

# LITHIUM HYDRAZONYL ANTHRAQUINOID CATALYST FOR THE SELECTIVE SYNTHESIS OF CYCLIC BIODEGRADABLE PLA

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## BIODEGRADABLE PLASTICS FROM NATURAL RESOURCES: PLA

Poly lactide (PLA) is an environmentally friendly alternative to petroleum-based polymers as lactide (monomer) can be obtained from natural resources. This biocompatible polyester has found a wide range of applications in medical implants, drug delivery systems, packaging, and microelectronics. Cyclic aliphatic polyesters, and in particular cyclic poly lactide (cPLA), have attracted increasing interest over the last years due to their unique physical properties, such as higher glass transition temperatures (T<sub>g</sub>), smaller hydrodynamic volumes, and lower intrinsic viscosities than their linear counterparts.

## THE RING-OPENING POLYMERIZATION (ROP) OF CYCLIC LACTIDE

PLA is generally synthesized via metal-mediated ring-opening polymerization (ROP) of lactide via the coordination-insertion mechanism. A wide range of metals are well-known to afford highly active catalytic systems for this reaction, such as tin, aluminum, zinc, main group metals, group 4 metals, group 3, and lanthanides. In this context, the use of lithium compounds is increasing due to their efficient, stable, cheap, and nontoxic features. We report herein the first lithium anthraquinoid catalyst<sup>2</sup> able to produce poly lactide at room temperature starting from both L- or rac-lactide in the absence of any other initiator.

### SELECTIVITY TOWARDS CYCLIC VS. LINEAR PLA

MALDI-TOF analyses clearly show only one population of cyclic nature for our monomeric LiAQ catalyst, and a mixture of linear and cyclic PLA when alternative dimeric lithium amides are used.

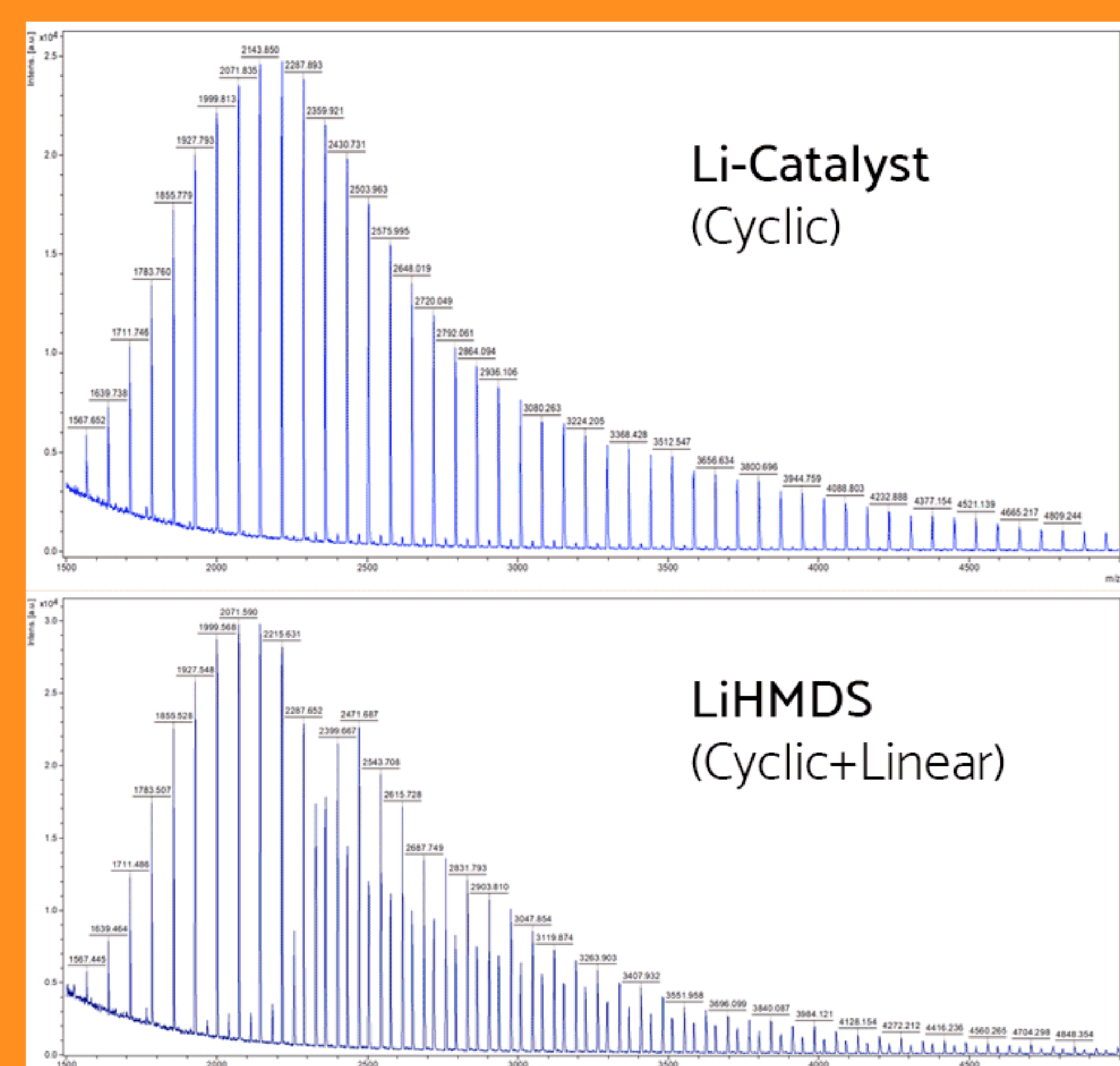
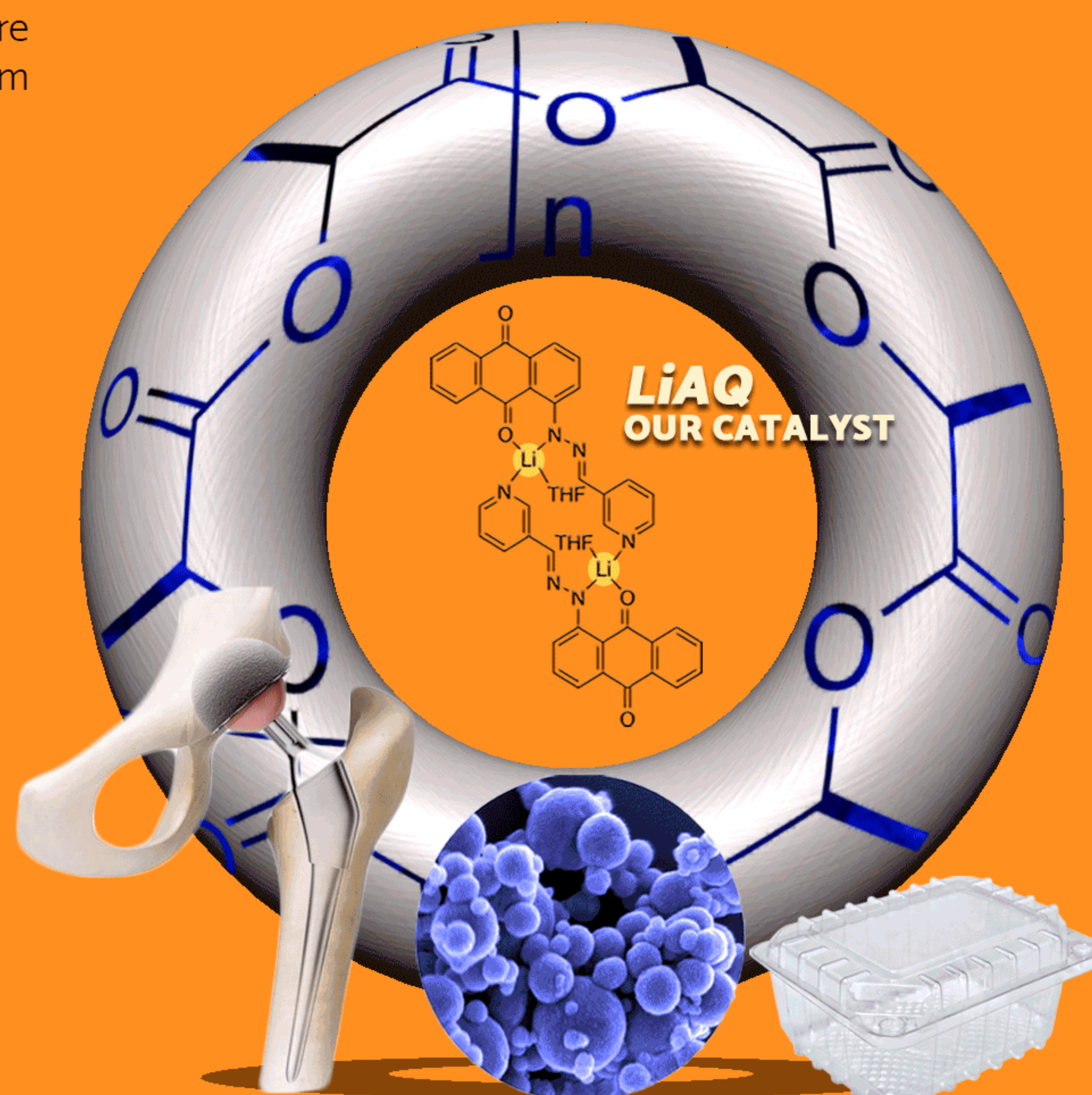


Figure 1. MALDI-TOF spectra of cyclic L-PLA obtained using 6 as catalyst in THF at a 50:1 [LA]<sub>0</sub>/[Cat] ratio.

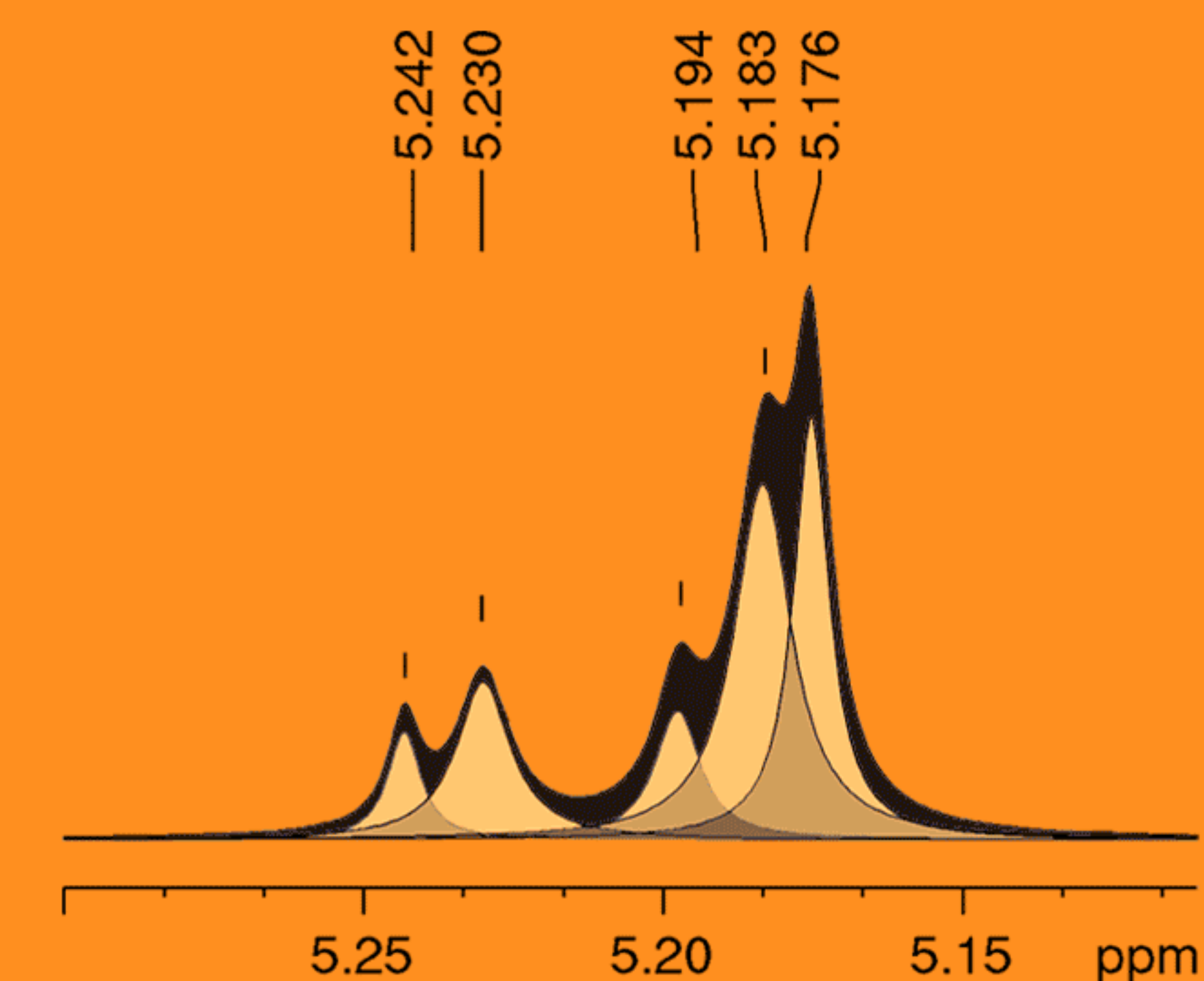
### FAST KINETICS & GOOD YIELDS

Up to 96% for L-Lactide and 75% for rac-Lactide.



### DETERMINATION OF THE STEREOCHEMICAL MICROSTRUCTURE

<sup>1</sup>H homodecoupled and <sup>13</sup>C{<sup>1</sup>H} NMR experiments together with signal deconvolution routines allowed us to elucidate the tacticity of the polymers, and to establish the stereoselectivity of the catalyst.



	m <sup>rr</sup> (si)	m <sup>mm</sup> (si)	m <sup>mr</sup> (ii)	m <sup>mm</sup> (ii)	m <sup>rr</sup> (si)
Tacticity*	ht	sb it	sb it	it	ht
$\delta$ (ppm)	5.23	5.22	5.18	5.17	5.16
L-/LiHMDS	-	-	-	100	-
L-/6	-	-	-	100	-
rac-/LiHMDS	8.9	14.6	11.8	37.8	27.0
rac-/6	6.6	16.0	10.9	37.9	28.6

\*ht = heterotactic; sb it = stereoblock isotactic; it = isotactic

Figure 2. Deconvolution of the homodecoupled <sup>1</sup>H NMR spectrum (500.13 MHz, CDCl<sub>3</sub>) of cyclic rac-PLA obtained with LiAQ at 50:1 [LA]<sub>0</sub>/[Cat] ratio in THF at room temperature. Table shows the relative areas and tacticity.

### MOLECULAR WEIGHT CONTROL

A good polymerization control is demonstrated by the linear relationship between the weight-average molecular weight (M<sub>w</sub>) and low monomero complex ratios ([M]<sub>0</sub>/[LiAQ]).

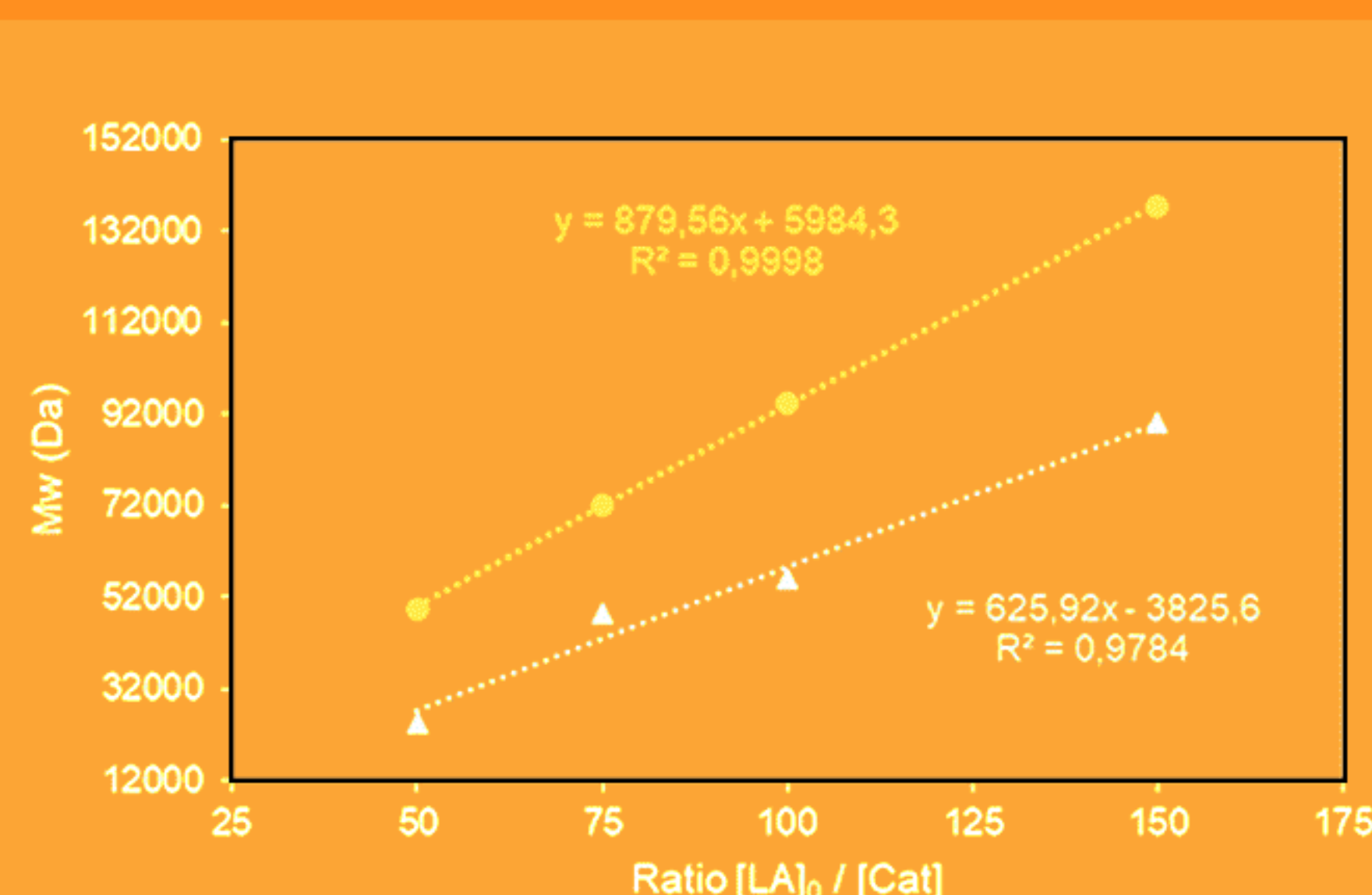


Figure 3. Polymerization of L-LA (circles) and rac-LA (triangles) catalyzed by our catalyst in THF at 25 °C.

### CONCLUSIONS

The ROP of lactide with the lithium anthraquinoid occurs readily in the absence of alcohol initiators, implicating that the catalyst can function as nucleophile for the ring-opening of L- and rac-lactides. DFT studies point to Li aggregation as an important factor controlling selectivity between linear and cyclic PLAs. Diffusion NMR was employed to calculate molecular weights and PDIs, together with <sup>1</sup>H, <sup>13</sup>C NMR and MALDI-TOF to verify the nature of the cyclic polymers.

### DFT CALCULATIONS: CYCLIC IS FAVOURED

Positive relative Gibbs values indicate that close species are more stable: back-biting to form cyclic polymers is favored. Negative values point to open species, which would either add a new monomer or end the process forming a linear polymer. The ability of ligands to preclude (or drive) lithium aggregation is the main responsible for the selectivity toward cyclic PLAs.

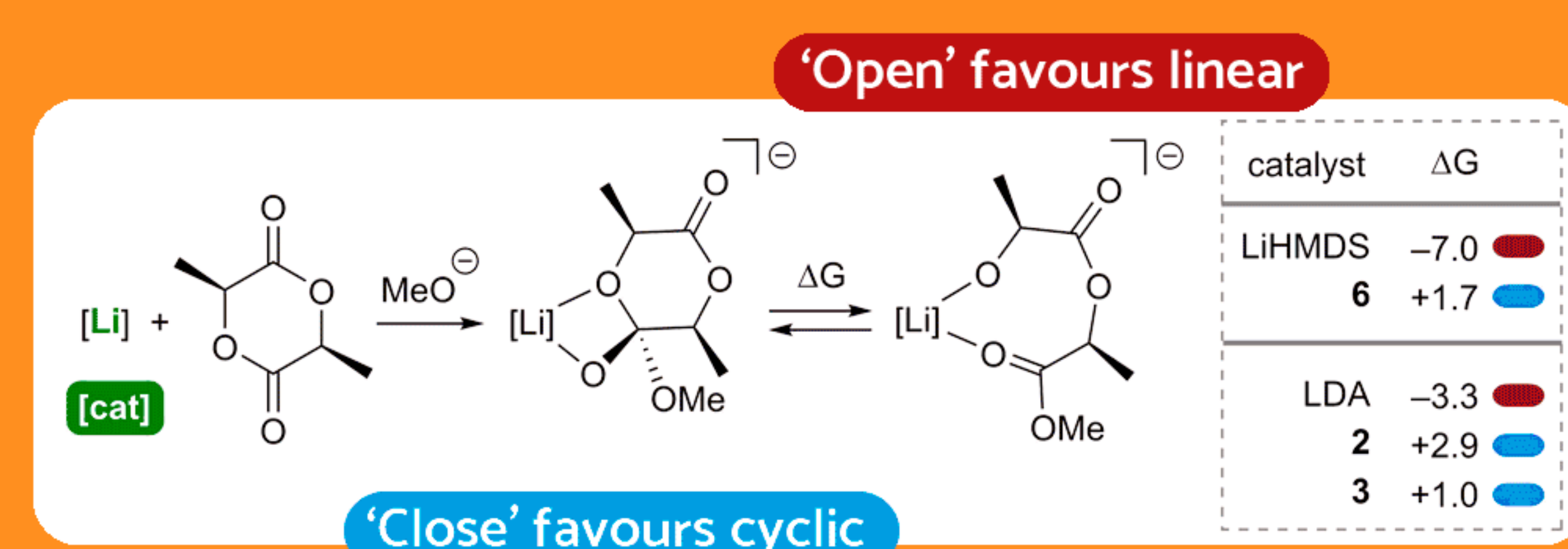


Figure 4. Relative Gibbs energies between close and open configurations for several Li-based catalysts. ΔG in kcal mol<sup>-1</sup>.

[1] Gregory, G. L.; Lopez-Vidal, E. M.; Buchard, A. Polymers from Sugars: Cyclic Monomer Synthesis, Ring-Opening Polymerisation, Material Properties and Applications. Chem. Commun. 2017, 53.

[2] Raya-Barón, A.; Oña-Burgos, P.; Rodríguez-Díéguez, A.; Fernández, I. Organometallics, 2018, 37, 2682-2689

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