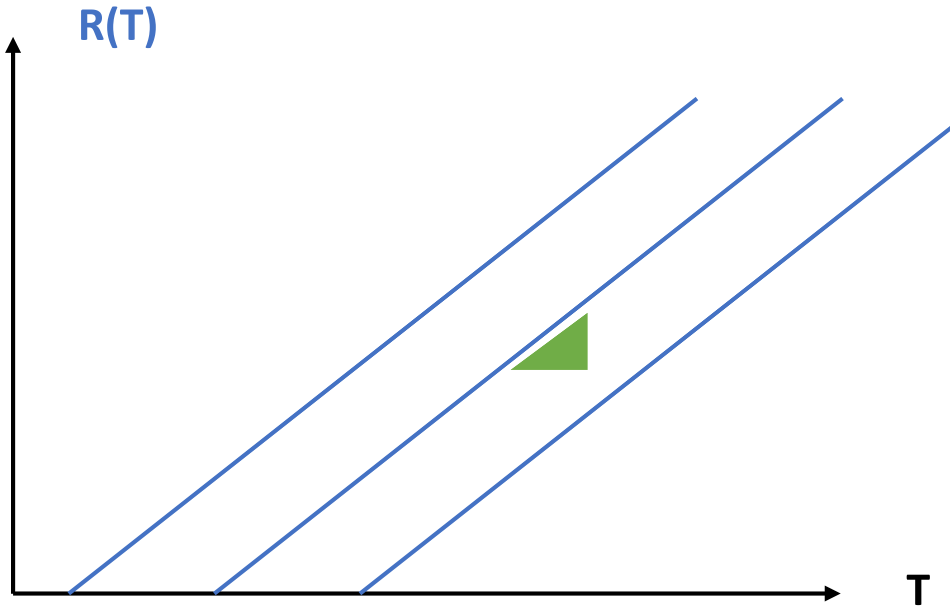

$$\begin{cases} G(T) = \widetilde{\Delta H}_R^{in}\dfrac{\dot{R}_A V}{\dot{F}_A^{in}} \\ R(T) = \boxed{\widetilde{C_P^*}(1+\kappa)}(T-T^*) \end{cases}$$

$\widetilde{C_P^*}\,(1+k)$: slope of the curve
Removed heat increases with increasing slope

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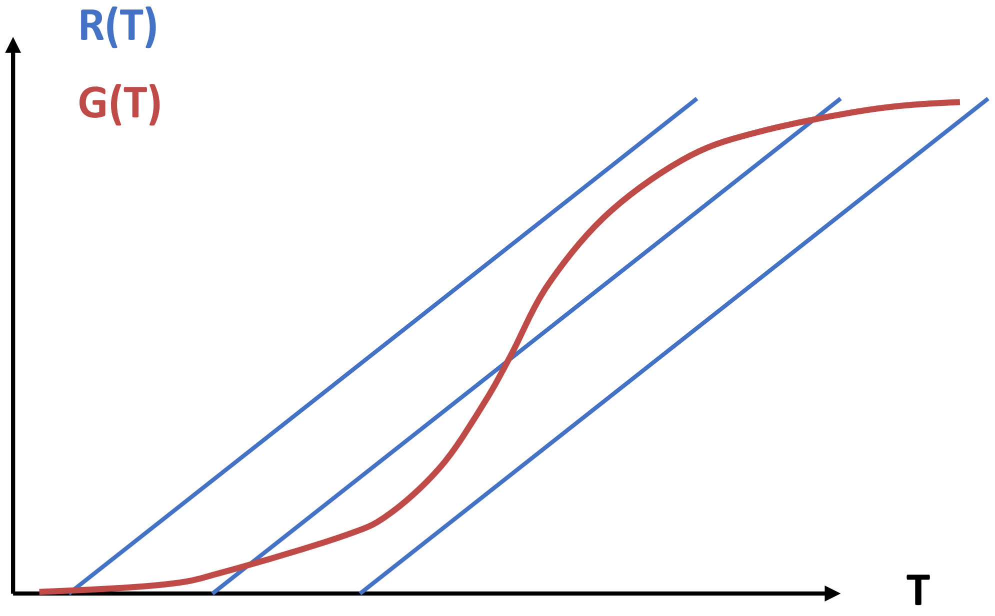

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Heat generated: it depends on the shape of the conversion → it depends on the reaction rate ($\dot{R}_A$) !

This is the shape for an irreversible reaction

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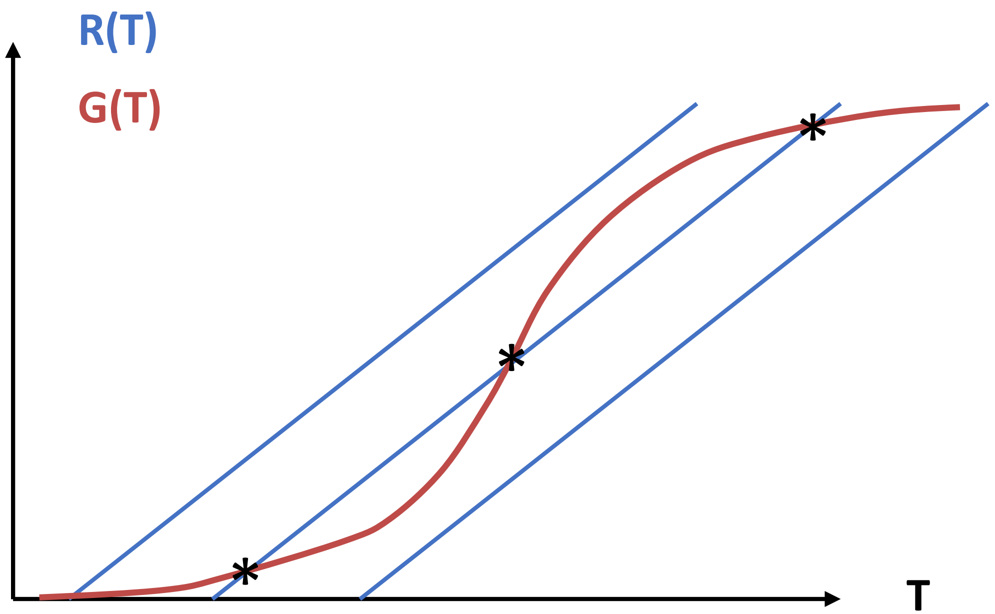

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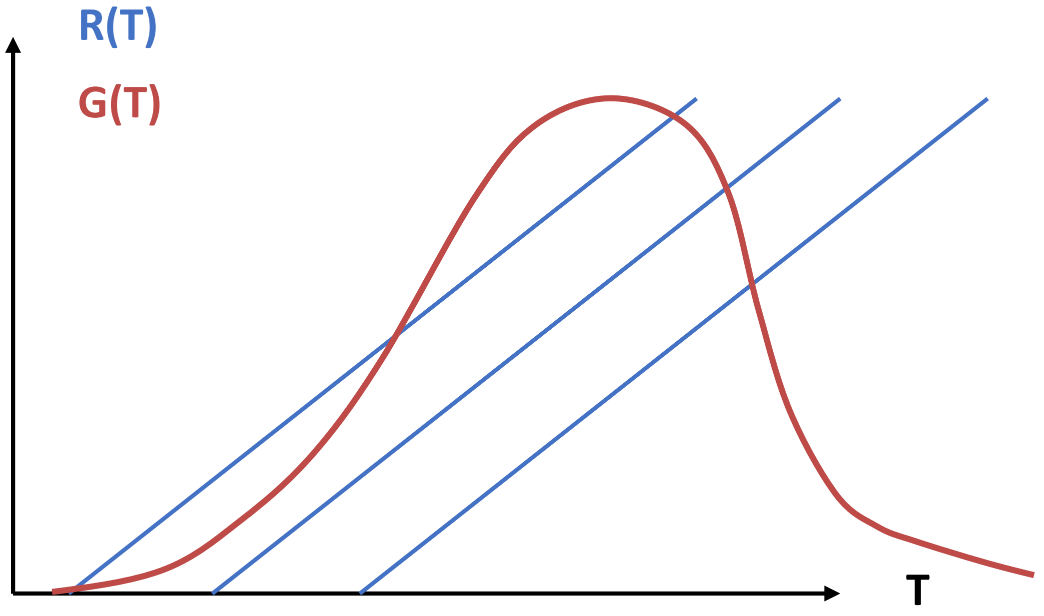

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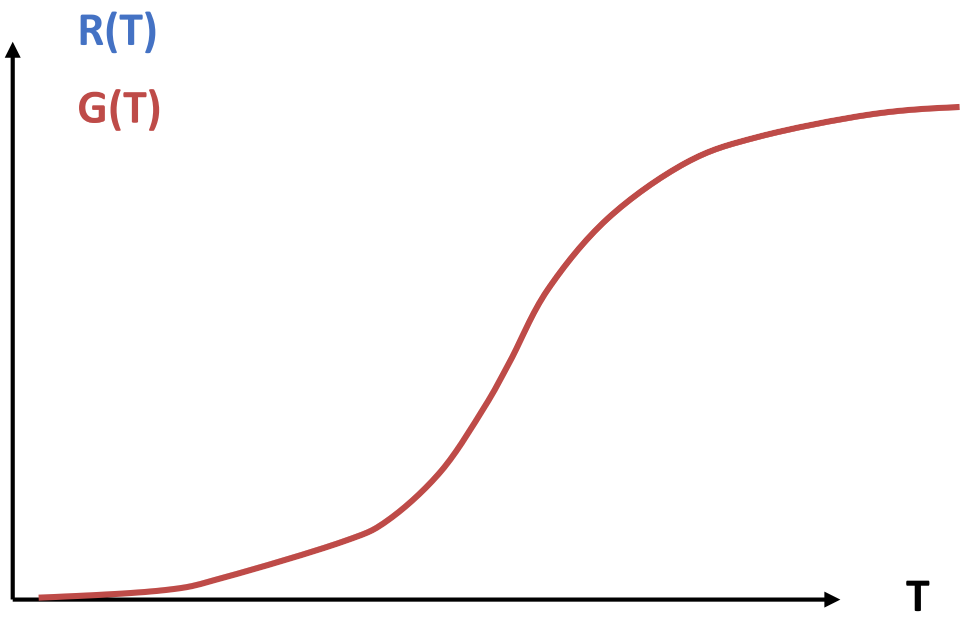
-X

Heat generated: it depends on the shape of the conversion → it depends on the reaction rate ($\dot{R}_A$) !

Reversible exothermic reactions can have maxima in the generated heat

Basic case of single irreversible reaction

What happens if you vary T in (and therefore T*) ? $\longrightarrow$ $T^* = \dfrac{\kappa T_{ext}^{in} + T_{in}}{\kappa + 1}$



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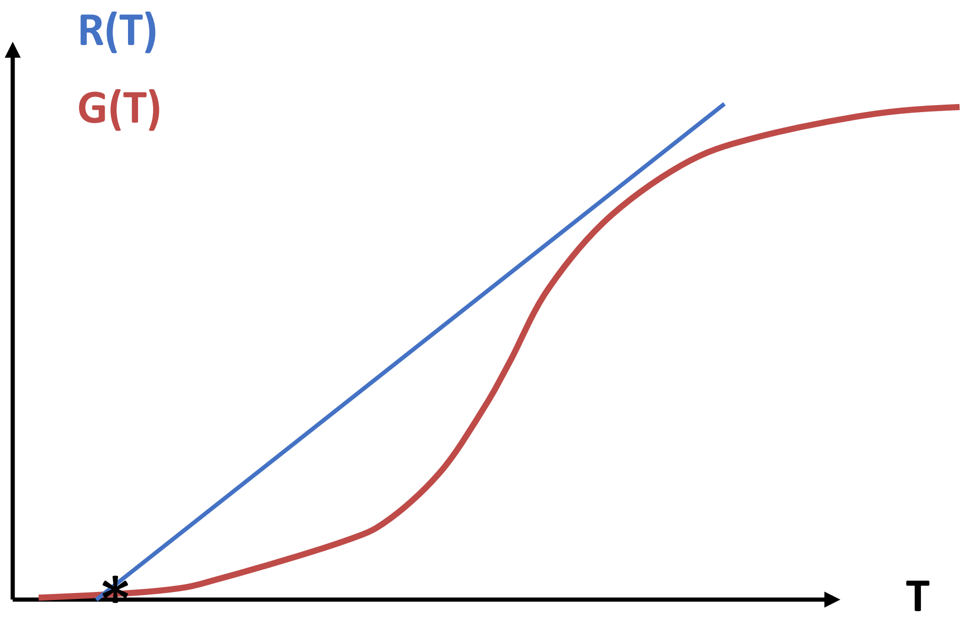

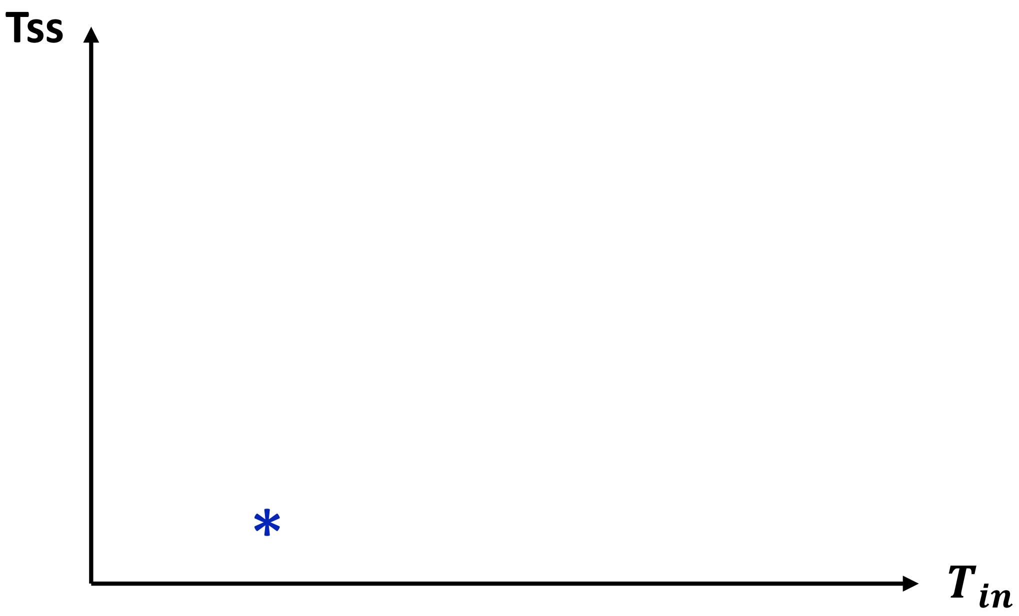

Low temperature steady state solution on the low branch

You find a certain steady state T based on your inlet temperature

MULTI STEADY STATE CSTR – STATIC STABILITY ANALYSIS

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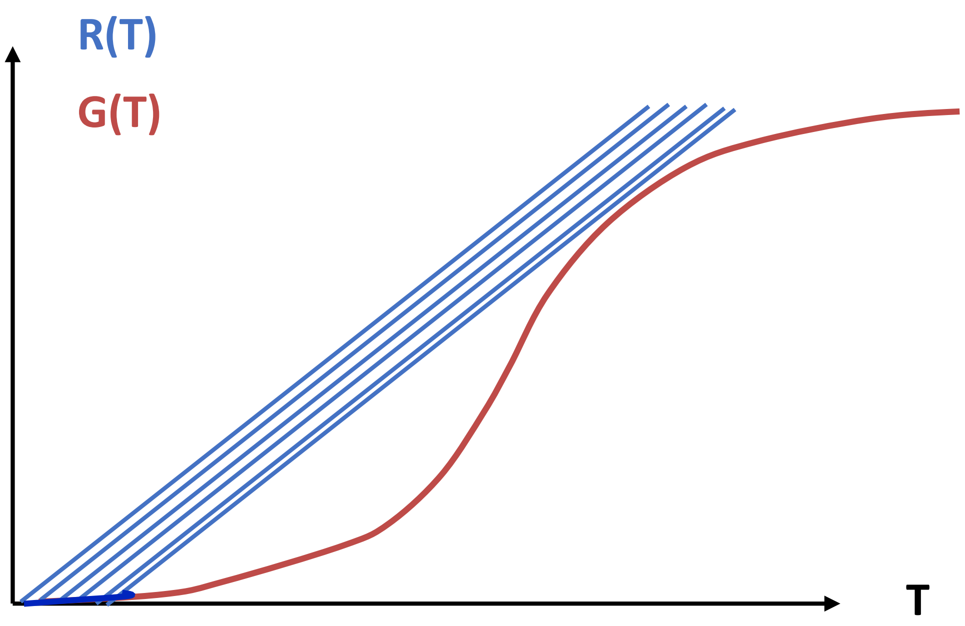

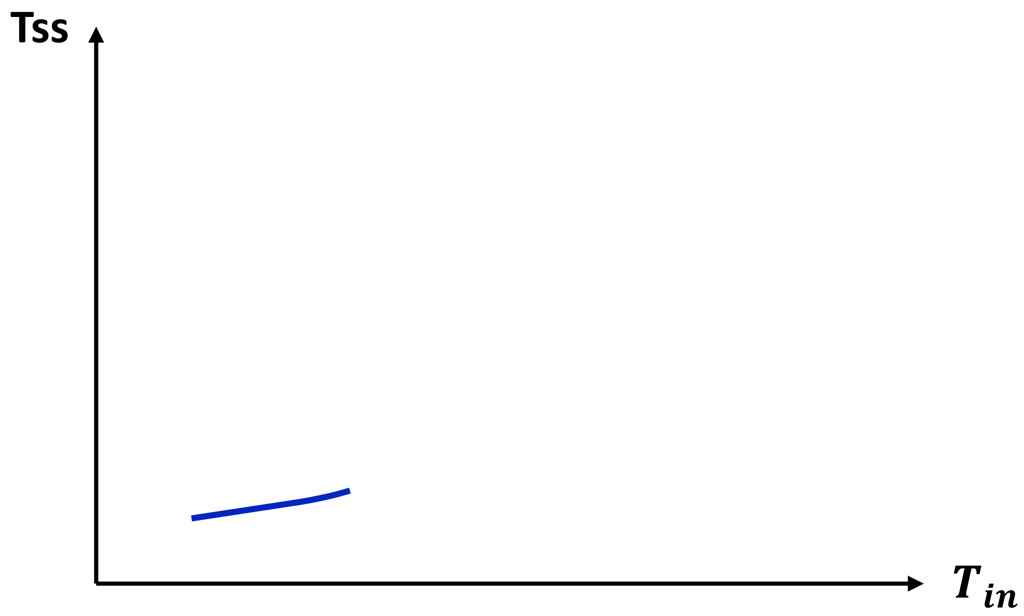

Low temperature steady state solution on the low branch: consider different T in

Consider all the T values of the steady states of the different inlet temperature: obtain the lower branch

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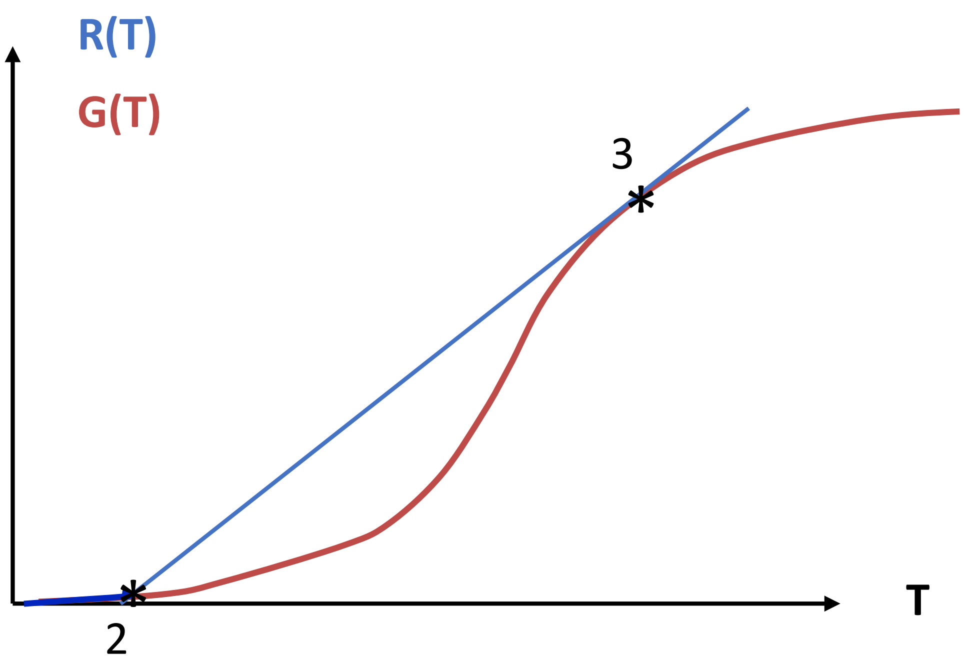

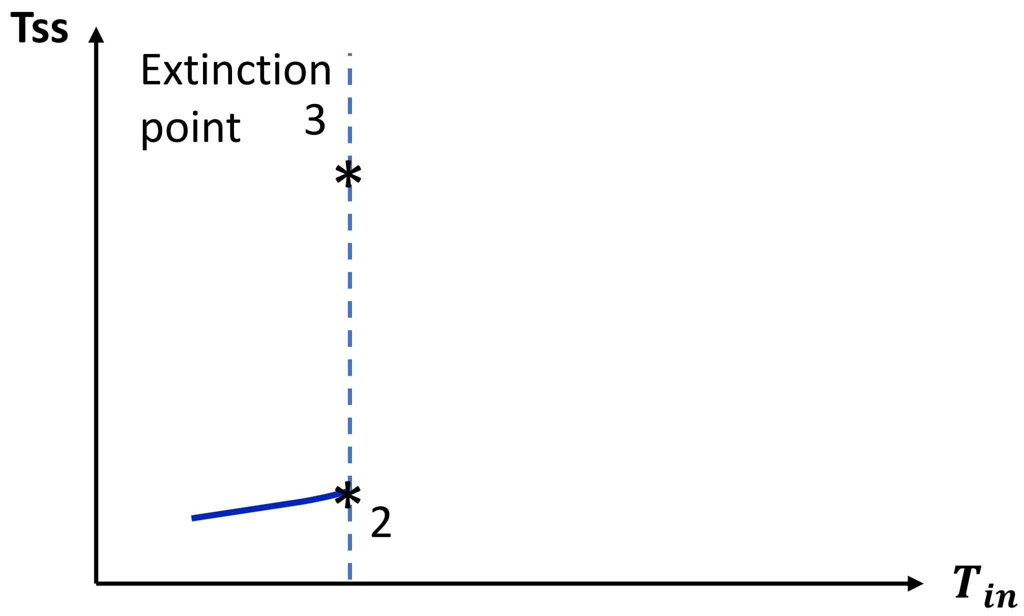

The curve R(T) is tangent to G(T):
2 steady state solutions

The same inlet value corresponds to 2 different steady state temperatures

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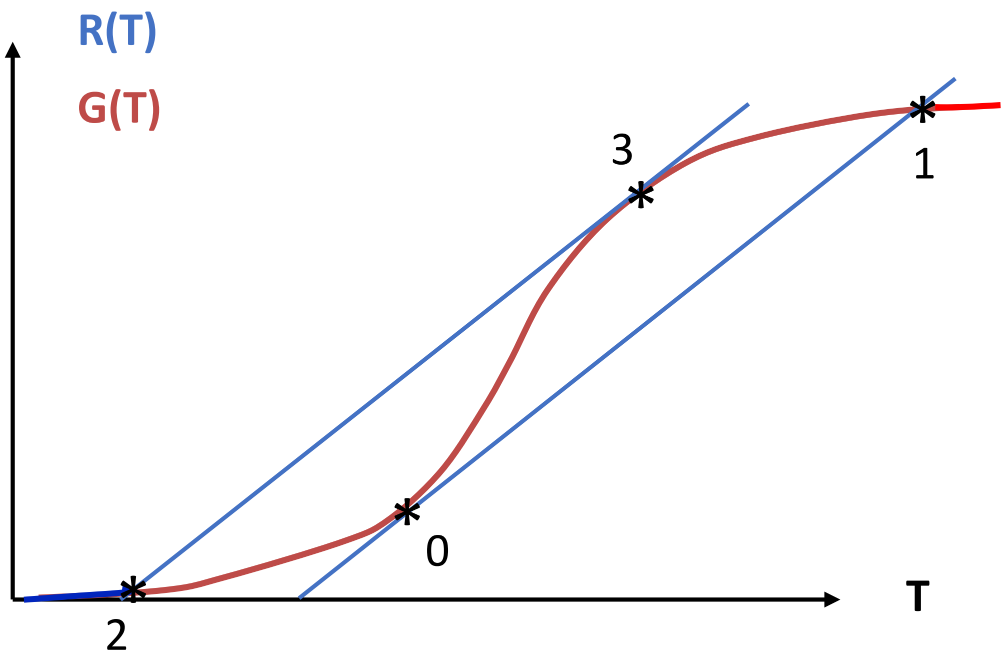

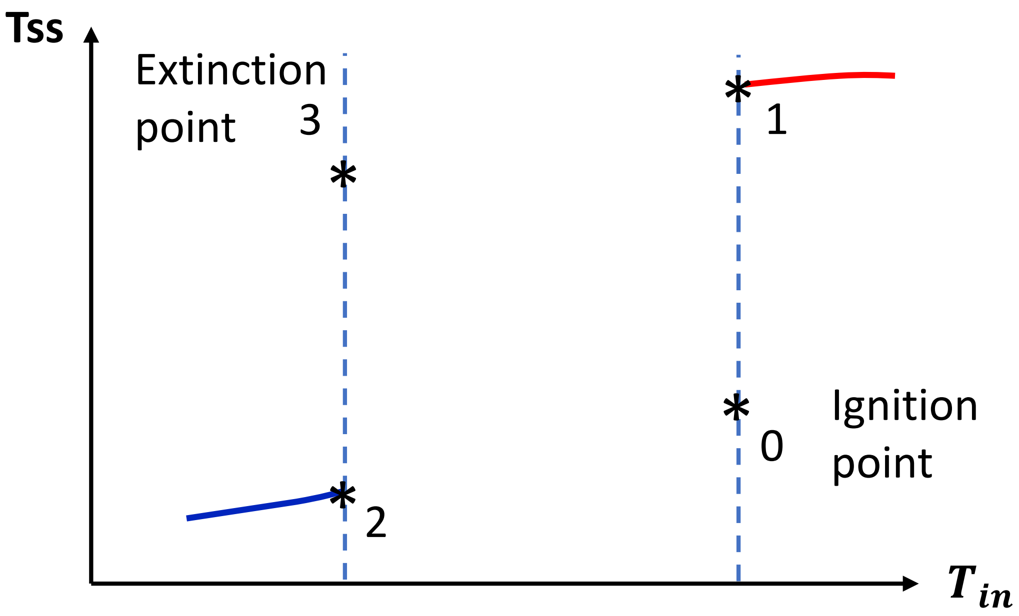

Same way of reasoning from very high inlet T to smaller values

The same inlet value corresponds to 2 different steady state temperatures

MULTI STEADY STATE CSTR – STATIC STABILITY ANALYSIS

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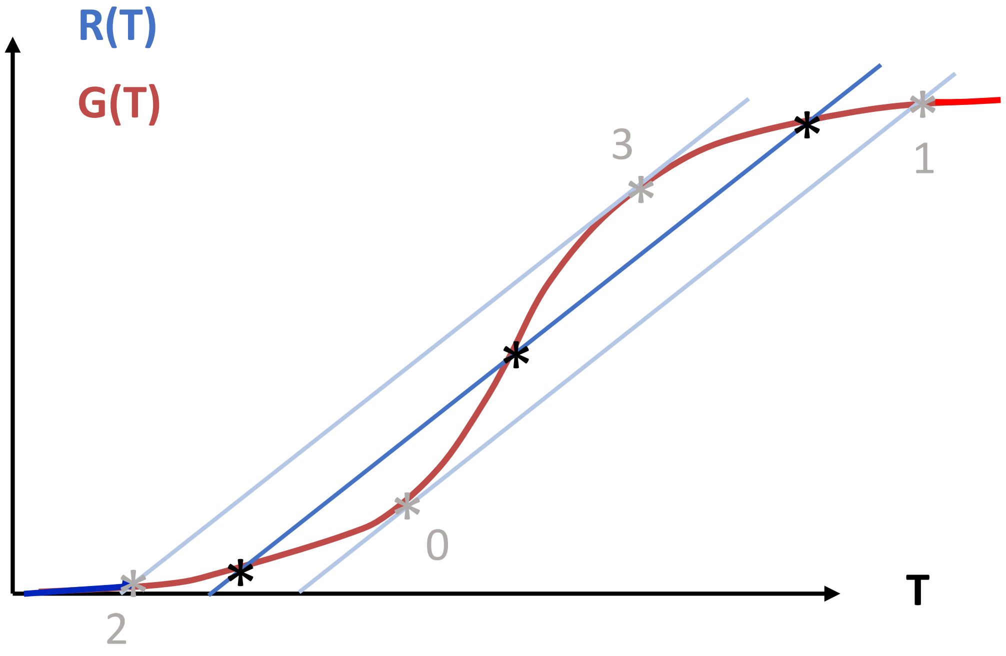

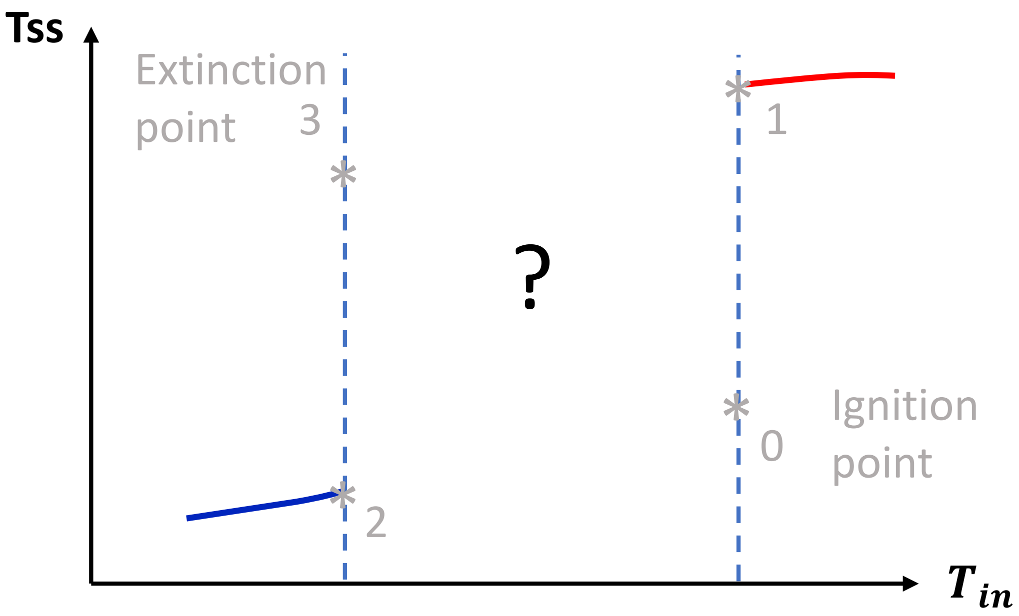

What happens in between?
Multiple steady state –>
You need to know if they are stable or not

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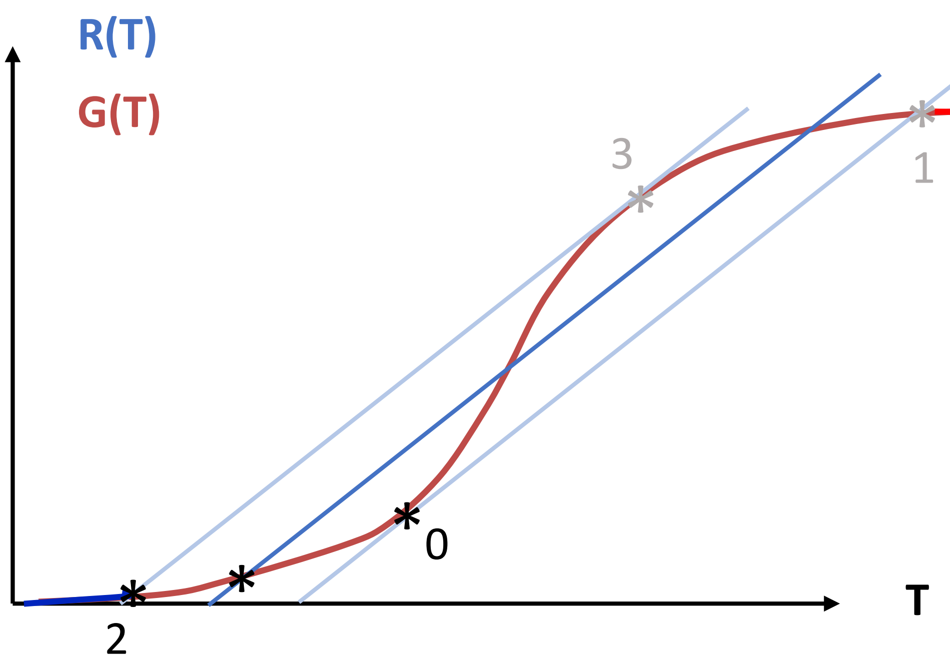

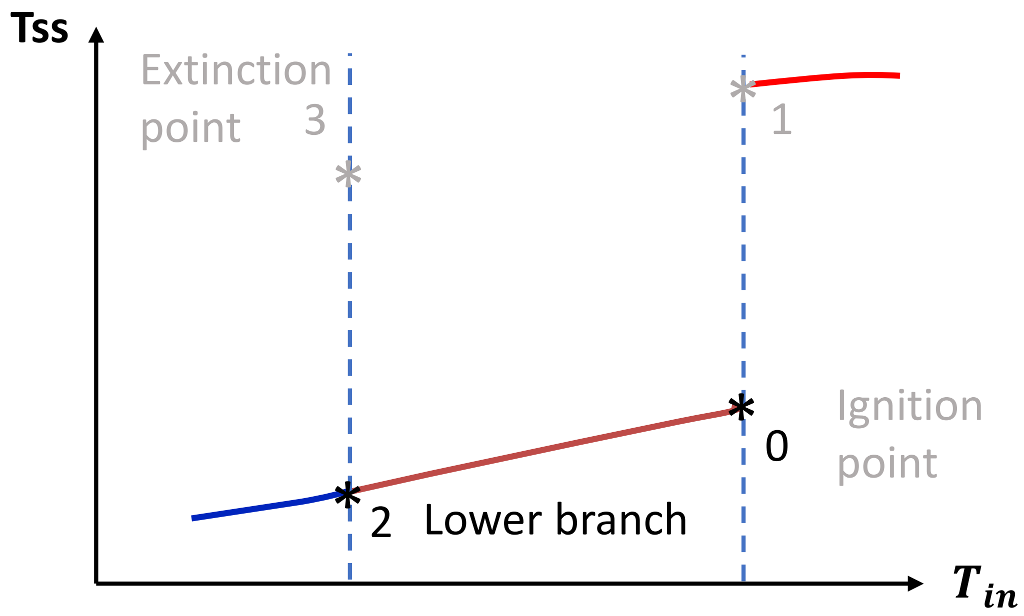

From 2 to 0:

$$\frac{dR}{dT} > \frac{dG}{dT}$$

In case of both negative and positive temperature perturbation, you go back to the initial state * → STABLE

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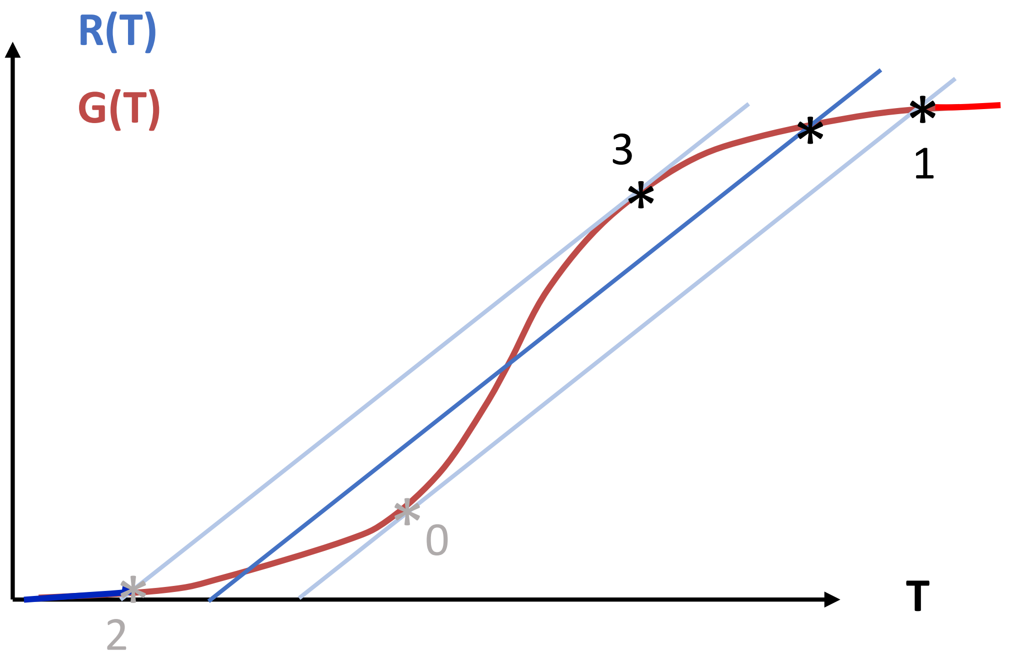

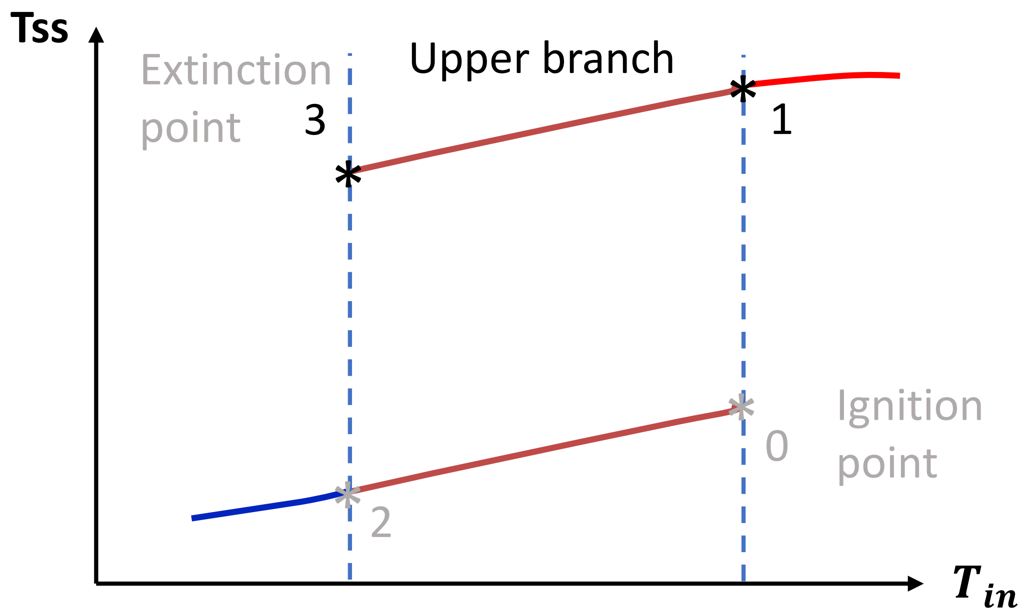

From 3 to 1:

$$\frac{dR}{dT} > \frac{dG}{dT}$$

In case of both negative and positive temperature perturbation, you go back to the initial state * → STABLE

Basic case of single irreversible reaction

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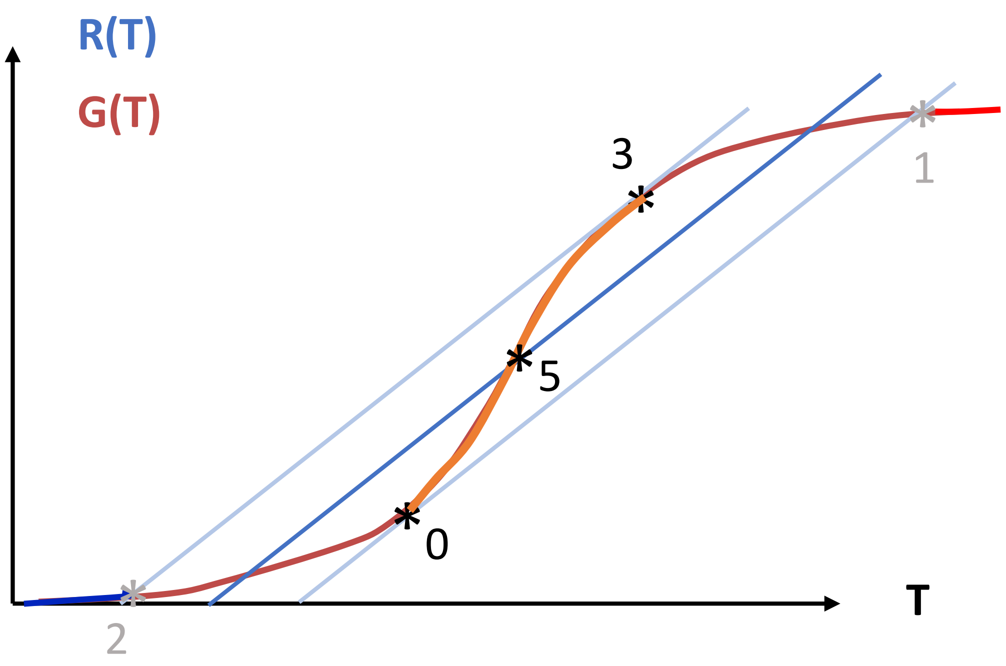

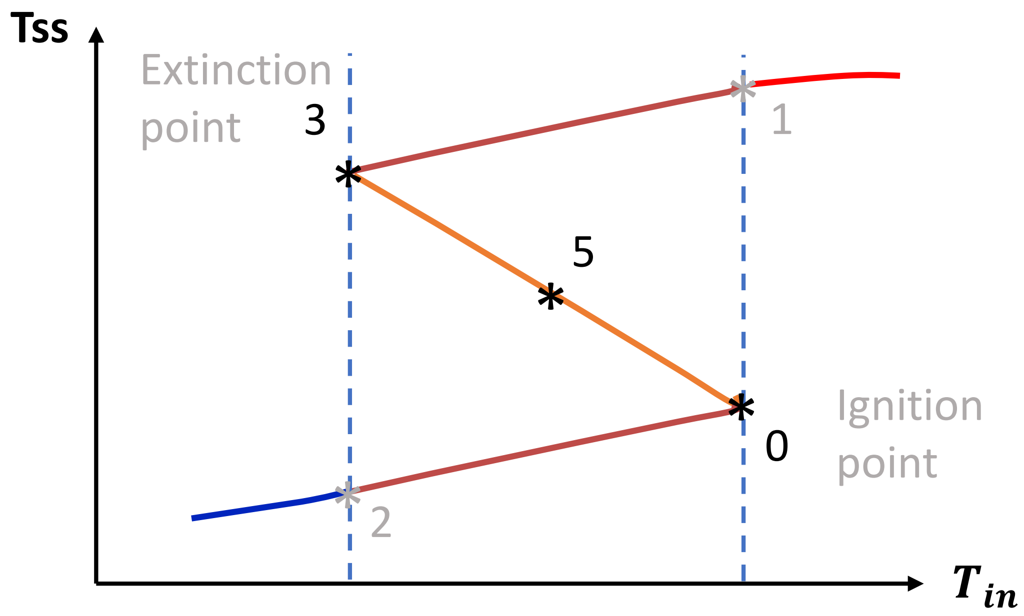

From 0 to 3:

$$\frac{dR}{dT} < \frac{dG}{dT}$$

The heat removal cannot compensate for the heat generation in case of both negative and positive T perturbaton → UNSTABLE

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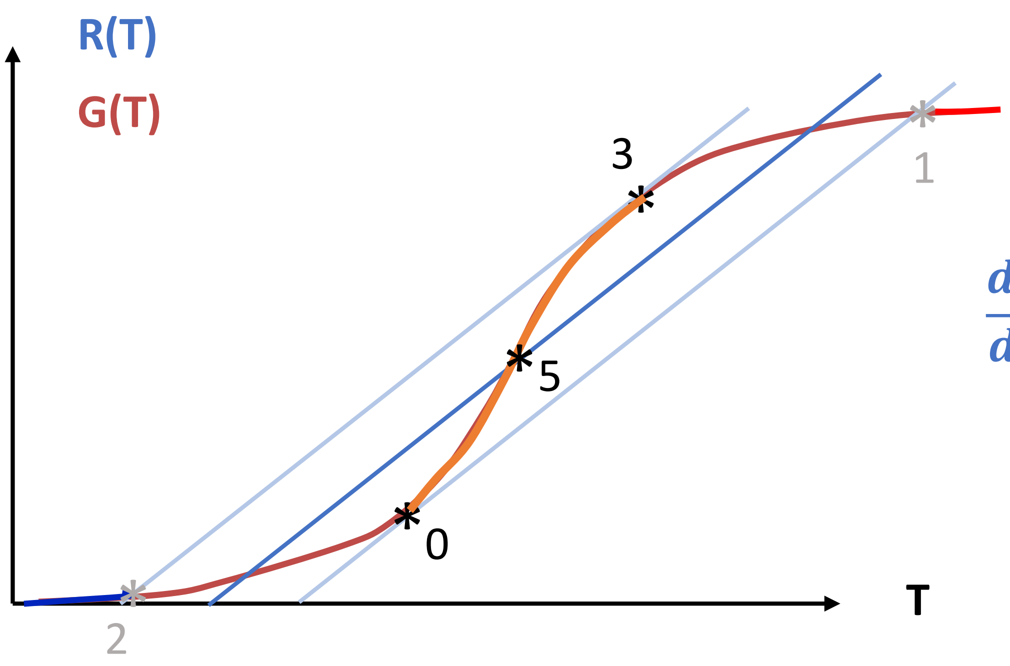
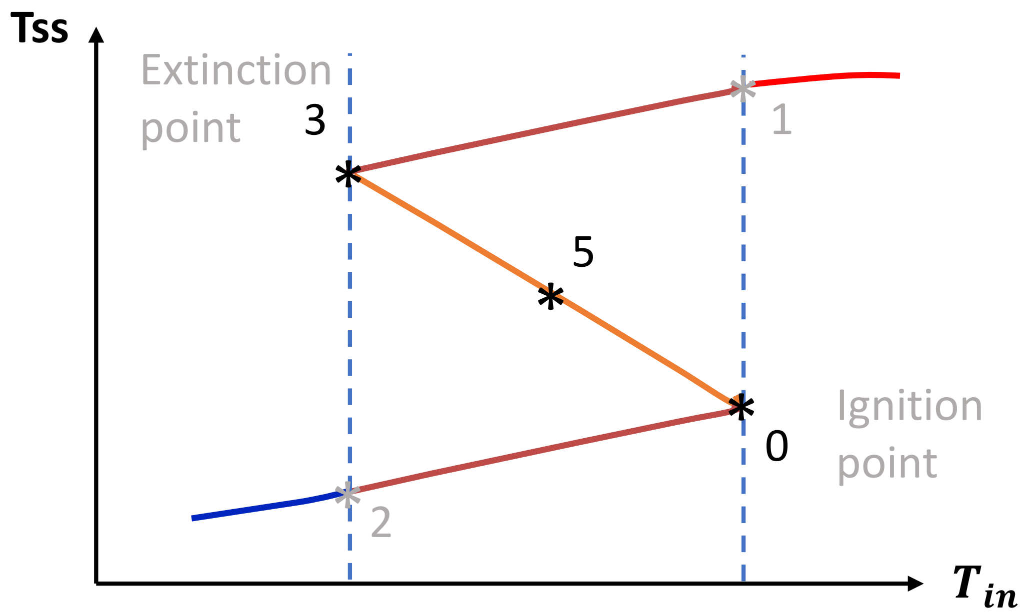


$$\frac{dR}{dT} < \frac{dG}{dT}$$



Note that: if we have a SS between 3 and 0, the SS temperature DECREASES with increasing inlet temperature

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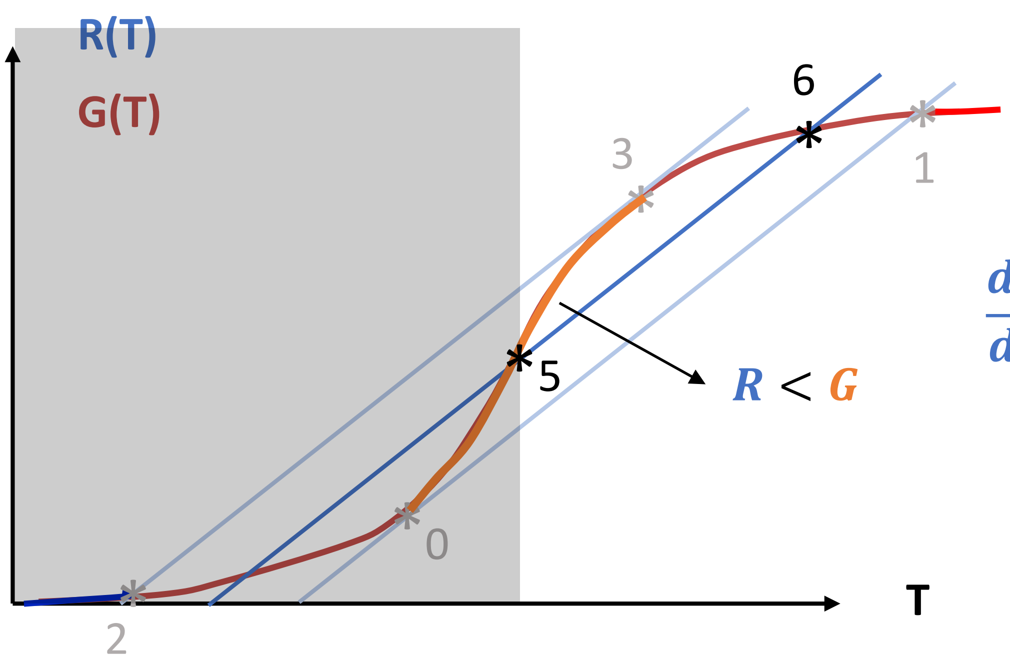

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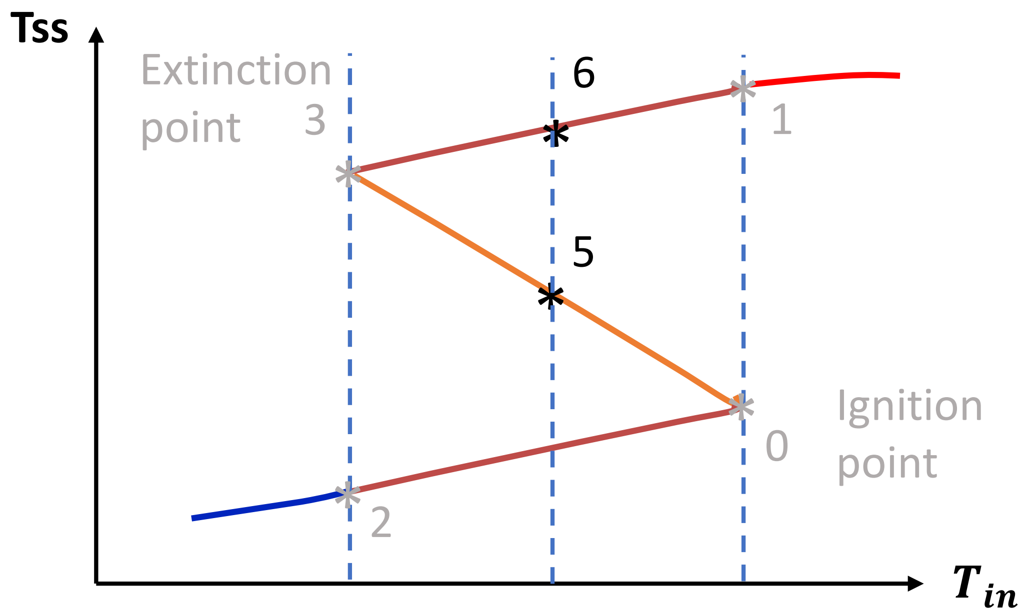

If we are at point *5:

dT > 0 positive perturbation:
The heat generated is higher than the heat removed and increases faster → go to SS *6 (upper branch)

Basic case of single irreversible reaction

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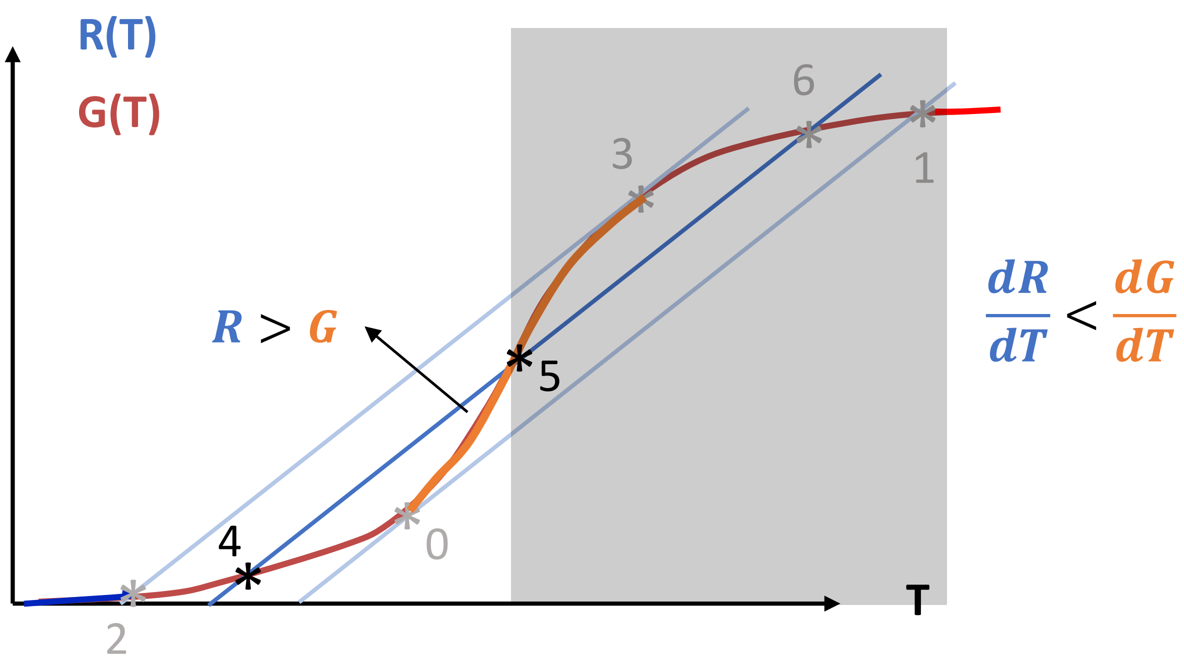

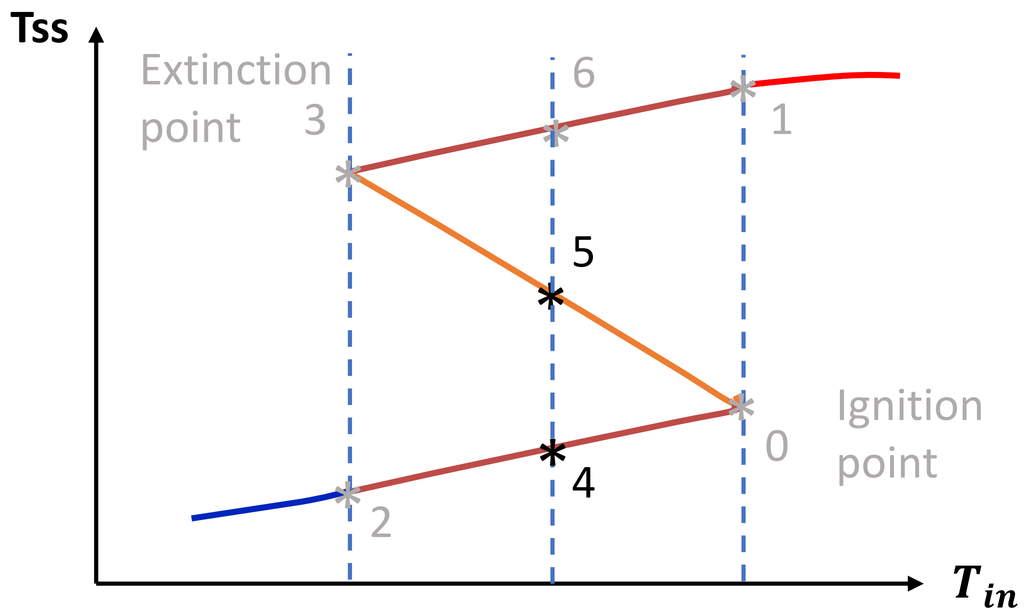

If we are at point *5:

dT < 0 positive perturbation:
The heat generated is smaller than the heat removed and increases faster → go to SS *4 (lower branch)

Basic case of single irreversible reaction

What happens if you vary T in (and therefore T*) ? → $T^* = \dfrac{\kappa T_{ext}^{in} + T_{in}}{\kappa + 1}$