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Green metrics calculations

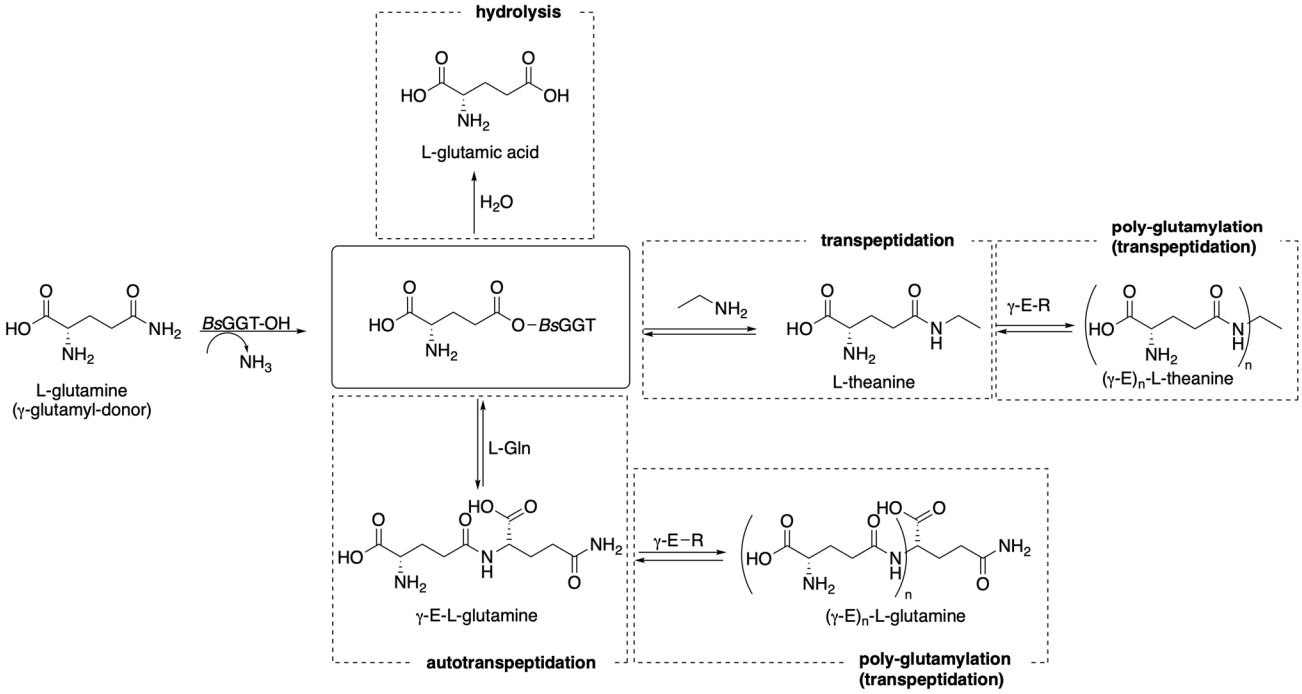

Figure S1. Reactions catalyzed by γ-glutamyl transferase from *Bacillus subtilis* (*Bs*GGT). γ-E-R= γ-glutamyl-compounds formed during the reaction.

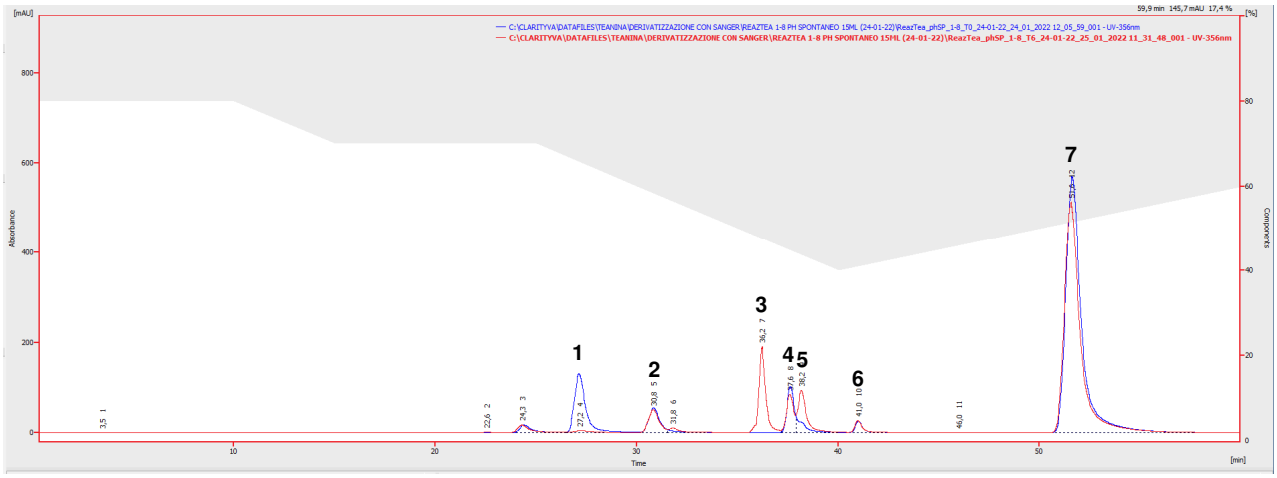

Figure S2. HPLC chromatogram of the enzymatic synthesis of L-Th at pH 11.6: t0 (blue line) and 6 h endpoint (red line). 1= L-Gln; 2 =L-Ser (internal standard); 3= L-Th; 4= Sanger's reagent; 5= ammonia; 6= derivatization artifact; 7= ethylamine.

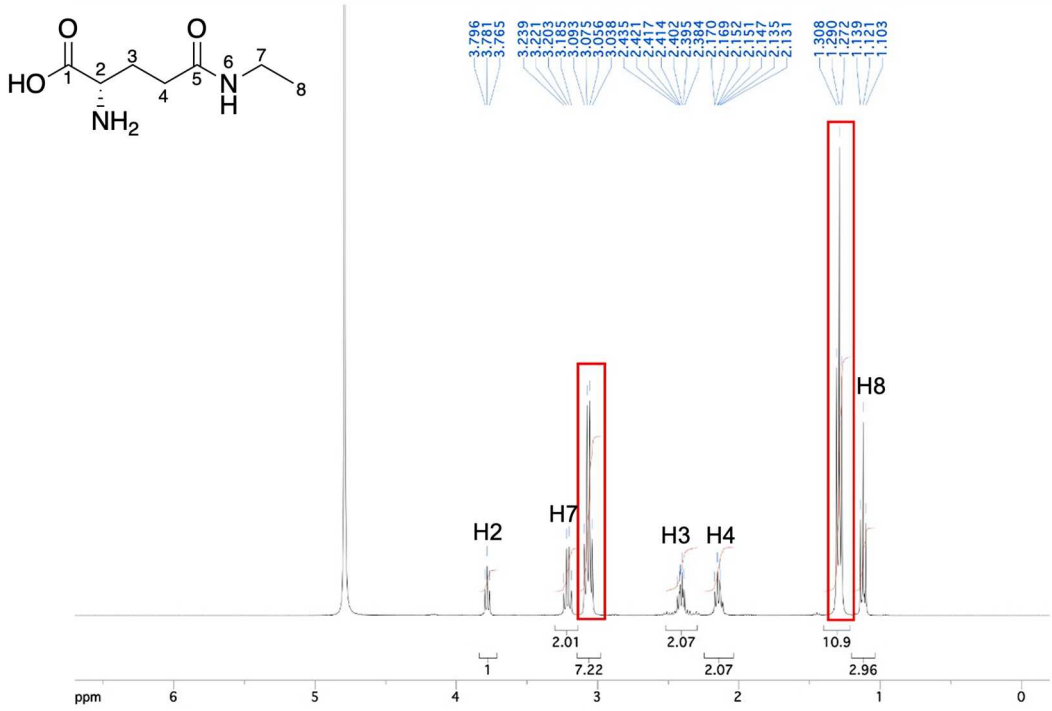

Figure S3. ^{1}H NMR spectrum of L-Th (D_2O) synthesized at pH 10.0. Ethyl signals from ethyl ammonium chloride are highlighted in red.

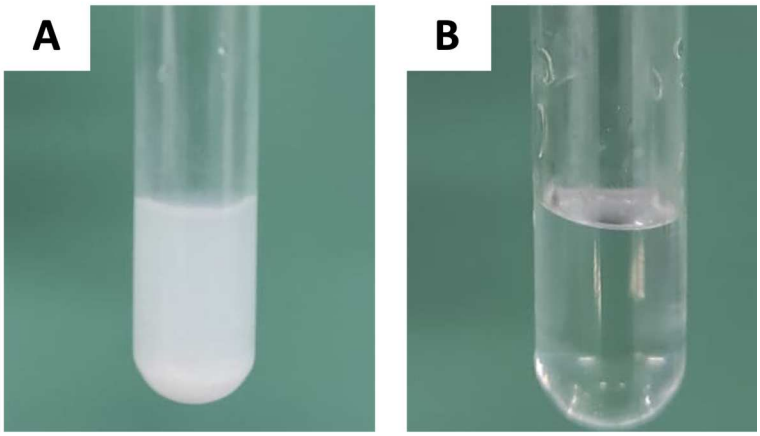

Figure S4. Silver nitrate precipitation test on L-Th synthesized at pH 10 (**A**) and at pH 11.6 (**B**).

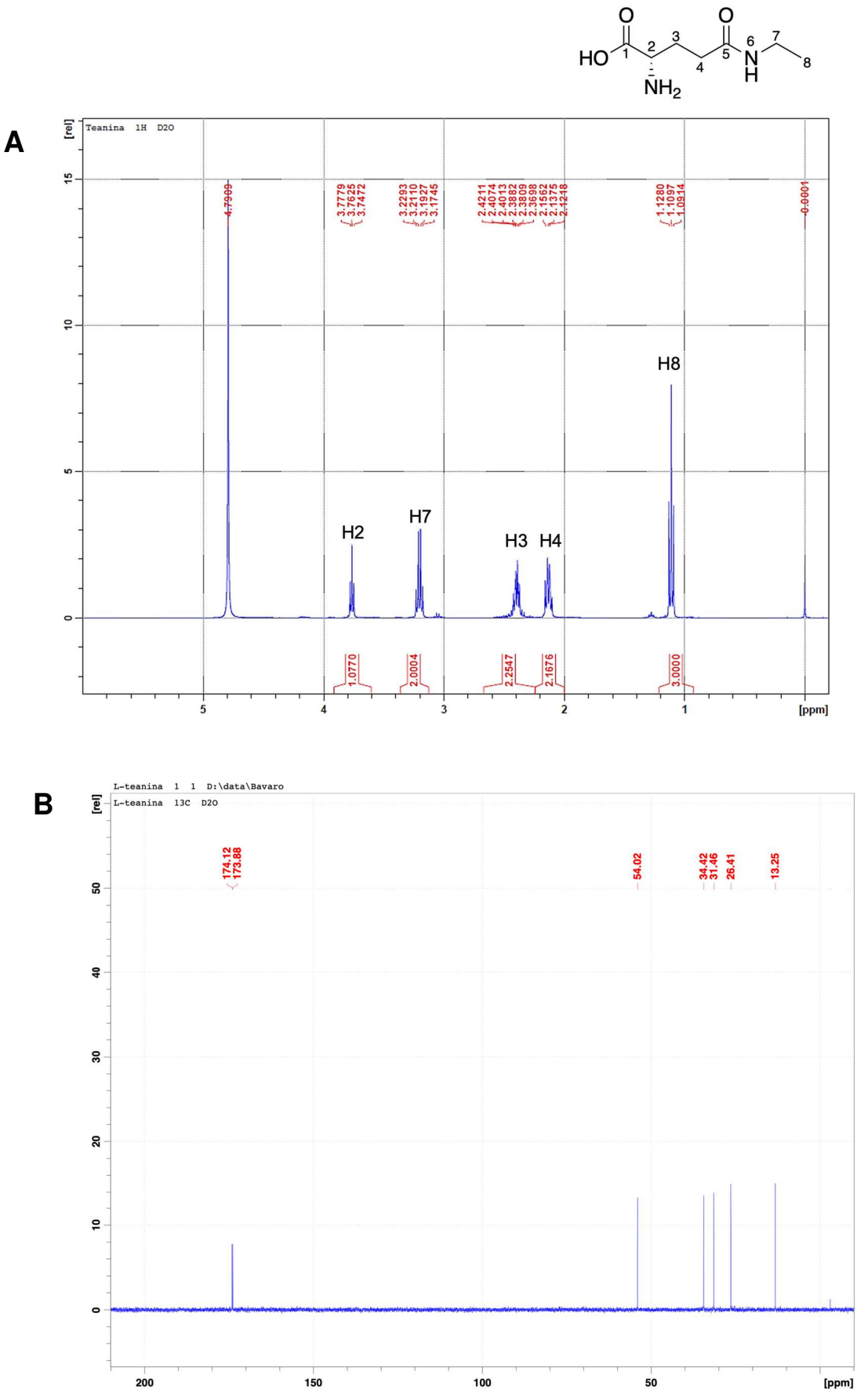

Figure S5. ^{1}H NMR (**A**) and ^{13}C NMR (**B**) spectra of L-Th (D_2O) synthesized at pH 11.6.

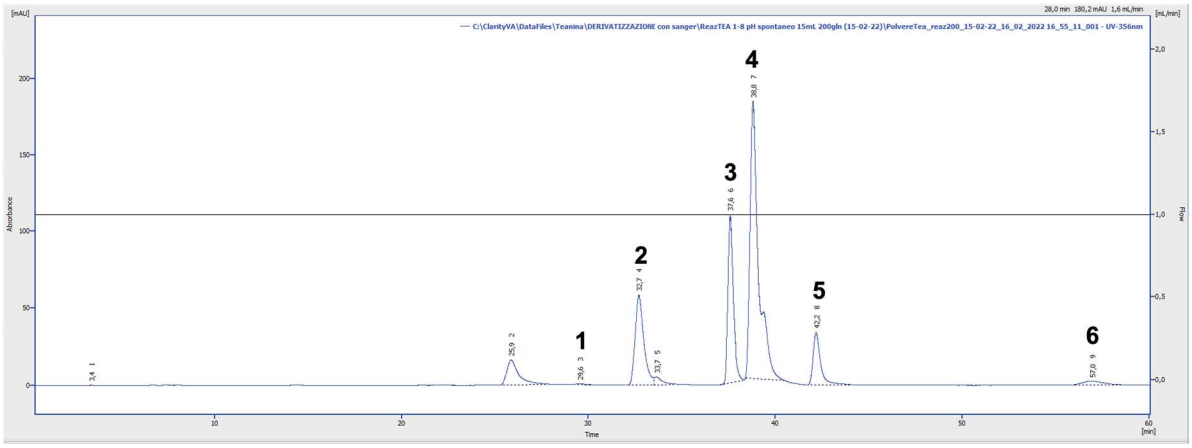

Figure S6. HPLC purity (%) determination of L-Th synthesized at pH 11.6. 1= L-Gln; 2 =L-Ser (internal standard); 3= L-Th; 4= Sanger's reagent; 5= derivatization artifact; 6= ethylamine.

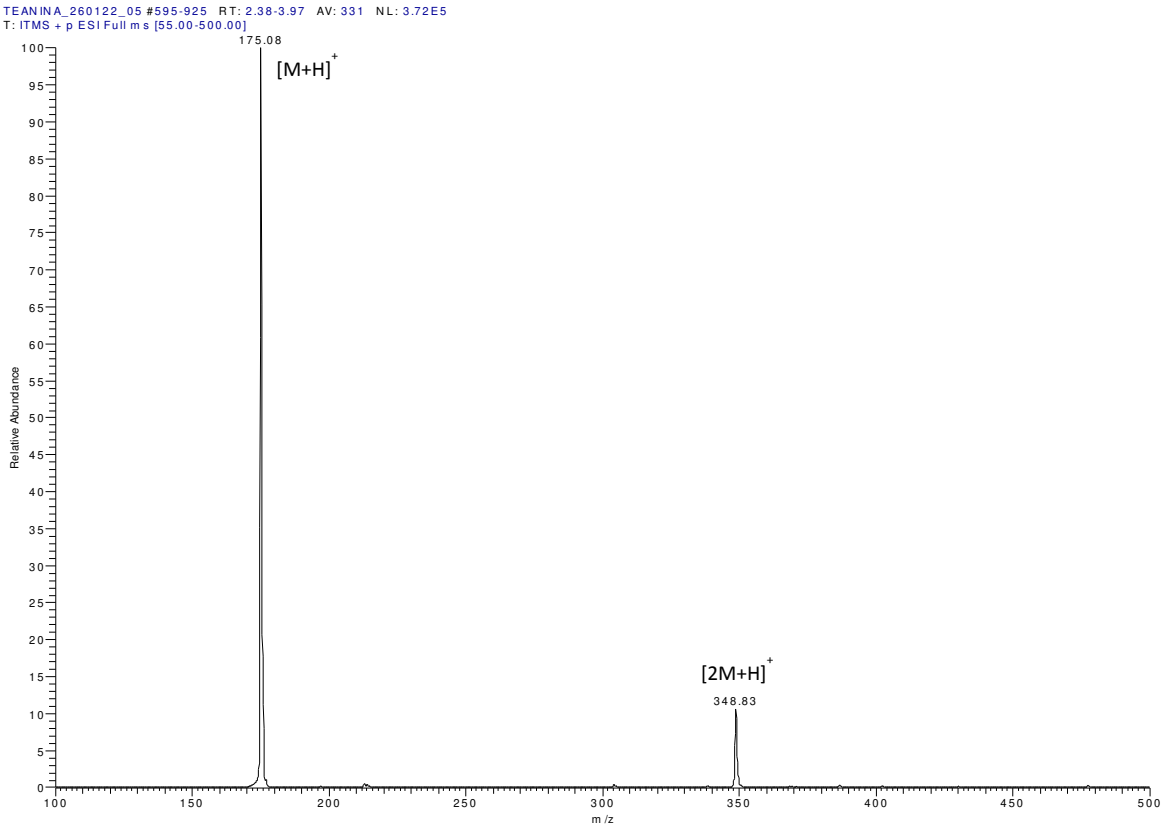

Figure S7. ESI-MS of L-Th synthesized at pH 11.6.

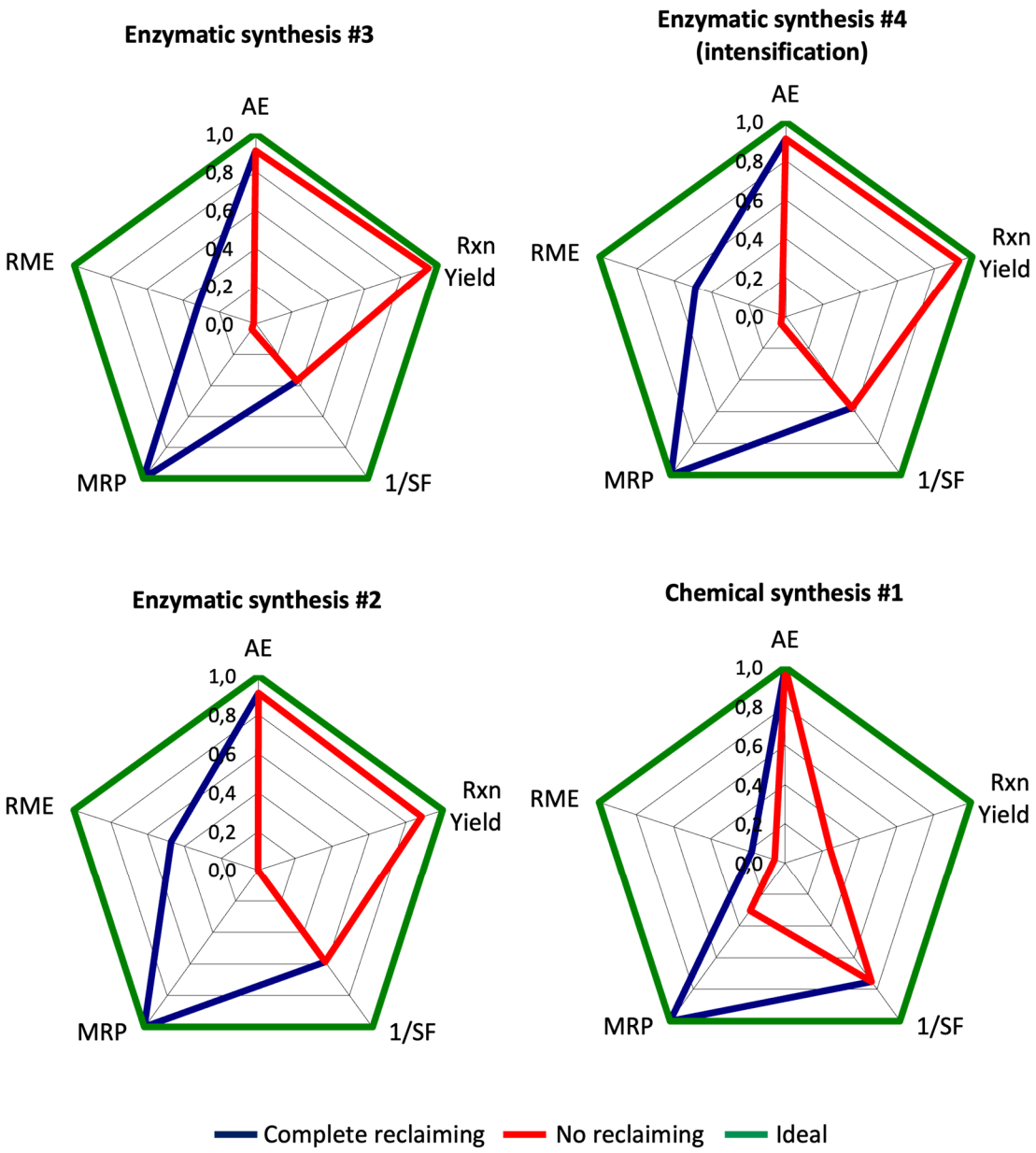

Figure S8. Radial pentagon representation for the syntheses of L-Th discussed in the text (#1-4).

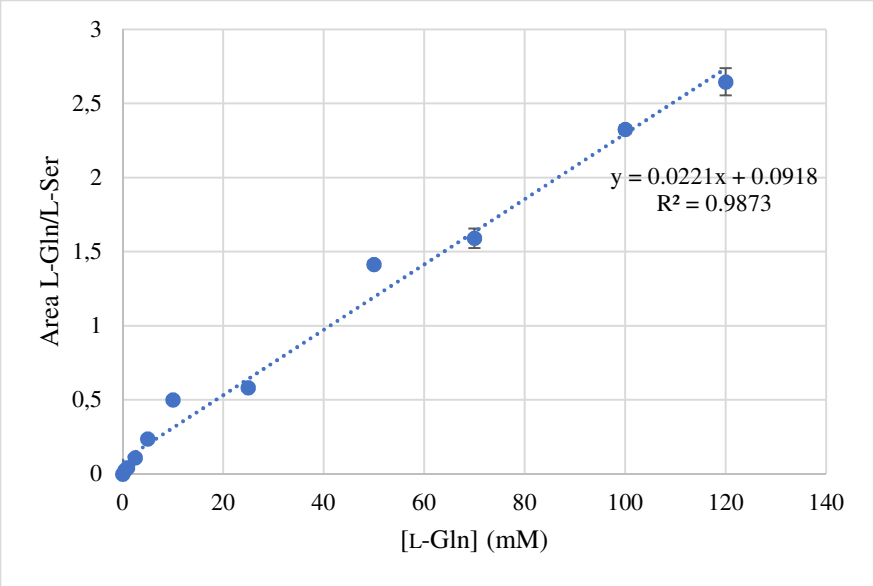

Figure S9. HPLC calibration curve of L-Gln.

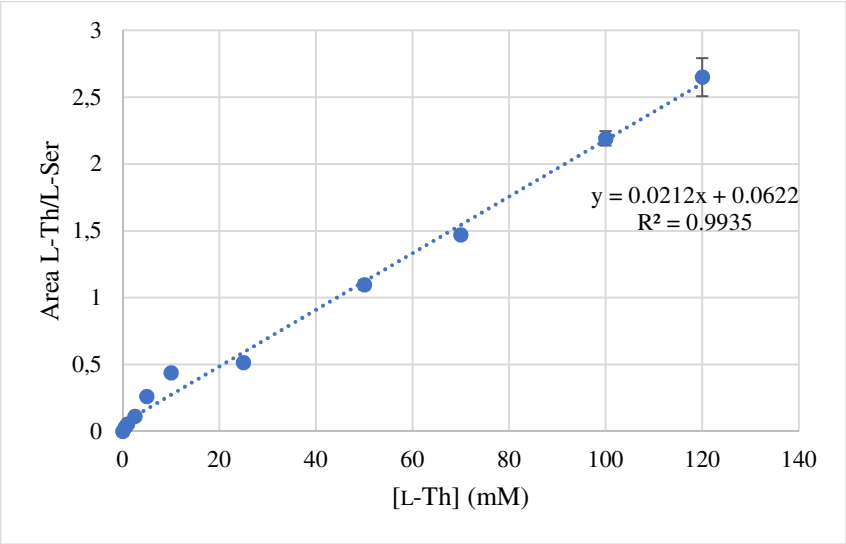

Figure S10. HPLC calibration curve of L-Th.

Table S1. Chemometric parameters for the preparative synthesis of L-Th reported in this work (Synth. #3).

Parameter	Complete Reclaiming	Partial Reclaiming	No Reclaiming	Ideal
AE	0.911	0.911	0.911	1
Rxn Yield	0.950	0.950	0.950	1
1/SF	0.368	0.368	0.368	1
MRP	1	0.036	0.036	1
RME	0.319	0.012	0.012	1

Table S2. Chemometric parameters for the intensified synthesis of L-Th reported in this work (Synth. #4).

Parameter	Complete Reclaiming	Partial Reclaiming	No Reclaiming	Ideal
AE	0.911	0.911	0.911	1
Rxn Yield	0.929	0.929	0.929	1
1/SF	0.575	0.575	0.575	1
MRP	1	0.045	0.045	1
RME	0.487	0.022	0.022	1

Table S3. Chemometric parameters for the enzymatic synthesis by Xu et al.[26] (Synth. #2).

Parameter	Complete Reclaiming	Partial Reclaiming	No Reclaiming	Ideal
AE	0.911	0,.11	0.911	1
Rxn Yield	0.885	0.885	0.885	1
1/SF	0.586	0.586	0.586	1
MRP	1	0.003	0.003	1
RME	0.472	0.001	0.001	1

Table S4. Chemometric parameters for the chemical synthesis by Zhang et al.[16] before recrystallization (Synth. #1).

Parameter	Complete Reclaiming	Partial Reclaiming	No Reclaiming	Ideal
AE	1.000	1.000	1.000	1
Rxn Yield	0.784	0.784	0.784	1
1/SF	0.752	0.752	0.752	1
MRP	1	0.305	0.305	1
RME	0.589	0.180	0.180	1

Table S5. Chemometric parameters for the chemical synthesis by Zhang et al.[16] after recrystallization (Synth. #1).

Parameter	Complete Reclaiming	Partial Reclaiming	No Reclaiming	Ideal
AE	1.000	1.000	1.000	1
Rxn Yield	0.240	0.240	0.240	1
1/SF	0.752	0.752	0.752	1
MRP	1	0.305	0.305	1
RME	0.181	0.055	0.055	1

RME= reaction

AE= atom economy; Rxn yield= reaction yield (between 0 and 1); 1/SF= 1/stoichiometric factor (SF= 1 for stoichiometric reactions; SF >1 when excess of reagents is used); MRP= material recovery parameter; mass efficiency.

$$E^{+} = E + \frac{W \times CI}{\text{mass of desired product (kg)}} \qquad \left[\begin{array}{l} W = \text{electrical power used (kWh)} \\ CI = \text{carbon intensity } \frac{\text{kg } (CO_2)}{\text{kWh}} \end{array}\right]$$

$$\textbf{(C)limate Factor} = \frac{\text{total mass of } CO_2 \text{ emitted}}{\text{mass of product formed}} \quad \textbf{(kg } CO_2\textbf{/ kg product)}$$

Case 1. This paper (Synth. #3)
Reaction is carried out by stirring at **25 °C** (which can be considered room temperature) for **6 h**
The estimated consumption for stirring at r.t. is 10 W (from different commercial stirrers)
Then:
10 W x 6 h = 60 W·h = 0.060 KW·h
According to OECD average (2015) the equivalency is 404 g CO_2/KW·h.[60]
Therefore 0.060 KW·h x 404 g CO_2/KW·h = **24.24 g CO_2**
C-Factor = 24.24 g CO_2 / (0.248 g) =97.742 ≈ **98**

Case 2. This paper (Synth. #4)
Reaction is carried out by stirring at **25 °C** (which can be considered room temperature) for **6 h**
The estimated consumption for stirring at r.t. is 10 W (from different commercial stirrers)
Then:
10 W x 6 h = 60 W·h = 0.060 KW·h
According to OECD average (2015) the equivalency is 404 g CO_2/KW·h.[60]
Therefore 0.060 KW·h x 404 g CO_2/KW·h = **24.24 g CO_2**
C-Factor = 24.24 g CO_2 / (0.485 g) =49.979 ≈ **50**

Case 3. Enzymatic synthesis (Synth. #2)[26]
Reaction is carried out by ultrasound power **100 Wat** for **16 h**
Then:
100 W x 16 h = 1600 W·h = 1.6 KW·h
According to OECD average (2015) the equivalency is 404 g CO_2/KW·h.[60]
Therefore 1.6 KW·h x 404 g CO_2/KW·h = **646.4 g CO_2**
C-Factor = 646.4 g CO_2 / (18.61 g) =34.734 ≈ **35**

Case 4. Chemical synthesis (Synth. #1)[16]
a) Before recrystallization
Reaction is carried out by heating at **35 °C** for **10 days**
The estimated consumption for heaters is 300 W (from different commercial stirrers)
Then:
300 W x 240 h = 72000 W·h = 72 KW·h
According to OECD average (2015) the equivalency is 404 g CO_2/KW·h.[60]
Therefore 72 KW·h x 404 g CO_2/KW·h = 29088 g CO_2 ≈ **29 kg CO_2**
C-Factor = 29088 g CO_2 / (37.01 g) =785.94 ≈ **786**

b) After recrystallization
For recrystallization: the residual mixture was dissolved in warm (**45 °C**) water and allowed to crystallize in 84% ethanol at **4 °C** for **5-7 days**

- No indication of warming time. Assumption: 1 h
- The estimated consumption for heaters is 300 W (from different commercial stirrers)
- Then:
- 300 W x 1 h = 300 W·h = 0.3 KW·h
- According to OECD average (2015) the equivalency is 404 g CO_2/KW·h.[60]
- Therefore 0.3 KW·h x 404 g CO_2/KW·h = **121.2 g CO_2**

- Cooling at 4 °C, time 6 days (between 5 and 7) = 144 h
- The estimated consumption for heaters/coolers is 300 W (from different commercial stirrers)
- Then:
- 300 W x 144 h = 43200 W·h = 43.2 KW·h
- According to OECD average (2015) the equivalency is 404 g CO_2/KW·h.[60]
- Therefore 43.2 KW·h x 404 g CO_2/KW·h = 17452.8 g CO_2 = **17.45 kg CO_2**

OVERALL upon RECRYSTALLIZATION: 17.57 kg CO_2 (0.121 kg +17.45 kg)

TOTAL PROCESS (Reaction plus recrystallization) = 29 kg + 17.57 kg **≈ 46.6 kg CO_2**
C-Factor = 46600 g CO_2 / (37.01 g) =1256.1 **≈ 1256**