Electronic Supplementary Material (ESI) for Organic Chemistry Frontiers.

Supramolecularly Assisted Synthesis of Chiral Tripodal Imidazolium Compounds

Adriana Valls, Belén Altava,* M. Isabel Burguete, Jorge Escorihuela, Vicente Martí-Centelles and Santiago V. Luis*

Departamento de Química Inorgánica y Orgánica, Universitat Jaume I, Av. de Vicent Sos Baynat, s/n 12071, Castellón, Spain, E-mail: luiss@uji.es; Tel: +34 964728239; Fax: +34 964728214

ELECTRONIC SUPPLEMENTARY INFORMATION

Index:

Page

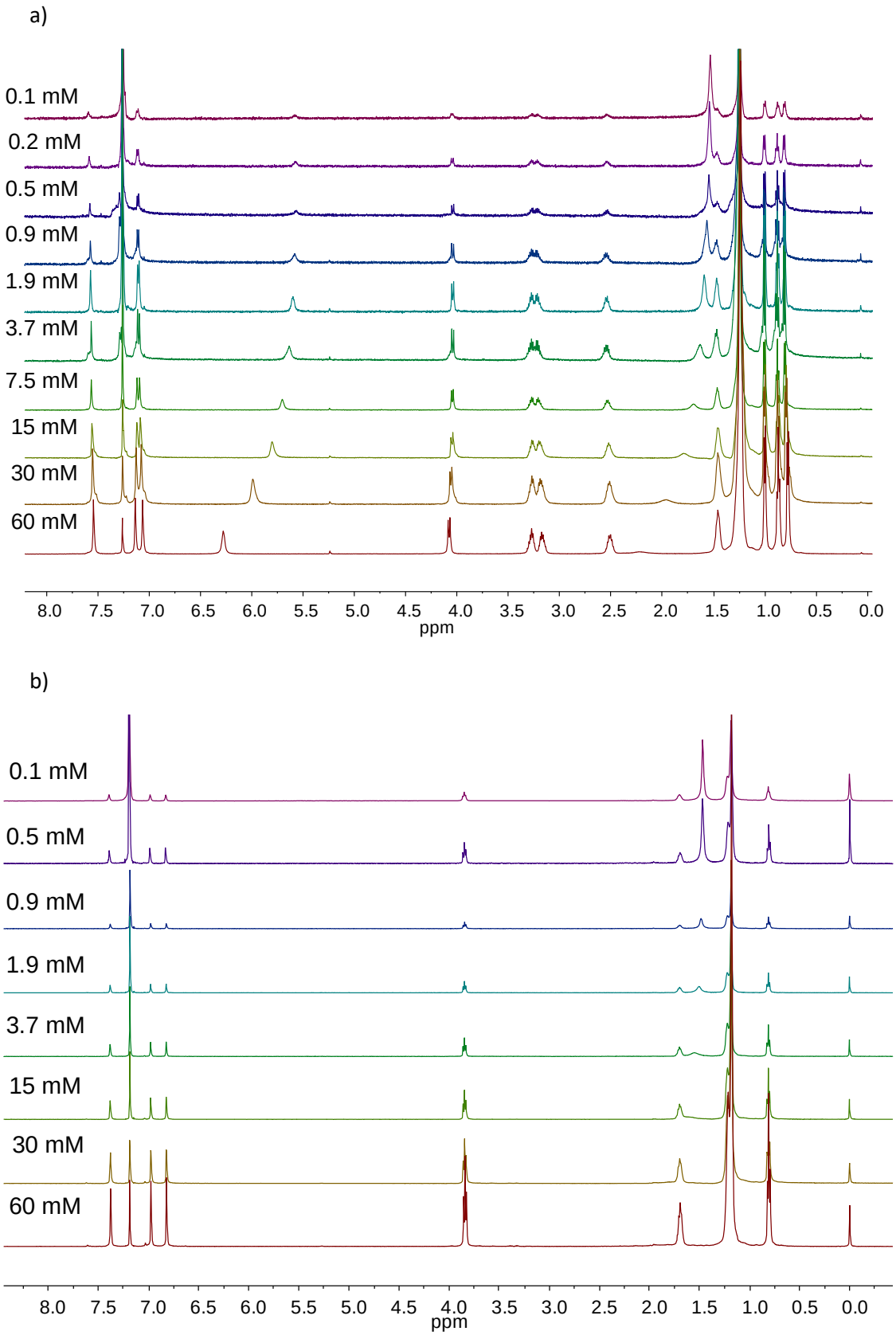


Fig. S1 Aggregation studies in $CDCl_3$; a) Partial ^1H NMR (500 MHz) spectra for imidazole **C** at different concentrations; b) Partial ^1H NMR (500 MHz) spectra for imidazole **A** at different concentrations.

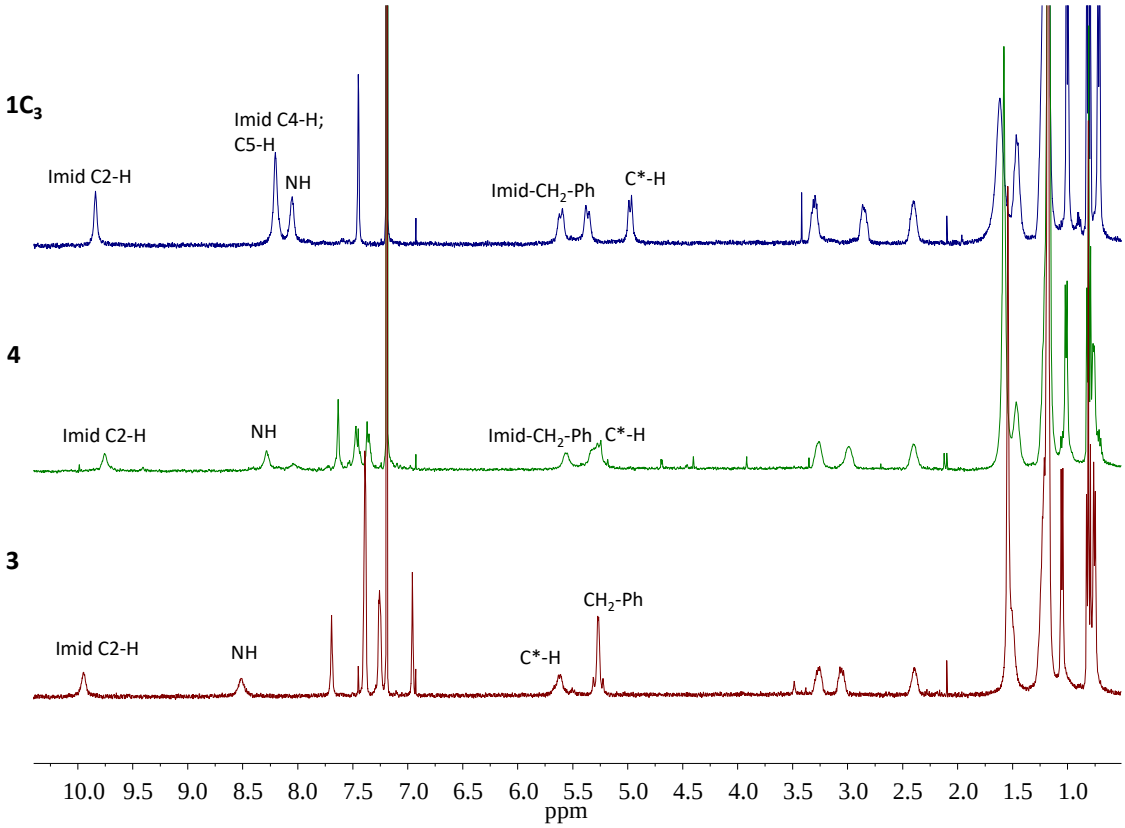


Fig. S2 Partial ^{1}H NMR (500 MHz) spectra of **3**, **4**, and **1C$_3$** (4 mM in $CDCl_3$)

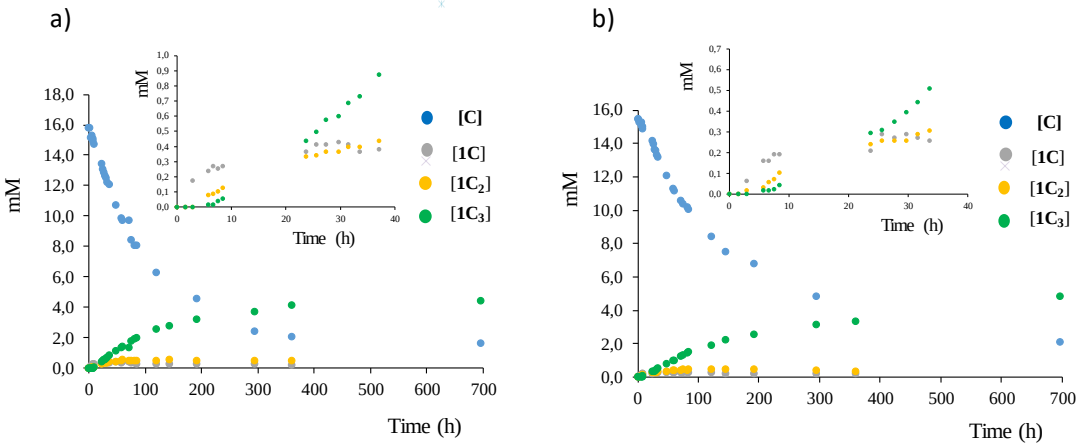


Fig. S3 a) Kinetic profiles (^{1}H NMR, 300 MHz) for the reaction between imidazole **C** (15.8 mM) and **1** (7.5 mM) in $CDCl_3$; b) Kinetic profiles (^{1}H NMR, 300 MHz) for the reaction between imidazole **C** (15.5 mM) and **1** (5.5 mM) in $CDCl_3$. C2-H proton signal followed for **1C**, **1C$_2$** and **1C$_3$** and C2-H and C*H proton signals followed for **C**. The insets show an expansion of the initial period for the reaction.

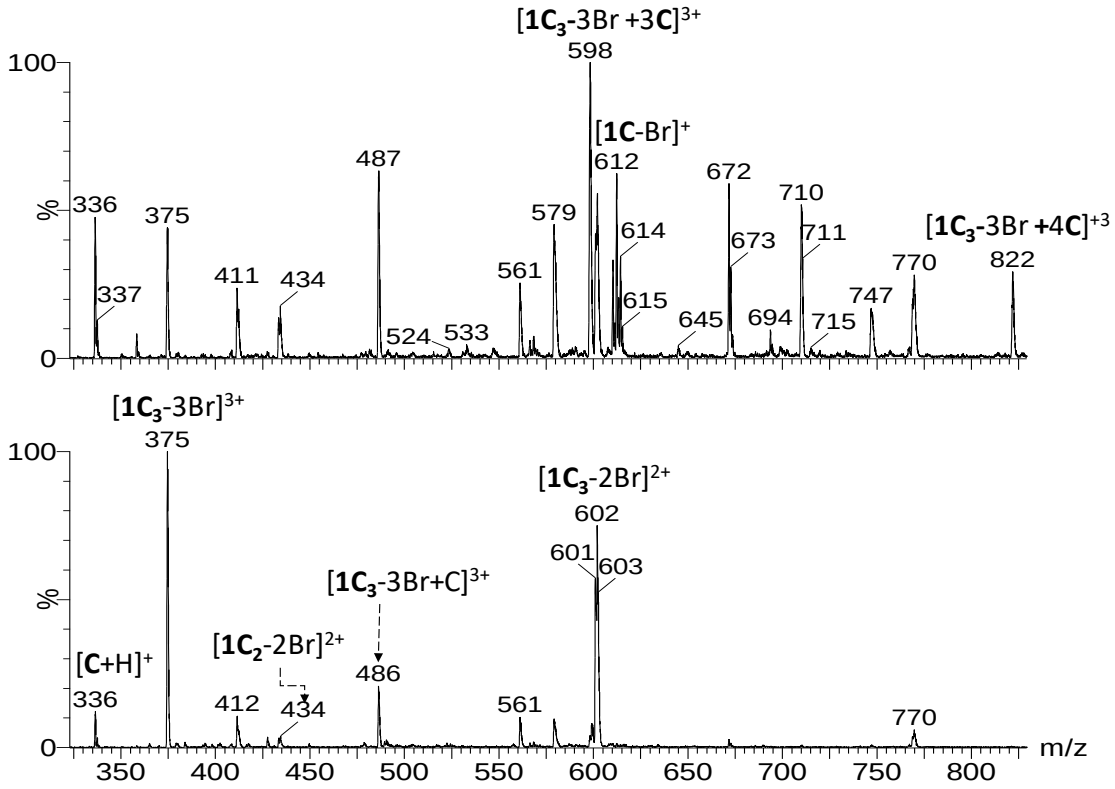


Fig. S4 ESI-MS in positive ion mode from the reaction mixture between trisbromomethylbenzene **1** (5.5 mM) and imidazole **C** (15.5 mM) after 48 h (top) and after 697 h of reaction (bottom).

Table S1 Summary of ESI-MS data obtained in positive ion mode for the reaction between trisbromomethylbenzene **1** and imidazole **C** using molar ratios of 1, 2.1 and 2.8 after 48 h of reaction in $CDCl_3$

			Ratio 1/C		
		Ions m/z (%)	**1/1**	**1/2.1**	**1/2.8**
Compound (Mw)	**1C$_3$** (1363.5)	**[1C$_3$-3Br +4C]$^{+3}$**	----	821.8 (13)	821.8 (28)
		[1C$_3$-3Br +3C]$^{+3}$	710.2 (9)	710.2 (45)	710.2 (50)
		[1C$_3$-3Br +2C]$^{+3}$	598.2 (20)	598.2 (100)	598.2 (100)
		[1C$_3$-3Br +C]$^{+3}$	486.6 (10)	486.6 (100)	486.6 (100)
		[1C$_3$-2Br]$^{+2}$	601.9 (77)	601.9 (73)	601.9 (53)
		[1C$_3$-3Br]$^{+3}$	374.6 (75)	374.6 (19)	374.6 (42)
	1C$_2$ (1027.9)	**[1C$_2$-2Br]$^{+2}$**	434.6 (17)	434.6 (15)	434.6 (17)
	1C (692.4)	**[1C-Br]$^{+}$**	612.4 (100)	612.4 (85)	612.4 (60)
	C (335.5)	**[C+C+H]$^{+}$**	671.8 (16)	671.8 (53)	671.8 (60)
		[C+H]$^{+}$	336.6 (48)	336.6 (50)	336.6 (48)

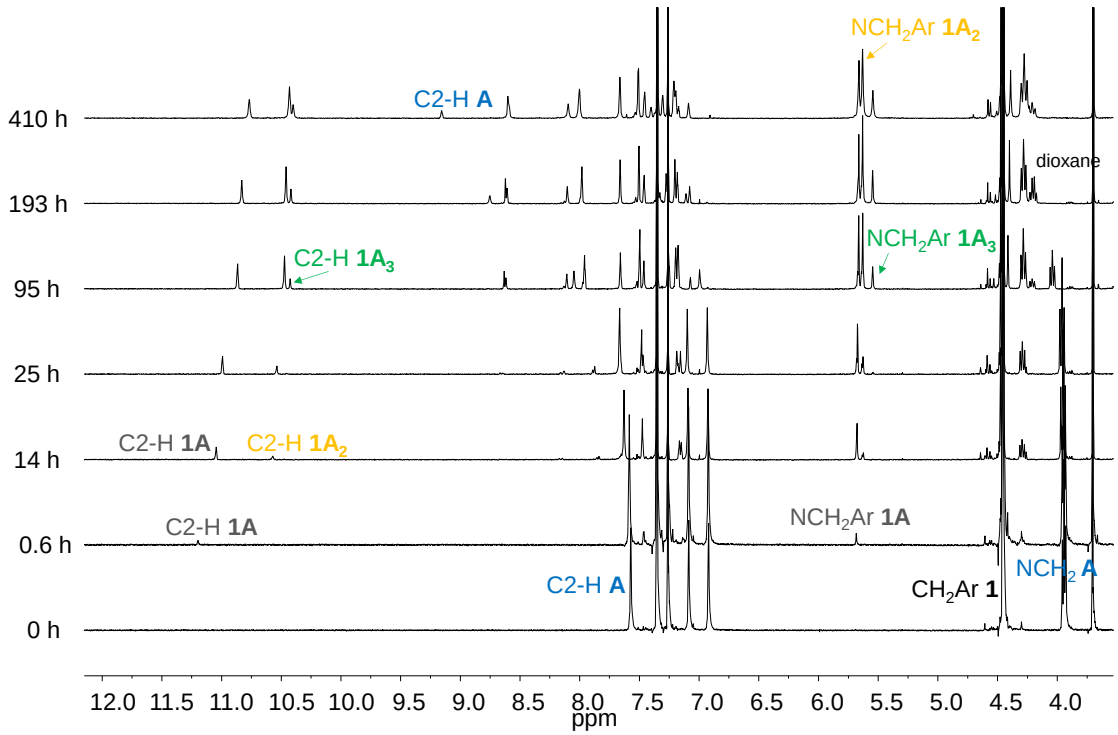


Fig. S5 Evolution with time of the ^{1}H NMR (400 MHz) spectra for the reaction between **1** (13 mM) and imidazole **A** (13 mM) in $CDCl_3$

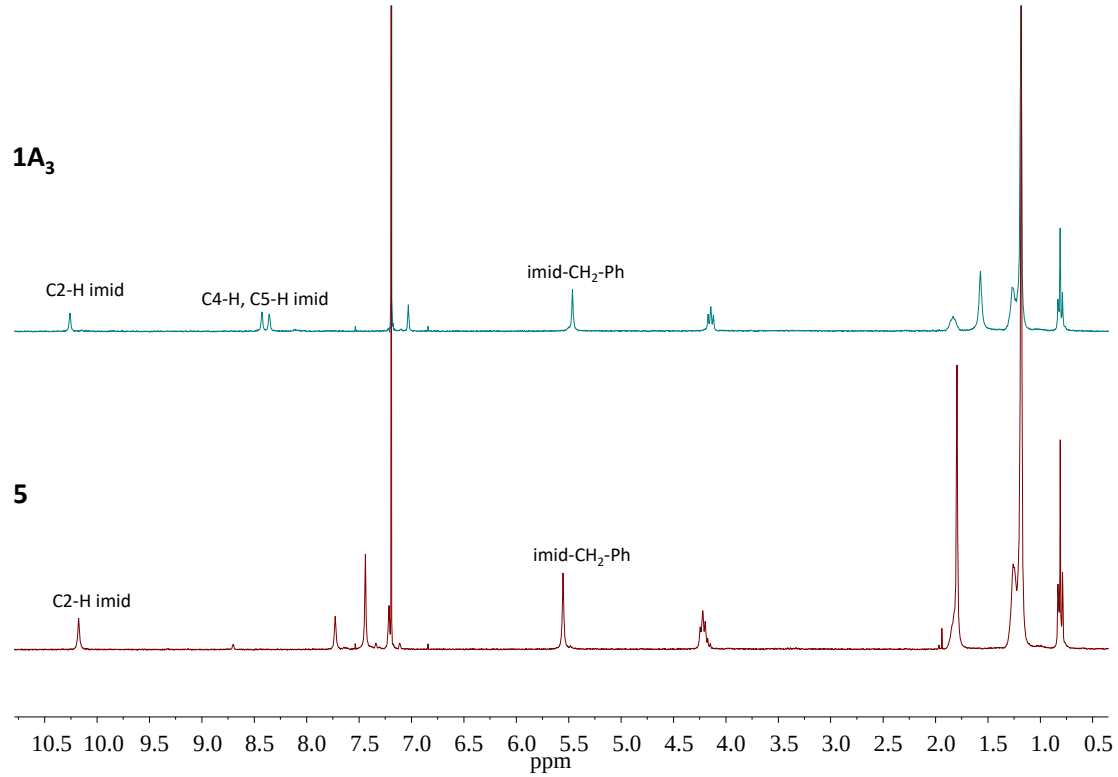


Fig. S6 Partial ^{1}H NMR spectra (500 MHz) of **5** (2 mM) and **1A$_3$** (2 mM) in $CDCl_3$.

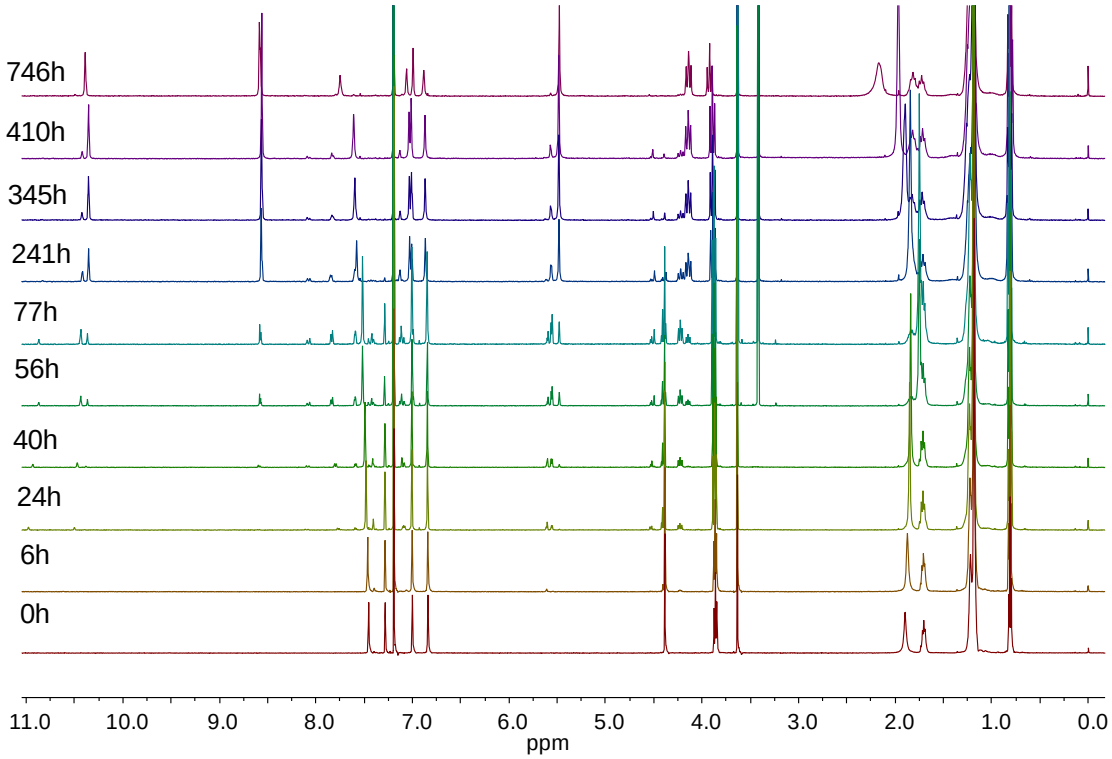


Fig. S7 Evolution with time of the ^{1}H NMR (500 MHz) spectra for the reaction between **1** (3.6 mM) and imidazole **A** (18.6 mM) in $CDCl_3$.

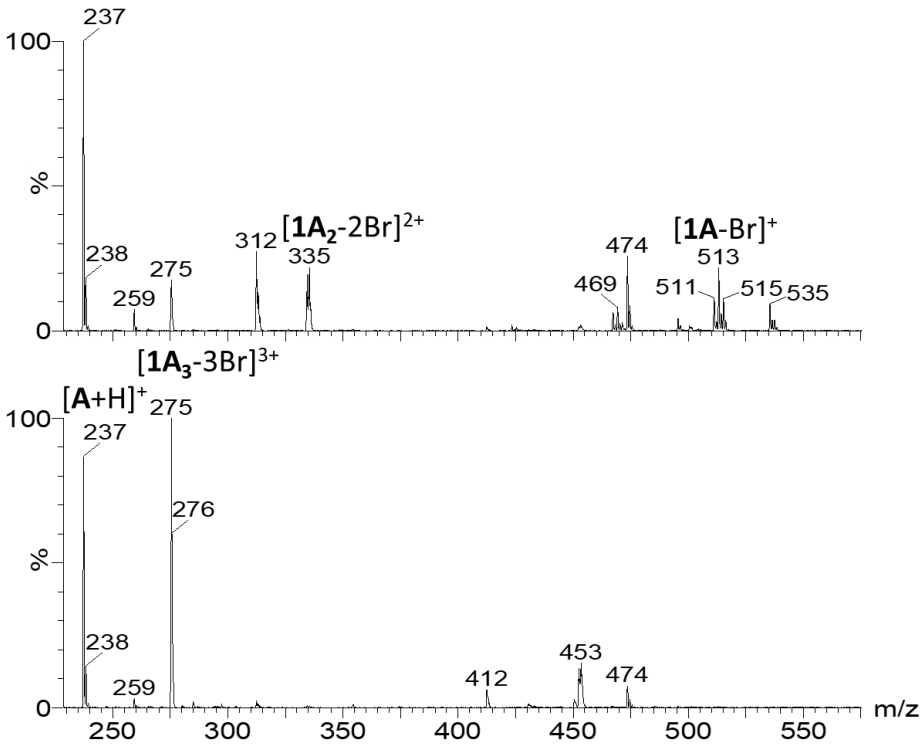


Fig. S8 ESI-MS in positive ion mode for the reaction between **1** (3.6 mM) and imidazole **A** (18.6 mM) after 48 h (top) and after 747 h (bottom)

Table S2 Summary of ESI-MS data obtained in positive ion mode for the reaction between trisbromomethylbenzene **1** and imidazole **A** using molar ratios of 1 and 5.2 after 48 h of reaction in $CDCl_3$

			Ratio 1/A	
		Ions m/z (%)	1/1	1/5.2
Compound (Mw)	**$1A_3$** (1066.1)	**$[1A_3\text{-}3Br]^{+3}$**	275.4 (29)	275.4 (28)
	$1A_2$ (829.7)	**$[1A_2\text{-}2Br]^{+2}$**	335.4 (38)	335.4 (22)
	1A (593.3)	**$[1A\text{-}Br]^{+}$**	513.2 (100)	513.2 (20)
	A (236.4)	**$[A+A+H]^{+}$**	---	473.5 (25)
		$[A+H]^{+}$	237.4 (30)	237.4 (100)

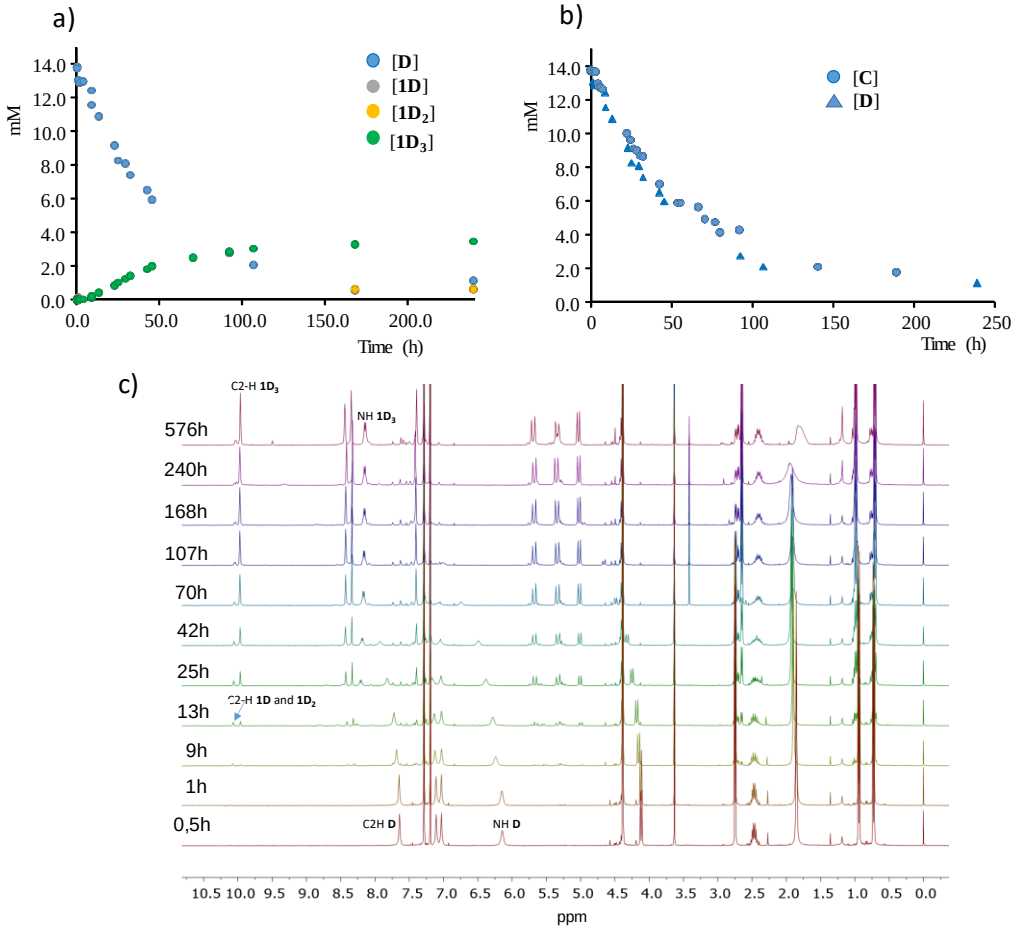


Fig. S9 a) Kinetic profiles (^{1}H NMR, 400 MHz, $CDCl_3$) for the reaction between **1** (12.7 mM) and imidazole **D** (13.8 mM); b) Conversion *vs*. time of imidazoles **C** and **D** (^{1}H NMR, 400 MHz, $CDCl_3$) in their reaction with **1** (1 equiv.); The C2-H proton signal was followed for **1D**, **$1D_2$** and **$1D_3$** and the C2-H and C*H proton signals for **C** and **D**; c) Evolution of ^{1}H NMR spectra (400 MHz) with time for the reaction between imidazole **D** (13.8 mM) and **1** (12.7 mM) in $CDCl_3$.

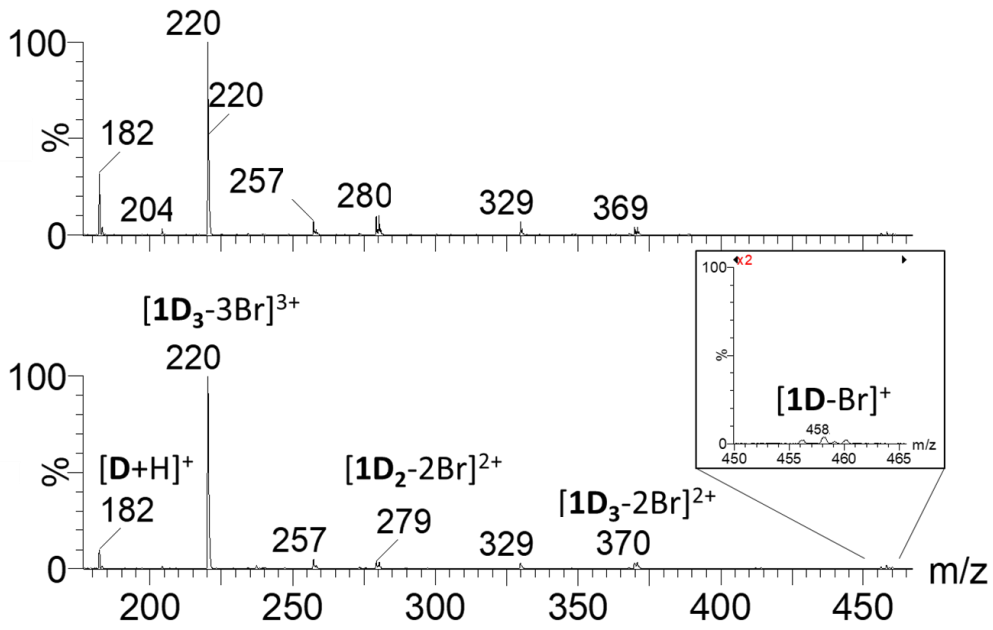


Fig. S10 ESI-MS in positive ion mode for the reaction between imidazole **D** (13.8 mM) and **1** (12.7 mM) after 48 h (top) and 576 h (bottom) in $CDCl_3$

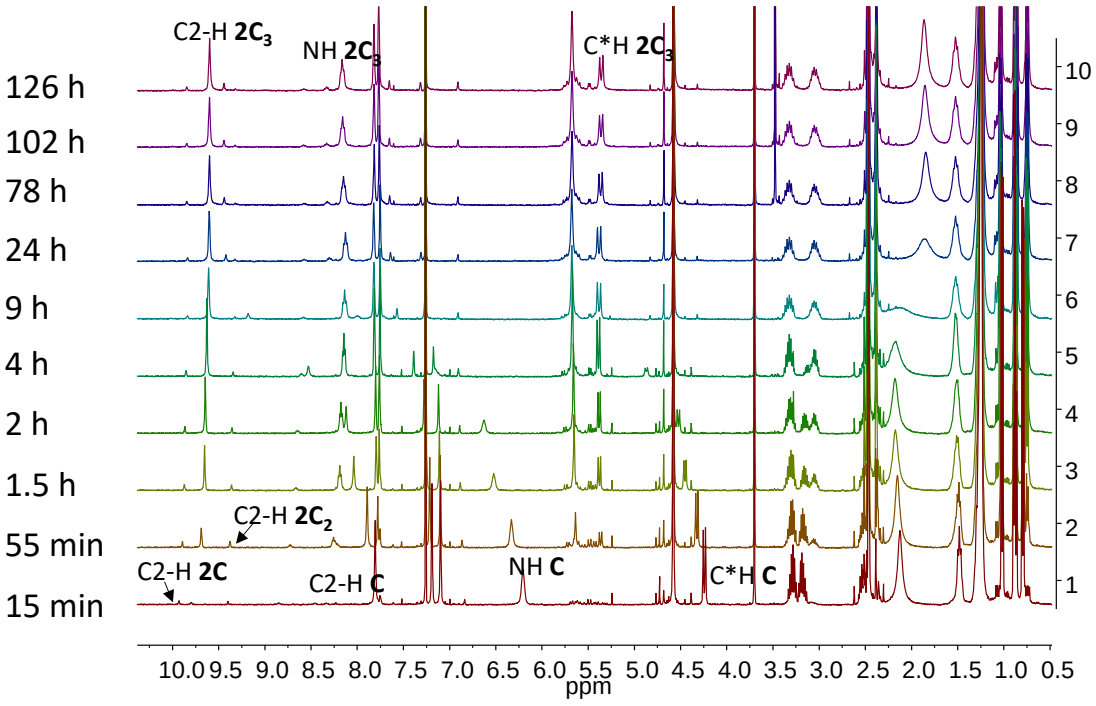


Fig. S11 a) Evolution with time of ^{1}H NMR (400 MHz) partial spectra for the reaction between **C** (14.8 mM) and **2** (15.6 mM) in $CDCl_3$

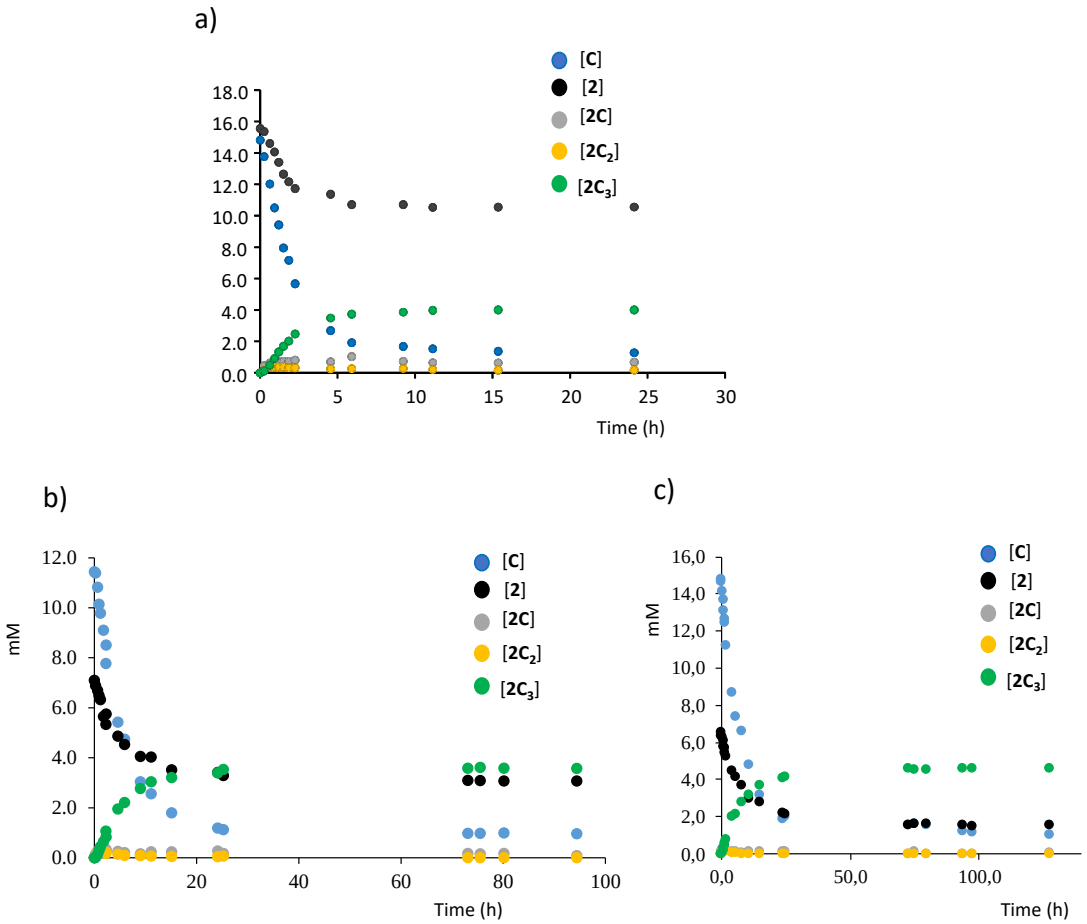


Fig. S12 a) Kinetic profiles for the reaction between **C** and **2** (15.6 mM) of (ratio **C**/**2**=1) in $CDCl_3$; b) Kinetic profiles for the reaction between **C** and **2** (7.1 mM) of (ratio **C**/**2**=1.6) in $CDCl_3$; c) Kinetic profiles for the reaction between **C** (14.8 mM) and **2** (6.5 mM) (ratio **C**/**2**= 2.3) in $CDCl_3$. The C2-H proton signal was followed for **2C**, **2C$_2$** and **2C$_3$**, the C2-H and C*H proton signals for **C** and the benzylic signal for **2**

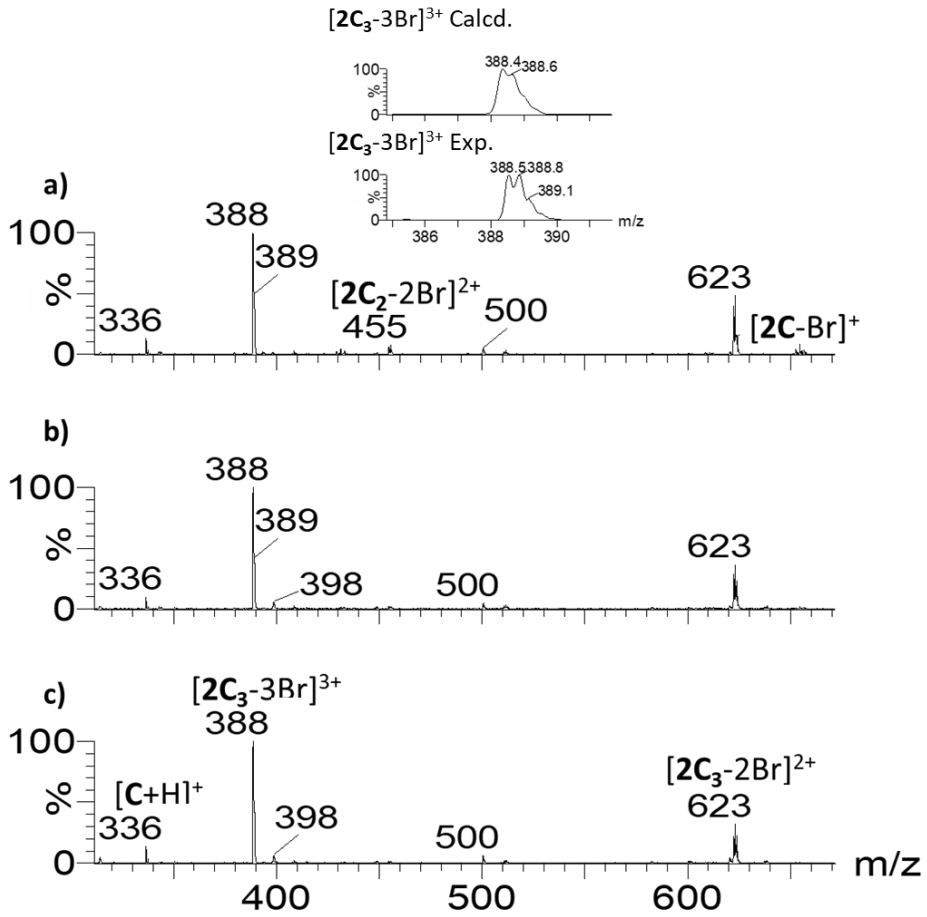


Fig. S13 ESI-MS in positive ion mode for the reaction between **2** and imidazole **C** after 48 h in $CDCl_3$; a) 14.8 mM of **C** and 15.6 mM of **2 (**ratio **C/2**≈1); b**)** 11.4 mM of **C** and 7.1 mM of **2** (ratio **C/2**=1.6)**;** c) 14.8 mM of **C** and 6.5 mM of **2** (ratio **C/2**=2.3)

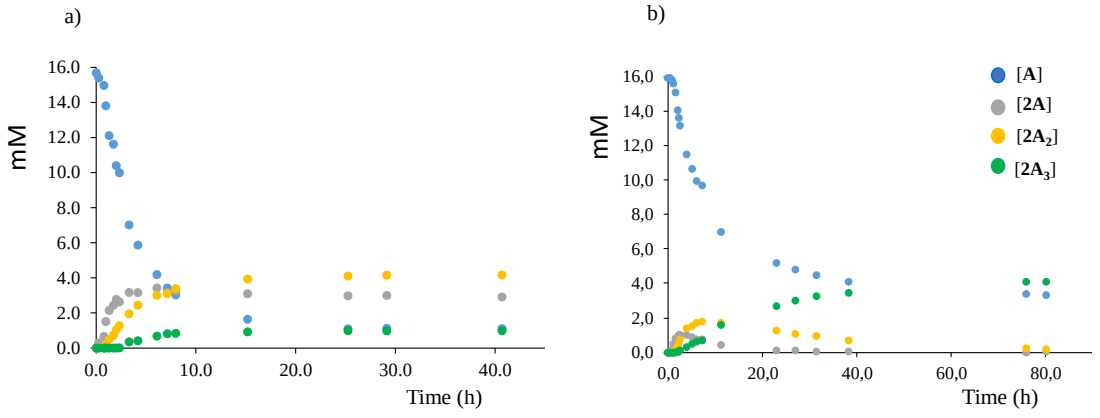


Fig. S14 Kinetic profiles (^{1}H NMR, 500MHz, $CDCl_3$) for the reaction between imidazole **A** and **2**; a) 13.8 mM of **2** and 15.7 mM of **A** (ratio **A/2** =1.1); b) 5.2 mM of **2** and 16.0 mM of **A** (ratio **A/2**=3.1). The C2-H proton signal was followed for **2A**, **$2A_2$** and **$2A_3$** and the C2-H and N-CH_2 proton signals for **A**

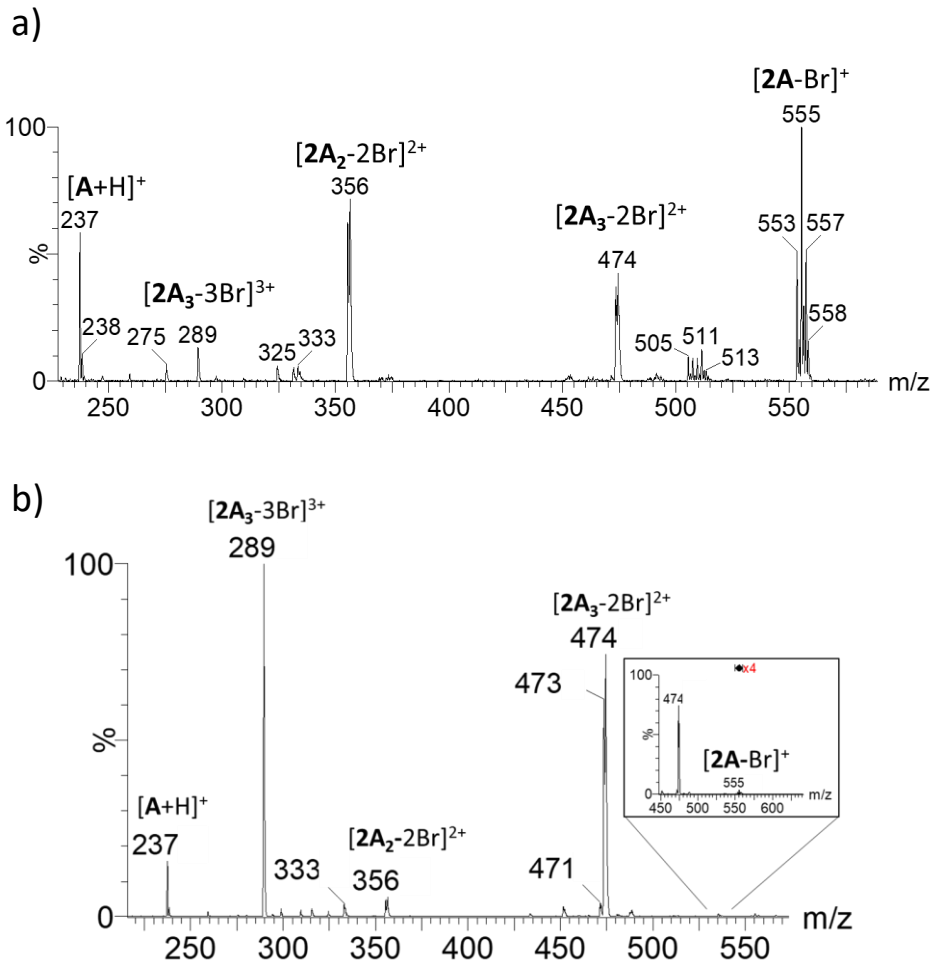
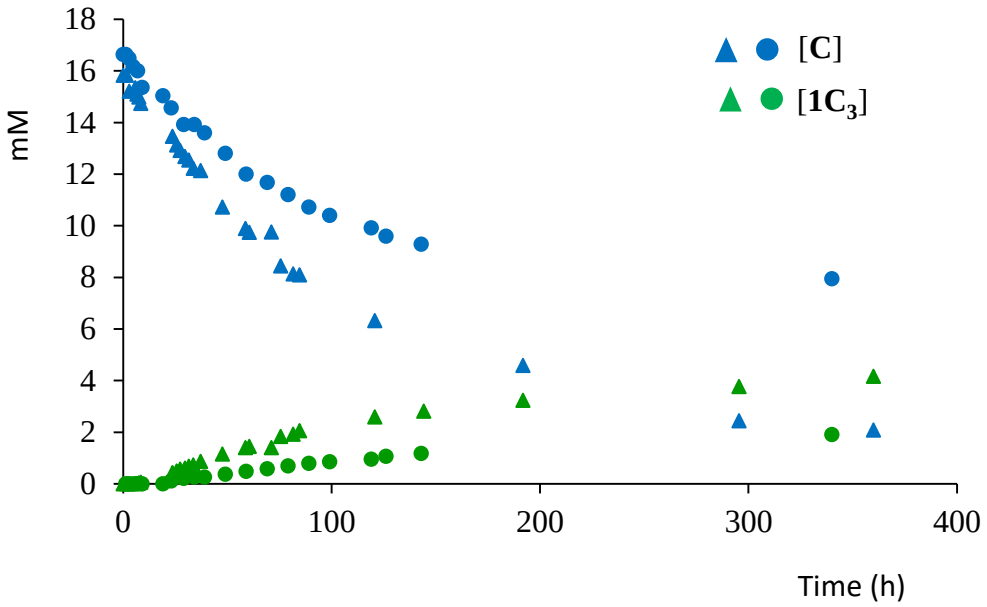


Fig. S15 a) ESI-MS in positive ion mode for the reaction between **2** (15.7 mM) and imidazole **A** (13.8 mM) after 48 h; b) ESI-MS in positive ion mode for the reaction between **2** (5.2 mM) and imidazole **A** (16 mM) after 48 h

a)



b)

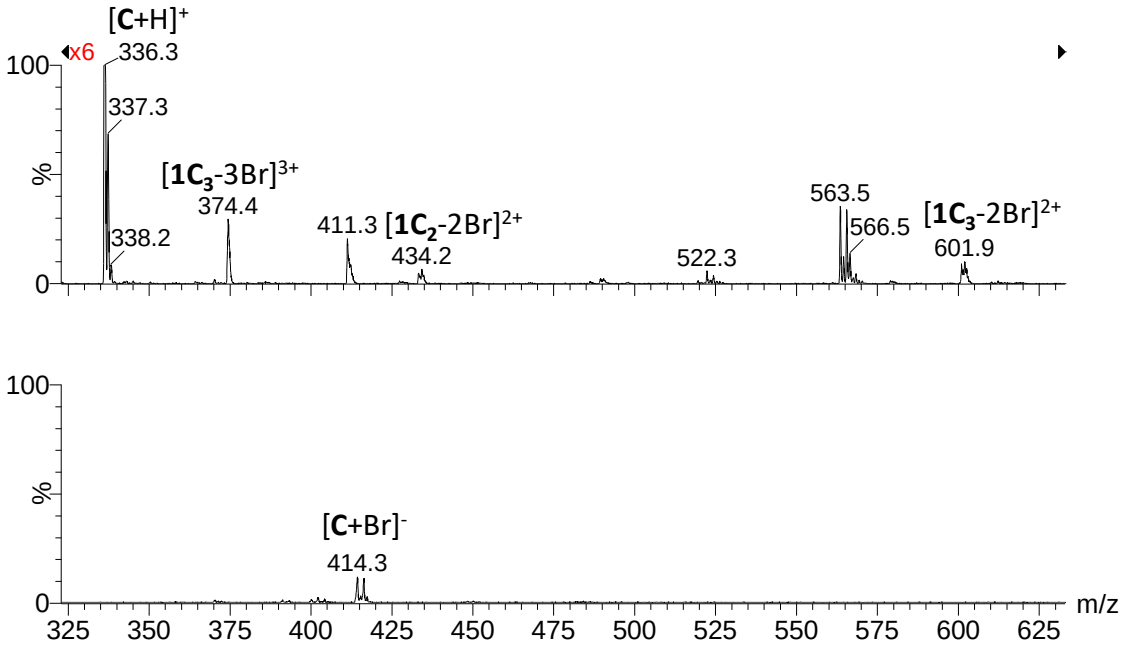


Fig. S16 Reaction between **1** (*ca*. 8 mM) and **C** (*ca*. 16 mM) (*ca.* 1/2 molar ratio) in $CDCl_3$; a) kinetic profiles (^{1}H NMR, 400 MHz) in the absence (triangles) and presence (circles) of NEt_4Br (9 mM); b) ESI-MS after 48 h in positive ion mode (top) and in negative ion mode (bottom) of the reaction in the presence of NEt_4Br

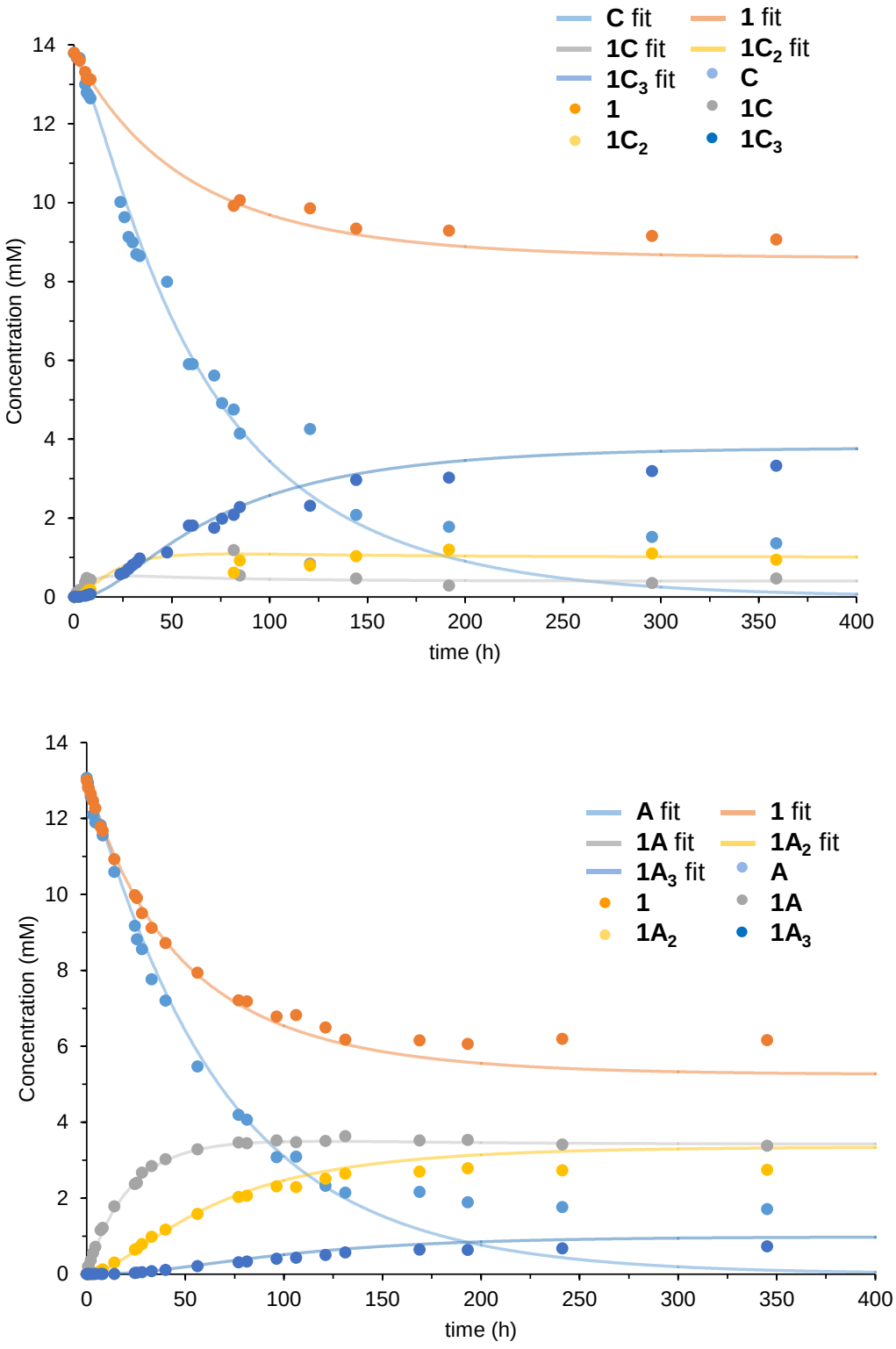


Fig. S17 Experimental (solid circles, ^{1}H NMR, 300 MHz (**C**), 500 MHz (**A**), $CDCl_3$) and calculated (solid lines) kinetic profiles for the reaction of of **1** **C** (13.8 mM) or **A** (13 mM) with **1** (1 equiv.). Top: imidazole **C** (dark blue), trisbromomethylbenzene **1** (orange), **1C** (grey), **1C$_2$** (yellow), **1C$_2$** (light blue). Bottom: imidazole **A** (light blue), trisbromomethylbenzene **1** (orange), **1A** (grey), **1A$_2$** (yellow), **1A3$_2$** (dark blue).

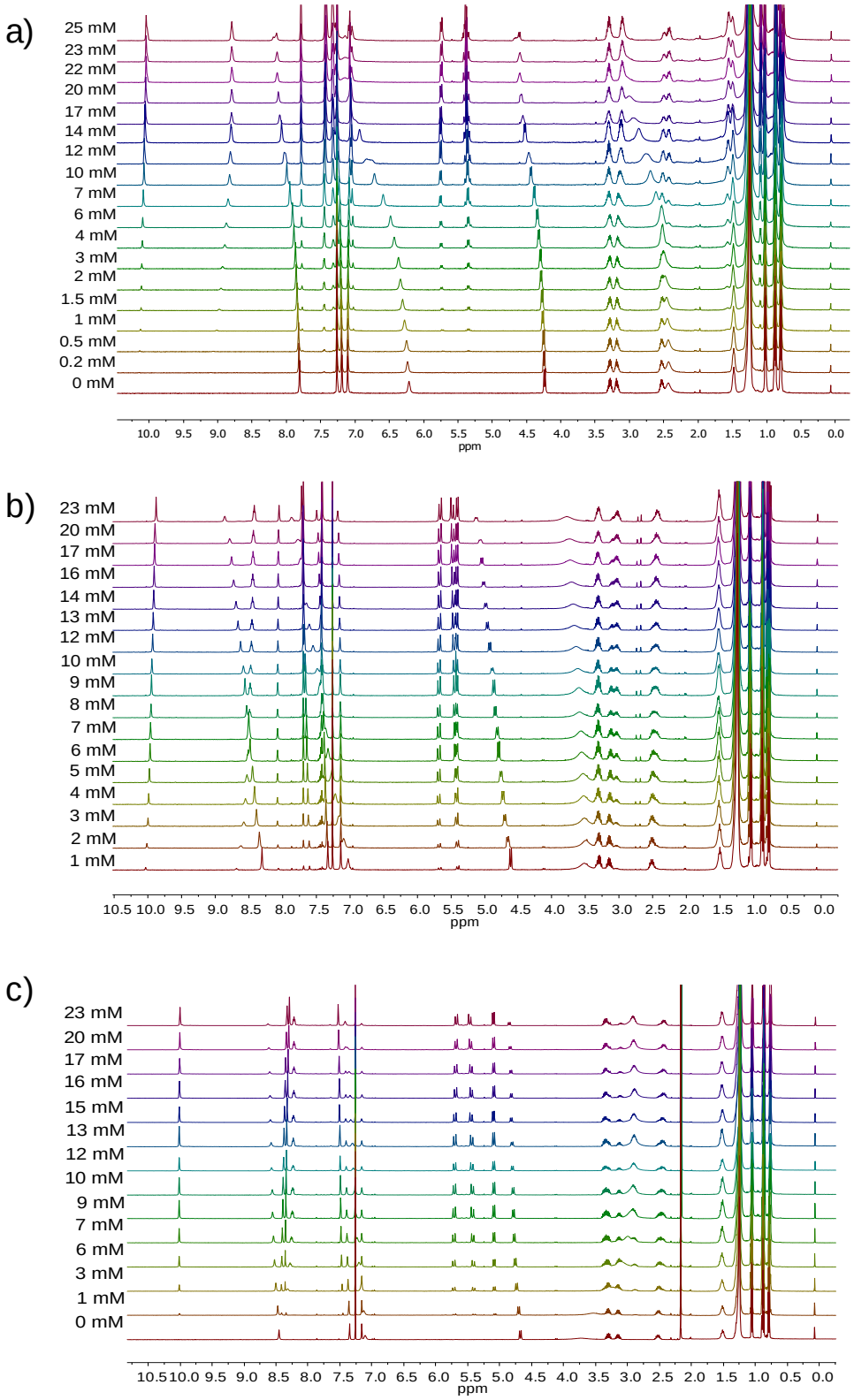


Fig. S18 ^{1}H NMR titration (500 MHz, $CDCl_3$) of imidazole **C** (15 mM) with a) increasing amounts of monoimidazolium **3**; b) increasing amounts of bisimidazolium **4** and c) increasing amounts of trisimidazolium **1C$_3$**

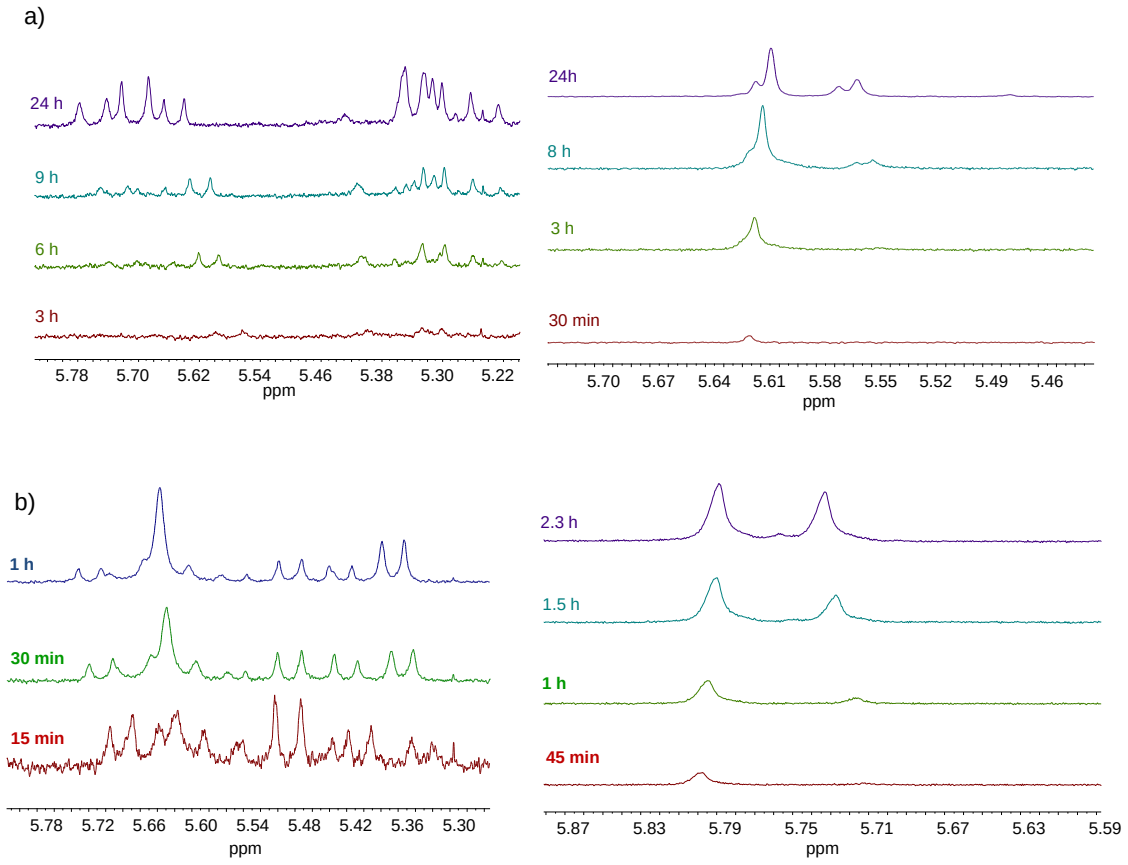


Fig. S19 a) Partial ^{1}H NMR (300 MHz for **C**, 500 MHz for **A**, $CDCl_3$) spectra for the reaction between **1** and **C** (left) and between **1** and **A** (right) at different times (*ca.* 1/1 molar ratios). b) Partial ^{1}H NMR (400 MHz for **C**, 500 MHz for **A**, $CDCl_3$) spectra for the reaction between **2** and **C** (left) and between **2** and **A** (right) at different times (*ca.* 1/1 molar ratios).

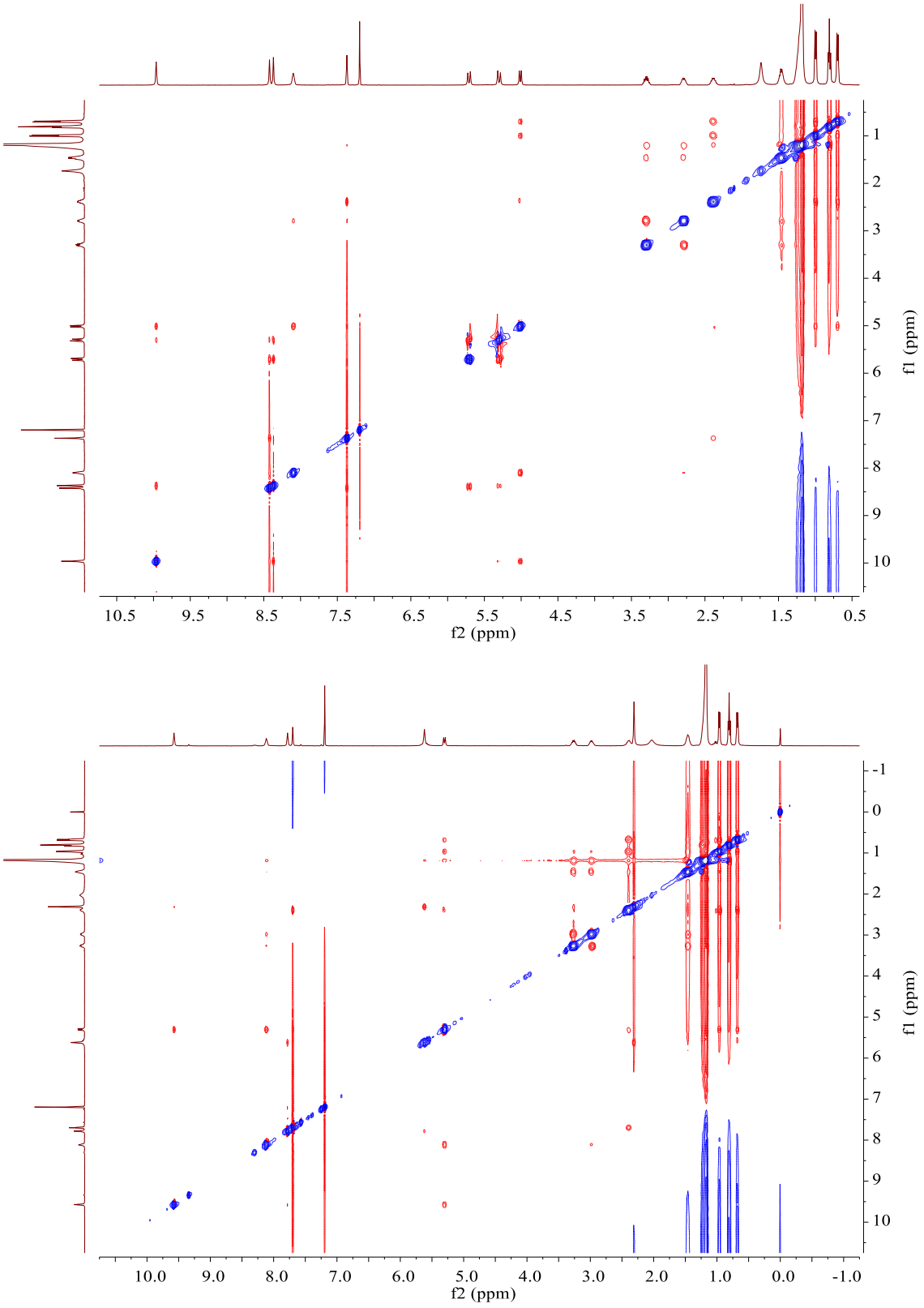
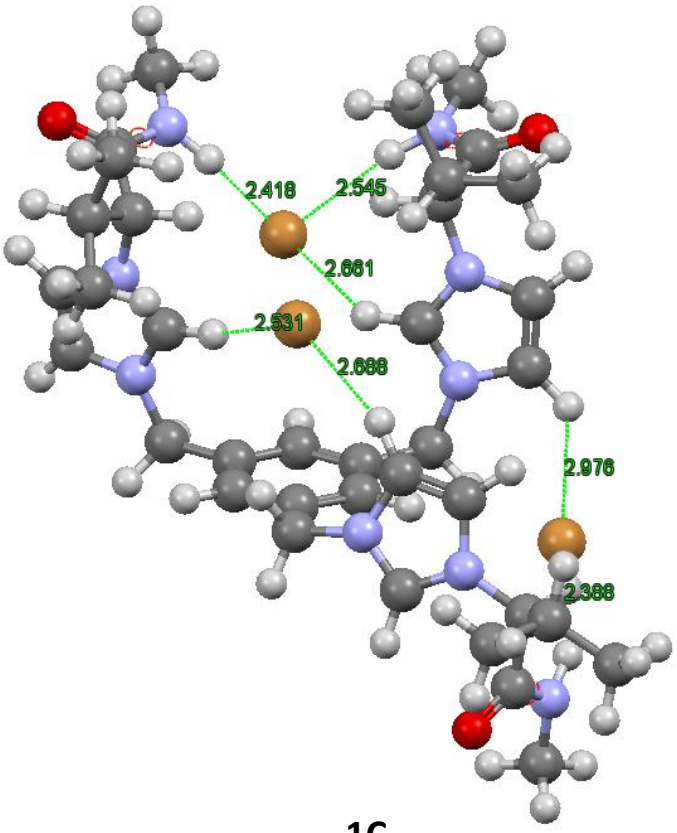
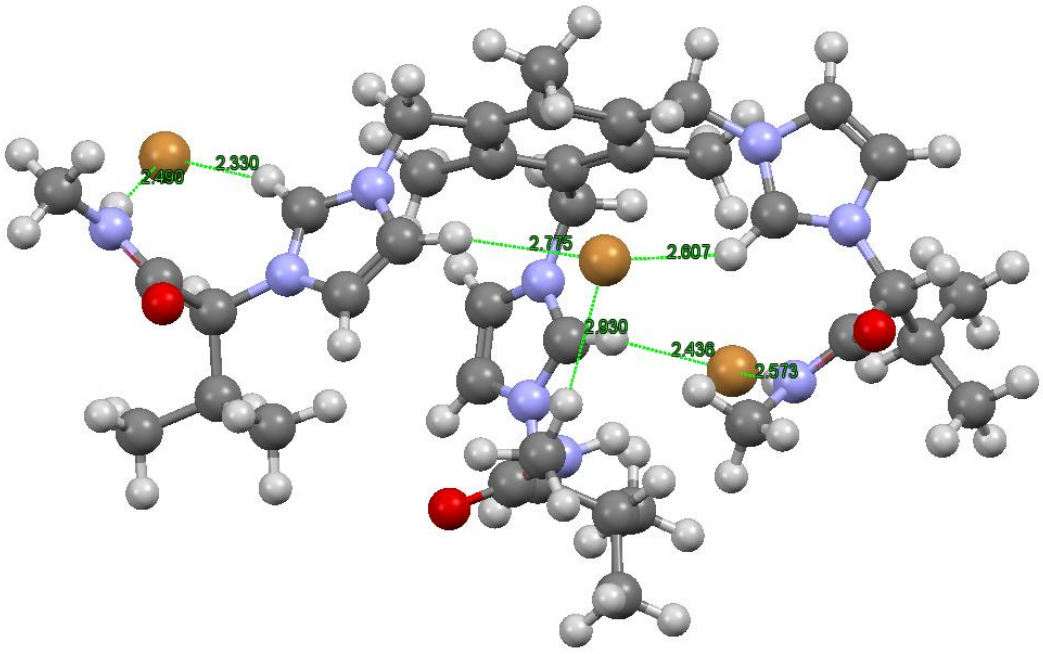


Fig. S20 ROESY spectra (400 MHz, $CDCl_3$) for **$1C_3$** (top) and **$2C_3$** (botton) at 6 mM



1C$_3$



2C$_3$

Fig. S21 Minimum energy structures (DFT, B3LYP) obtained for **1C$_3$** and **2C$_3$**

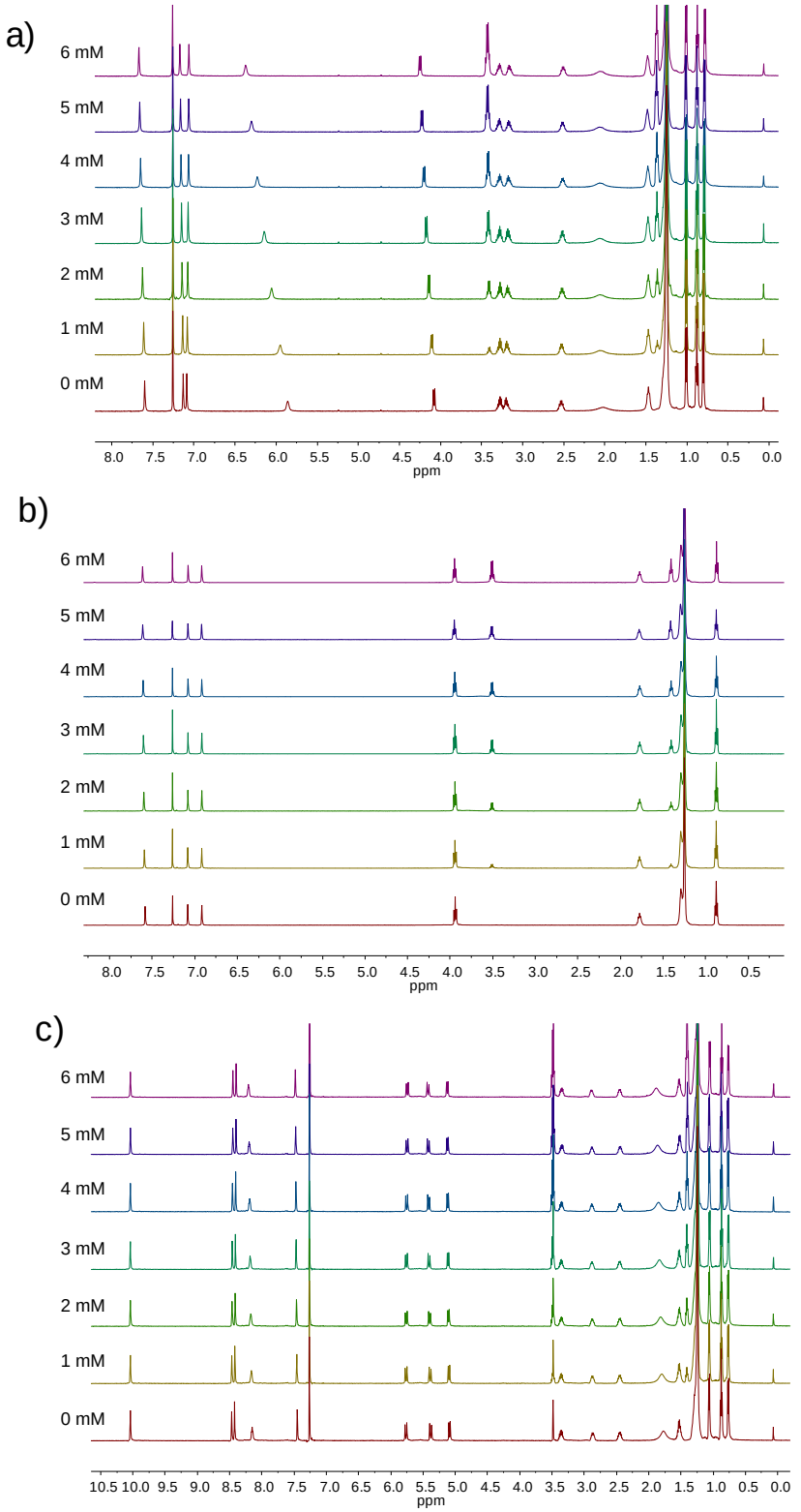
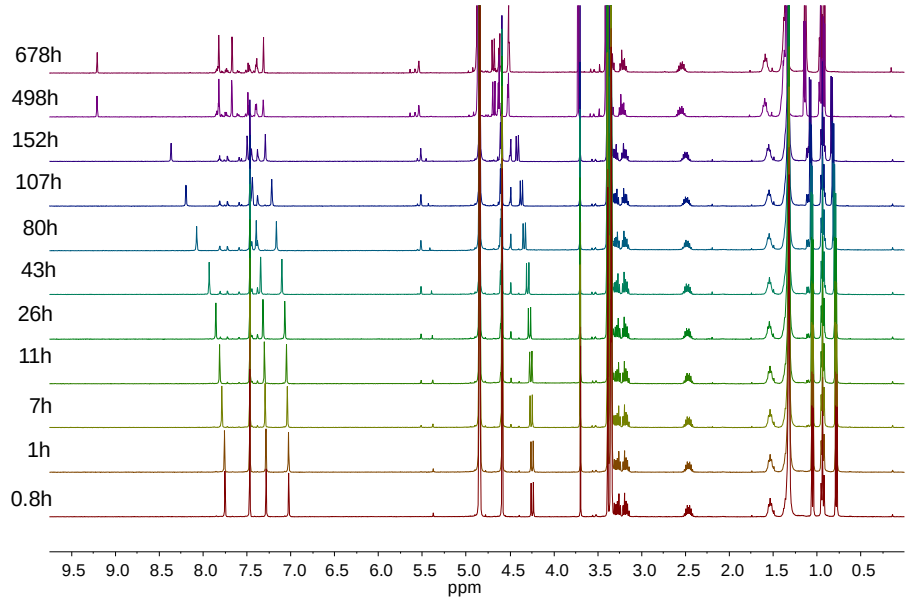


Fig. S22 a) Partial ^{1}H NMR (500 MHz) spectra for imidazole **C** (15 mM, $CDCl_3$) in the presence of increasing concentrations of bromide anion; b) Partial ^{1}H NMR (500 MHz) spectra for imidazole **A** (15 mM, $CDCl_3$) in the presence of increasing concentrations of bromide anion; c) Partial ^{1}H NMR (500 MHz) for **1C$_3$** (15 mM, $CDCl_3$) in the presence of increasing concentrations of bromide anion.

a)



b)

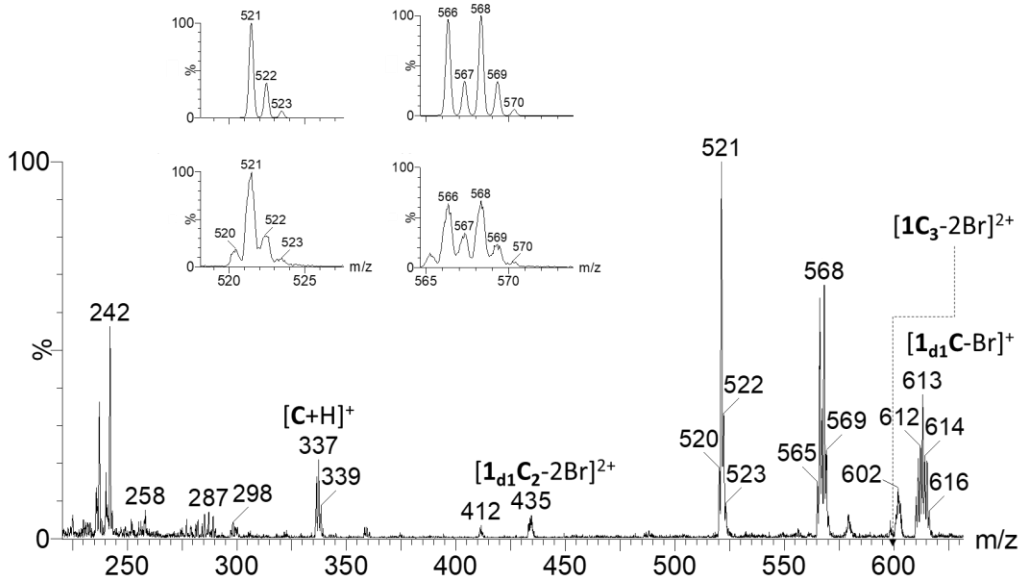


Fig. S23 a) Evolution with time of the ^{1}H NMR (400 MHz) spectra for the reaction between imidazole **C** (13.3 mM) and **1** (9 mM) in CD_3OD; b) ESI-MS in positive ion mode for the reaction between imidazole **C** (13.3 mM) and **1** (9 mM) after 679 h in CD_3OD. Peaks at m/z 521 and 568 are associated to the **1C** deuterated monotopic species with one or two of the remaining -CH_2Br groups transformed into –CH_2OCD_3 groups

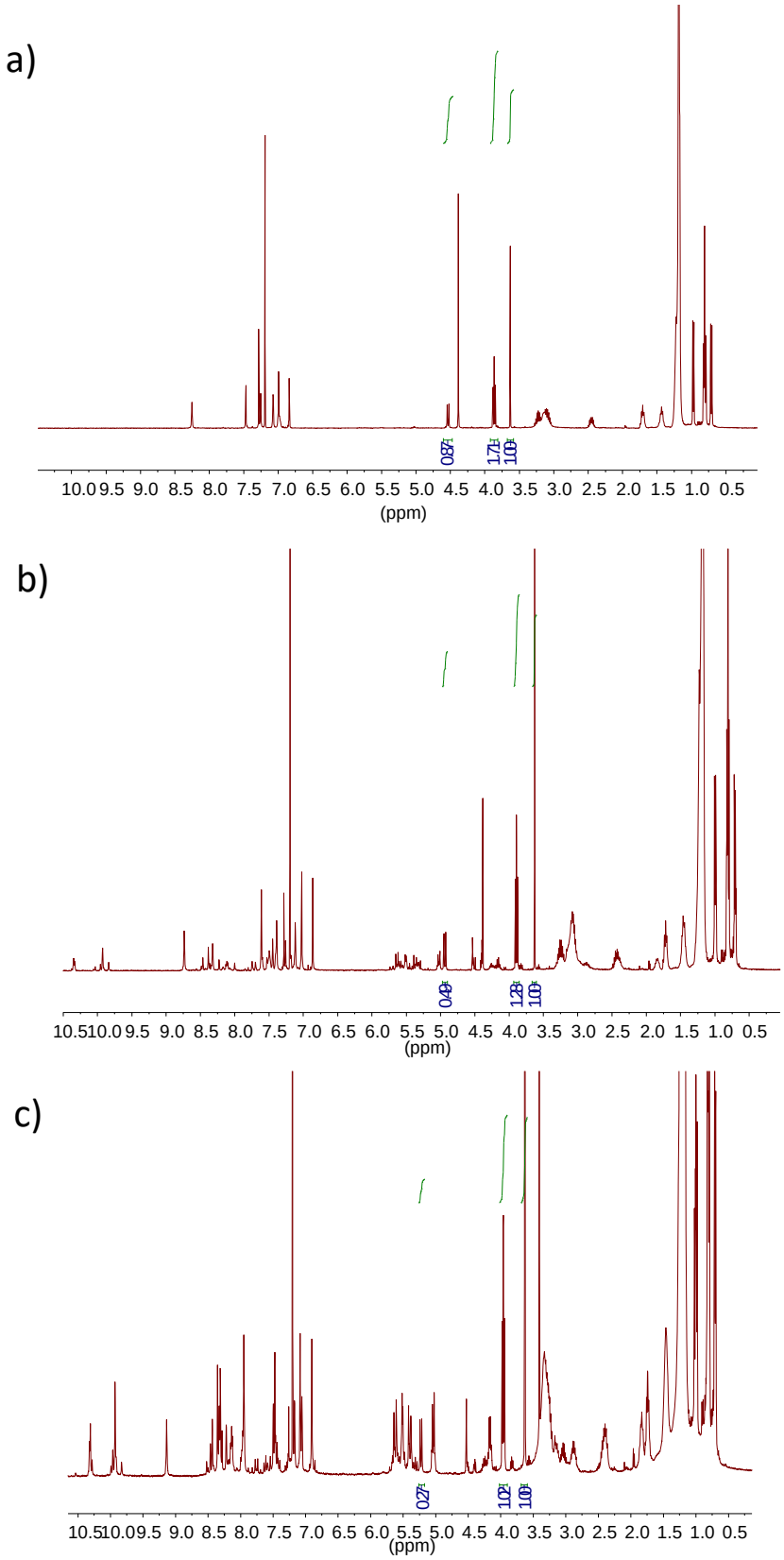


Fig. S24 Partial ^{1}H NMR (400 MHz, $CDCl_3$) for the competitive reaction involving trisbromomethylbenzene **1** (5.5 mM) and imidazoles **A** (13.7 mM) and **C** (13.9 mM); a) at 0 h of reaction; b) at 90 h of reaction; c) at 184 h of reaction

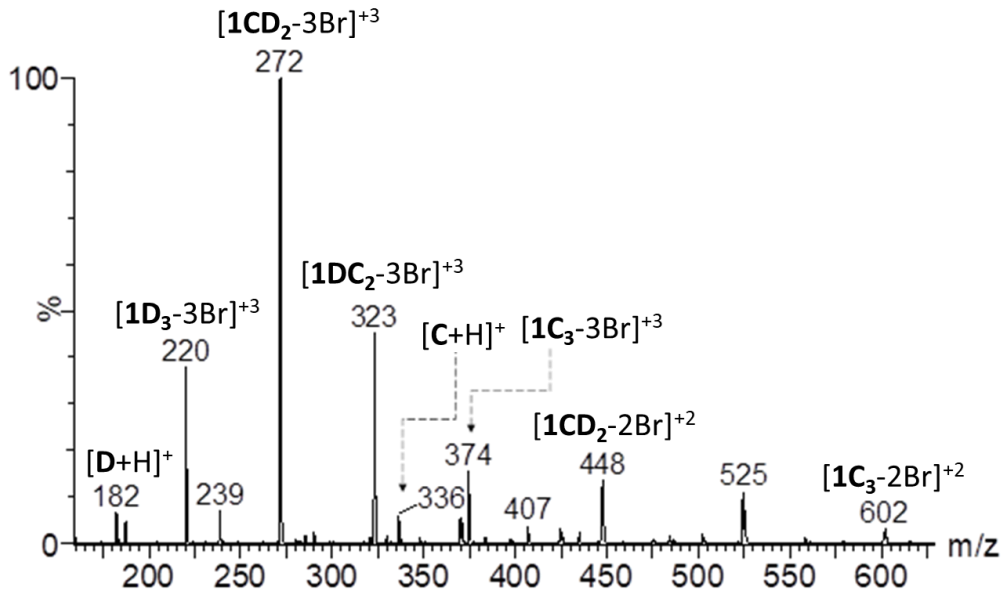


Fig. S25 ESI-MS in positive ion mode for the competitive reaction involving trisbromomethylbenzene **1** (5 mM) and imidazoles **C** (3 equiv.) and **D** (3 equiv.) after 120 h in $CDCl_3$

Table S3 Summary of ESI-MS data obtained in positive ion mode for the competitive reaction involving trisbromomethylbenzene **1** (5 mM) and imidazoles **C** (3 equiv.) and **D** (3 equiv.) after 120 h in $CDCl_3$

		Ions m/z (%)	m/z (%relative abundance)
Compound (Mw)	**1CD$_2$** (1054.9)	[**1CD$_2$**-3Br]$^{3+}$	271.7 (100)
		[**1CD$_2$**-2Br]$^{2+}$	447.9 (17)
	1DC$_2$ (1209.2)	[**1DC$_2$**-3Br]$^{3+}$	323.2 (46)
	1D$_3$ (900.6)	[**1D$_3$**-3Br]$^{3+}$	220.2 (38)
	1C$_3$ (1363.5)	[**1C$_3$**-3Br]$^{3+}$	374.4 (18)
		[**1C$_3$**-2Br]$^{2+}$	602.0 (5)
	D (181.2)	[**D**+H]$^{+}$	182.2 (7)
	C (335.5)	[**C**+H]$^{+}$	336.0 (6)

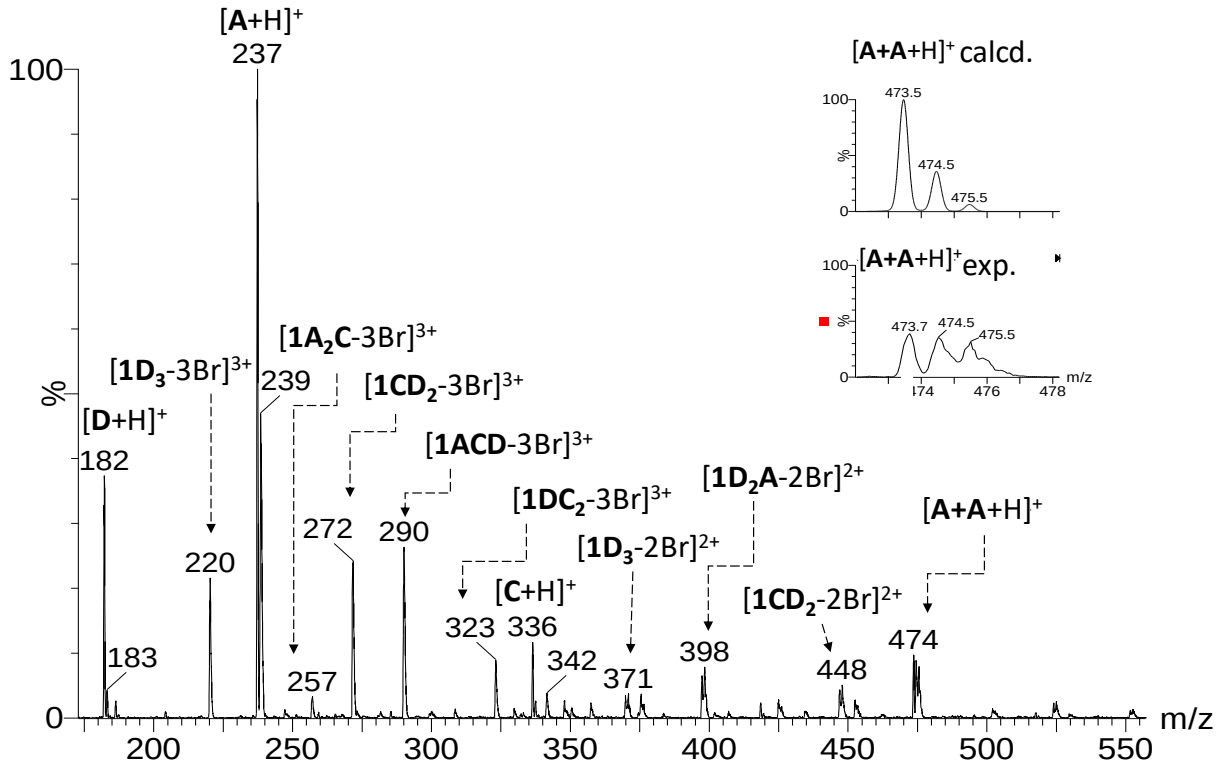


Fig. S26 ESI-MS in positive ion mode for the competitive reaction involving trisbromomethylbenzene **1** (5 mM) and imidazoles **C** (3 equiv.), **D** (3 equiv.) and **A** (3 equiv.) after 120h in $CDCl_3$

Table S4 Calculated relative activation energies (kcal/mol) for the diferent transition states leading to the formation of tripodal imidazolium compounds **$1B_3$**, **$2B_3$**, **$1D_3$** and **$2D_3$**. Imaginary frequencies are given in brackets. TS1, TS2 and TS3 correspond to the TSs for the formation of the monotopic, ditopic and tritopic imidazolium compounds

Tripodal final compound	TS1	TS2	TS3
$1B_3$	27.0 (-368.0240)	23.1 (-367.8148)	24.2 (-369.3739)
$2B_3$	25.6 (-348.3856)	20.8 (-334.6638)	19.9 (-342.3857)
$1D_3$	23.7 (-383.6526)	13.5 (-362.9522)	11.1 (-368.1623)
$2D_3$	21.4 (-366.1168)	12.8 (-343.4482)	10.6 (-340.1058)