



**HAL**  
open science

# Crystallization- and Metal-Driven Selection of Discrete Macrocycles/Cages and Their Metallosupramolecular Polymers from Dynamic Systemic Networks

Yan Zhang, Arie van Der Lee, Mihail Barboiu

► **To cite this version:**

Yan Zhang, Arie van Der Lee, Mihail Barboiu. Crystallization- and Metal-Driven Selection of Discrete Macrocycles/Cages and Their Metallosupramolecular Polymers from Dynamic Systemic Networks. *Chemistry*, 2022, 4 (4), pp.1281-1287. 10.3390/chemistry4040084 . hal-04065319

**HAL Id: hal-04065319**

**<https://hal.umontpellier.fr/hal-04065319>**

Submitted on 6 Jun 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License

Communication

# Crystallization- and Metal-Driven Selection of Discrete Macrocycles/Cages and Their Metallosupramolecular Polymers from Dynamic Systemic Networks

Yan Zhang <sup>1,2</sup>, Arie van der Lee <sup>1</sup> and Mihail Barboiu <sup>1,\*</sup> 

<sup>1</sup> Institut Européen des Membranes, UMR-CNRS 5635, Université Montpellier, Place Eugène Bataillon, CC 047, CEDEX 5, 34095 Montpellier, France

<sup>2</sup> Key Laboratory of Carbohydrate Chemistry and Biotechnology, Ministry of Education, School of Pharmaceutical Sciences, Jiangnan University, 1800 Lihu Avenue, Wuxi 214122, China

\* Correspondence: mihail-dumitru.barboiu@umontpellier.fr

**Abstract:** Reversible imine- and metal-coordination reactions are dynamic enough to produce complex libraries of macrocycles, cages, and supramolecular polymers in solution, from which amplification effects have been identified in solution or during crystallization in response to ligand- and metal-driven selection modes. Crystallization-driven selection can lead to the amplification of unexpected metallosupramolecular architectures. The addition of Ag<sup>+</sup> triggered the change of the optimal components, so that the crystallization process showed different ligand preferences than in solution. The most packed constituents are amplified in the solid state, taking into account the optimal coordination of metal ions together with non-specific non-covalent interactions between the macrocycle packed in dimers or trimers in the solid state.

**Keywords:** supramolecular chemistry; macrocycles; cages; dynamic chemistry; crystallization



**Citation:** Zhang, Y.; van der Lee, A.; Barboiu, M. Crystallization- and Metal-Driven Selection of Discrete Macrocycles/Cages and Their Metallosupramolecular Polymers from Dynamic Systemic Networks. *Chemistry* **2022**, *4*, 1281–1287. <https://doi.org/10.3390/chemistry4040084>

Received: 22 September 2022

Accepted: 15 October 2022

Published: 18 October 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

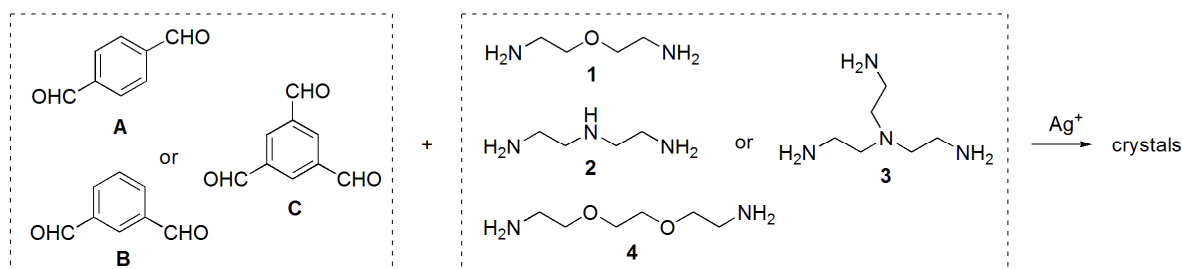
Constitutional dynamic chemistry (CDC) [1–4] has emerged as a new adaptive approach for the generation of emergent dynamic materials [2–9], molecular machines [10,11], bioactive compounds [12,13], cages [14–16], knots [17], rotaxanes [18], metallodendrimers [19], and macrocyclic [20] structures. Moreover, such dynamic systems can adapt under the influence of internal or external stimuli such as pH (Figure 2c,d), temperature [21], light [22,23], precipitation [24,25], and host enzyme [26,27] when optimal constituents can be selectively formed and amplified as the best/fittest constituents from the multicomponent dynamic library [28,29].

Among the different internal effectors, crystallization-driven selection can lead to out of phase amplification of the most stabilized constituents in solid state [30–32]. However, the out of equilibrium crystallization strategy has not been widely studied, probably due to the facility of obtaining high quality single crystals or other solid-state species that can be used for accurate structure determination.

Previously, we have reported the metal-driven single/double dynamic 3D cages from imine-connected systems [33]. The discovery of the “Ag<sup>+</sup>-driven” selection of crystalline interlocked cages showed the artwork of unexpected topologically complex metallosupramolecular architectures from very simple starting components. Herein, we present new results in the exploration of the crystallization-driven selection from dynamic libraries with expanded components, from the combination of single imine/carbonyl-amine and coordination bonds to dynamic covalent networks. More importantly, a comparison study of the constituent selection between solution and crystal states and between the presence and absence of metal coordination phenomena has been carried out, leading to a stimuli-induced switch of amplifications.

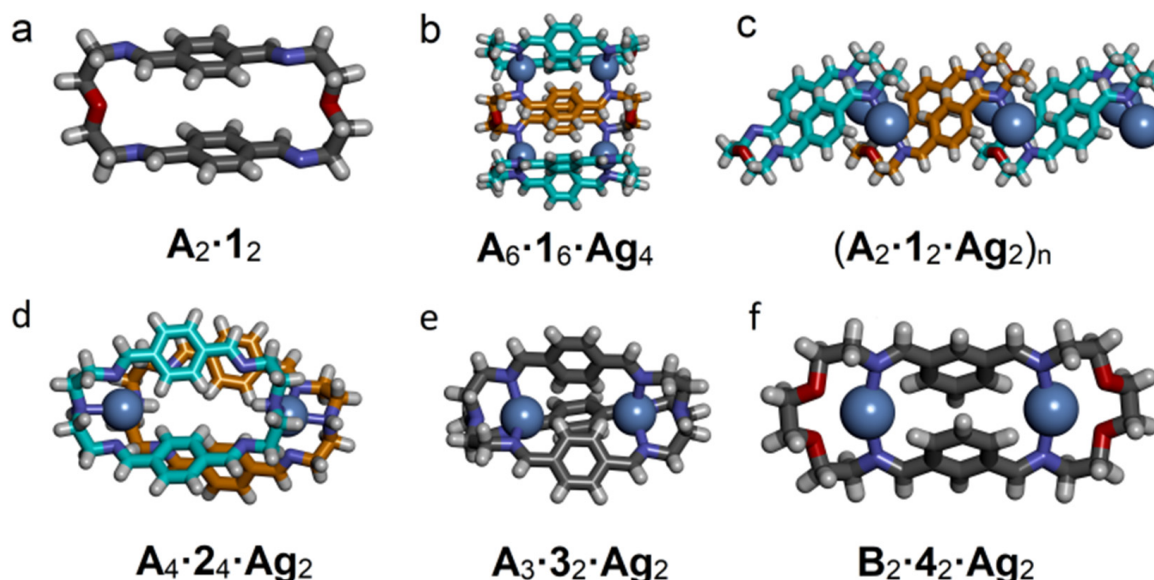
In order to establish dynamic systems for the purpose of crystallization-driven selection, different aldehydes A–C and amine 1–4 compounds (Scheme 1) were first screened for

the possibility of forming single-crystals. from the solution of simple methanolic mixtures of amine-aldehyde components.



**Scheme 1.** Approaches to forming dynamic imine macrocycle or cage crystals from different dialdehyde A–C and amine 1–4 compounds with or without the presence of  $\text{Ag}^+$  metal ions.

Terephthalaldehyde (A), for its good reactivity and linear structural geometry, was chosen to interact with different diamine derivatives through imine formation reactions in methanol. When 2-(2-aminoethoxy)-ethylamine (1) was added in a ratio of 1:1 to react with A, a crystalline macrocycle  $\text{A}_2 \cdot \text{1}_2$  was formed (Figure 1a) with the absence of a metal cation. Meanwhile, with the presence of silver triflate ( $\text{AgOTf}$ ), two types of crystals were simultaneously formed: a cage  $\text{A}_6 \cdot \text{1}_6 \cdot \text{Ag}_4$  with three-layered macrocycles connected by four  $\text{Ag}^+$  metal ions (Figure 1b) and a metal-coordinated supramolecular polymer of exo-coordinated macrocycles  $(\text{A}_2 \cdot \text{1}_2 \cdot \text{Ag}_2)_n$  (Figure 1c). The unexpected formation of crystalline multi-layer and polymeric macrocyclic superstructures instead of simple metallo-macrocyclic monomeric structures can probably be attributed to the preferred four coordination numbers and to the adaptive chelating bonds for  $\text{Ag}^+$  with no  $\text{Ag}^+ \text{-Ag}^+$  contacts within the frameworks. In particular, the rarely seen metallosupramolecular polymeric macrocycles  $(\text{A}_2 \cdot \text{1}_2 \cdot \text{Ag}_2)_n$  demonstrated the high structural diversity that can be discovered and provided by dynamic covalent chemistry.



**Figure 1.** Crystal structures of macrocyclic (a)  $\text{A}_2 \cdot \text{1}_2$ , metallosupramolecular macrocycles and cages (b)  $\text{A}_6 \cdot \text{1}_6 \cdot \text{Ag}_4$ , (c)  $(\text{A}_2 \cdot \text{1}_2 \cdot \text{Ag}_2)_n$ , (d)  $\text{A}_4 \cdot \text{24} \cdot \text{Ag}_2$ , (e)  $\text{A}_3 \cdot \text{32} \cdot \text{Ag}_2$ , and (f)  $\text{B}_2 \cdot \text{42} \cdot \text{Ag}_2$ .

When the compound diethylenetriamine (2) was mixed with dialdehyde A in a ratio of 1:1, no crystal was detected without the presence of the metal cation, leaving only a cyclic imine product formed in solution. With the addition of  $\text{Ag}^+$ , interestingly, the formed crystal  $\text{A}_4 \cdot \text{24} \cdot \text{Ag}_2$  was a cage (Figure 1d) constructed of double-layer macrocyclic

dimers instead of a polymeric-layered one. The  $\text{Ag}^+$  metal ions are four-coordinated by diethylenetriamine arms from two neighboring macrocycles.

By expanding the structure of the amine part from 2D to 3D, tris(2-aminoethyl)-amine (TREN) **3** was chosen to react with dialdehyde **A** and  $\text{AgOTf}$ , in a ratio of 3:2:2 and the crystal structure of cryptand  $\text{A}_3 \cdot 3_2 \cdot \text{Ag}_2$  was obtained (Figure 1e), with four nitrogen atoms in each TREN molecule to coordinate with  $\text{Ag}^+$  metal ions. The narrow-shaped structure with high atom density on each end and three aromatic rings in the middle gave very little space inside the cage. As a result, this very compact monomeric structure is the only one amplified in the solid state and no other polymeric crystal packing structures with a higher degree of complexity were detected during the crystallization process.

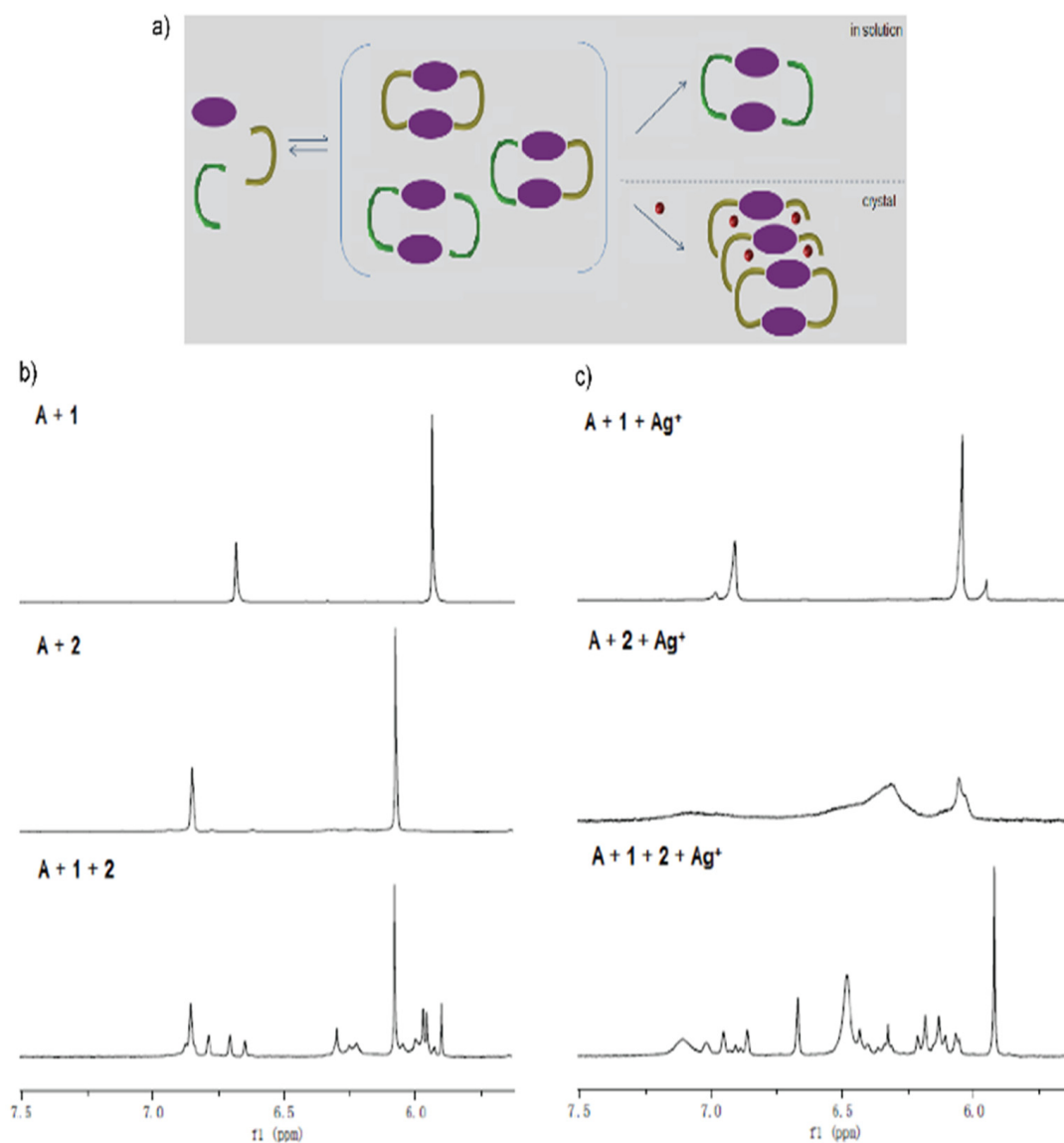
Efforts to increase the chain length by using 2,2'-(ethylenedioxy)-bis(ethylamine) **4** as the diamine to react with dialdehyde **A** did not result in the formation of any exploitable single-crystal formation, with or without the presence of  $\text{Ag}^+$ . On the other hand, isophthalaldehyde (**B**) led to macrocycle crystals  $\text{B}_2 \cdot 4_2 \cdot \text{Ag}_2$  upon interaction with diamine **4**, together with  $\text{AgOTf}$  (Figure 1f). The reason for the unique formation of the macrocycle between **B** and **4** can be attributed to the asymmetrically distributed aldehyde groups in **B**, which provided the possibility for the long-chain diamine **4** to naturally expand between the twisted two aromatic rings and the formation of two  $\text{O}_2\text{N}_2$  macrocycles coordinating the  $\text{Ag}^+$  metal ions on two inner coordinating sites. However, no crystals were further obtained by mixing dialdehyde **B** with amine compounds **1**, **2**, or **3**, even with the coordination possibilities with  $\text{Ag}^+$ , probably due to the steric hindrances from meta-positioned dialdehyde when mixed with short-chain amines.

So far, by one-to-one mixing of each aldehyde and amine compound, distinct crystal structures have been obtained and amplified through the out-of-phase crystallization-driven selection. Within this type of dynamic systems possessing the possibility of forming various formats of the products, including macrocycles, cages, and polymers, the obtained results have already demonstrated the high selectivity and screening efficiency of the crystallization-driven process. Furthermore, we would like to push the dynamic adaptive selection to a library scale by expanding the system with the addition of more starting components, for example, other aldehyde or amine compounds, together in one pot. However, due to the requirement for a certain degree of purity during the crystallization procedure, the size of the dynamic libraries has been limited.

Thus, we established two small dynamic libraries that were examined with or without the presence of  $\text{Ag}^+$ . The reactivity of different diamines or aldehydes in solution and the competitive crystallization ability in each dynamic library can be screened with proper references:

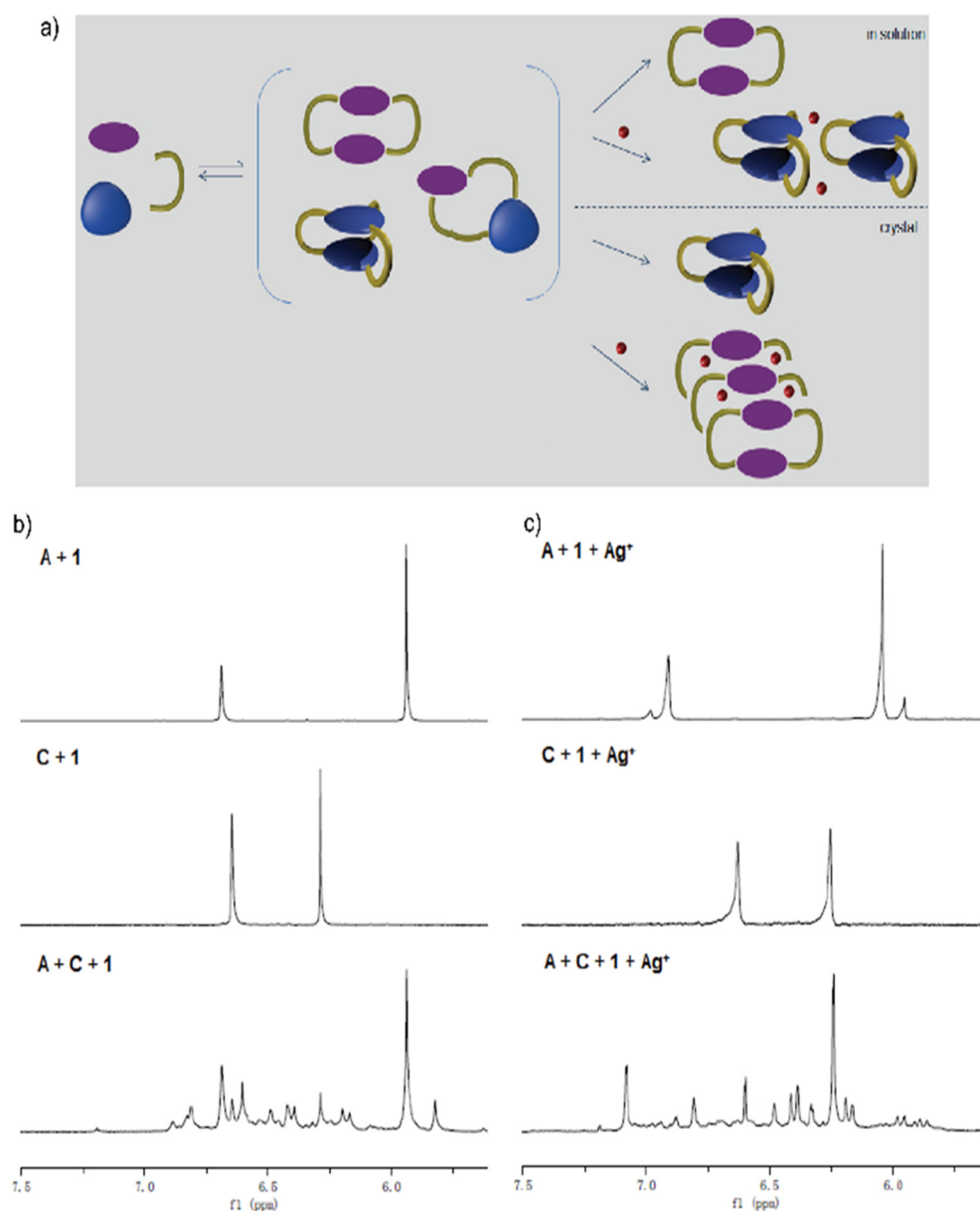
- **L1**: dialdehyde **A** with diamines **1** and **2**;
- **L2**: diamine **1** with aldehydes **A** and **C**.

The first library, **L1**, was generated by mixing **A**, **1**, and **2** in a molar ratio of 1:1:1. For analysis, the reaction in solution was followed by  $^1\text{H-NMR}$  while the crystals were collected and compared to the parameters of each possible crystal, respectively. In the absence of  $\text{Ag}^+$ , an excess of complex **A**·**2** was found in solution slowly exchanging with low-concentrated homocomplex **A**·**1** and heterocomplex **A**·**1**·**2** (Figure 2b), while no crystal formation was detected from these mixtures. After the addition of  $\text{Ag}^+$ , complex peak patterns could be identified from the NMR spectra, reminiscent of fast and low exchange species present in solution. Interestingly, homocomplex **A**·**1**· $\text{Ag}^+$  species could be easily identified in solution, although with a low conversion, while the  $\text{A}_6 \cdot 1_6 \cdot \text{Ag}_4$  cage was selectively formed in a solid crystalline state.



**Figure 2.** (a) Schematic presentation of a selection from the dynamic library L1 containing dialdehyde A and amines 1 and 2.  $^1\text{H-NMR}$  spectra of L1 (b) with the absence and (c) with the presence of  $\text{Ag}^+$ .

Then, a second library L2 containing dialdehyde A, 1,3,5-positioned trialdehyde C, and diamine 1, in a ratio of 3:2:3, was established. The same analytical methods as  $^1\text{H-NMR}$  and X-ray crystallography were adopted to monitor the dynamic systematic screening processes. We previously reported that trialdehyde C reacting with diamine 1 generates a cage of  $\text{C}_2\cdot\mathbf{1}_3$  or an interconnected cage metallosupramolecular  $\text{Ag}^+$  polymer  $(\text{C}_2\cdot\mathbf{1}_3\cdot\text{Ag}_2)_n$ . [16]. As a result, in the absence of  $\text{Ag}^+$ , the A·1 complex was preferred to be formed in the mixture, with a lower amount of C·1 shown in the  $^1\text{H-NMR}$  spectra (Figure 3b); meanwhile, crystal C·1 was detected out of solution as well. On the other hand, with the presence of  $\text{Ag}^+$  to coordinate and stabilize the imine products, the C·1·Ag complex was selectively produced in solution, while only the  $\text{A}_6\cdot\mathbf{1}_6\cdot\text{Ag}_4$  cage crystal was collected in solid state. These are very interesting results, since not only did the addition of  $\text{Ag}^+$  trigger the change of the optimal components, but also the crystallization process showed different ligand preferences than in solution (More detailed data see in supplementary materials).



**Figure 3.** (a) Schematic presentation of selection from a dynamic library containing dialdehyde **A**, trialdehyde **C**, and amine **1**. <sup>1</sup>H-NMR spectra of L2 (b) with the absence and (c) with the presence of Ag<sup>+</sup>.

In conclusion, we discovered new Ag<sup>+</sup> coordinated imine crystals from simple dialdehyde and amine compounds, which led to macrocycle crystal structures, cages of two- or three-layer macrocycles, and even supramolecular polymers. Among the various complex possibilities, the out-of-phase amplification has again proved the amplification effect of imine-connected systems. Furthermore, the dynamic libraries have been generated by mixing more than one aldehyde or amine compound in one system. The resulted change of constituent selection upon addition of Ag<sup>+</sup>, or by comparing chemical distribution in solution and solid states, has fully exemplified the adaptivity of dynamic systems towards different internal structural constraints.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/chemistry4040084/s1>, Figure S1:  $^1\text{H}$  NMR spectrum of crystal  $\text{A}_2 \cdot 1_2$ . Figure S2:  $^1\text{H}$  NMR spectrum of crystal  $\text{A}_6 \cdot 1_6 \cdot \text{Ag}_4$ . Figure S3:  $^1\text{H}$  NMR spectrum of crystal  $\text{A}_4 \cdot 2_4 \cdot \text{Ag}_2$ . Figure S4:  $^1\text{H}$  NMR spectrum of crystal  $\text{A}_3 \cdot 3_2 \cdot \text{Ag}_2$ . Figure S5:  $^1\text{H}$  NMR spectrum of crystal  $\text{B}_2 \cdot 4_2 \cdot \text{Ag}_2$ . Figure S6: Full  $^1\text{H}$  NMR spectra comparison for dynamic library 1, containing dialdehyde **A** and amine **1** and **2**, with or without the presence of  $\text{Ag}^+$ . Figure S7: Full  $^1\text{H}$  NMR spectra comparison for dynamic library 2, containing dialdehyde **A**, trialdehyde **C**, and amine **1**, with or without the presence of  $\text{Ag}^+$ . Table S1: Crystallographic data. References [34–38] are cited in the supplementary materials

**Author Contributions:** Conceptualization, M.B.; methodology, Y.Z.; validation, Y.Z., A.v.d.L. and M.B.; formal analysis, Y.Z. and A.v.d.L.; data curation, Y.Z.; writing—original draft preparation, Y.Z.; writing—review and editing, Y.Z. and M.B.; visualization, M.B.; supervision, M.B. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by Agence Nationale de la Recherche M-ERA NET 2019, ANR-20-MERA-0001-01, SMARTMATTER.

**Data Availability Statement:** The data presented in this study are available on request from the corresponding author.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Lehn, J.-M. From supramolecular chemistry towards constitutional dynamic chemistry and adaptive chemistry. *Chem. Soc. Rev.* **2007**, *36*, 151–160. [[CrossRef](#)] [[PubMed](#)]
2. Miller, B.L. (Ed.) *Dynamic Combinatorial Chemistry*. In *Drug Discovery, Bioorganic Chemistry and Materials Science*; John Wiley and Sons: Hoboken, NJ, USA, 2010.
3. Reek, J.N.H.; Otto, S. (Eds.) *Dynamic Combinatorial Chemistry*; Wiley-VCH: Weinheim, Germany, 2010.
4. Barboiu, M. (Ed.) *Constitutional Dynamic Chemistry*; Topics in Current Chemistry; Springer: Berlin/Heidelberg, Germany, 2012; Volume 322.
5. Goor, O.J.G.M.; Hendrikse, S.I.S.; Dankers, P.Y.W.; Meijer, E.W. From supramolecular polymers to multicomponent biomaterials. *Chem. Soc. Rev.* **2017**, *46*, 6621–6637. [[CrossRef](#)] [[PubMed](#)]
6. Lutz, J.-F.; Lehn, J.-M.; Meijer, E.W.; Matyjaszewski, K. From precision polymers to complex materials and systems. *Nat. Rev. Mater.* **2016**, *1*, 1–14. [[CrossRef](#)]
7. Liu, B.; Thayumanavan, S. Substituent effects on the pH sensitivity of acetals and ketals and their correlation with encapsulation stability in polymeric nanogels. *J. Am. Chem. Soc.* **2017**, *139*, 2306–2317. [[CrossRef](#)] [[PubMed](#)]
8. Zeng, X.; Liu, G.; Tao, W.; Ma, Y.; Zhang, X.; He, F.; Pan, J.; Mei, L.; Pan, G. A drug-self-gated mesoporous antitumor nanoplatfrom based on pH-sensitive dynamic covalent bond. *Adv. Funct. Mater.* **2017**, *27*, 1605985. [[CrossRef](#)]
9. Zhang, Y.; Barboiu, M. Constitutional Dynamic Materials—Toward Natural Selection of Function. *Chem. Rev.* **2016**, *116*, 809–834. [[CrossRef](#)]
10. Kasseem, S.; van Leeuwen, T.; Lubbe, A.S.; Wilson, M.R.; Feringa, B.L.; Leigh, D.A. Artificial molecular motors. *Chem. Soc. Rev.* **2017**, *46*, 2592–2621. [[CrossRef](#)]
11. Foy, J.T.; Li, Q.; Goujon, A.; Colard-Itté, J.-R.; Fuks, G.; Moulin, E.; Schiffmann, O.; Dattler, D.; Funeriu, D.P.; Giuseppone, N. Dual-light control of nanomachines that integrate motor and modulator subunits. *Nat. Nanotechnol.* **2017**, *12*, 540–545. [[CrossRef](#)]
12. Zhang, Y.; Hu, L.; Ramström, O. Double parallel dynamic resolution through lipase-catalyzed asymmetric transformation. *Chem. Commun.* **2013**, *49*, 1805–1907. [[CrossRef](#)]
13. Zhang, Y.; Vongvilai, P.; Sakulsombat, M.; Fischer, A.; Ramström, O. Asymmetric Synthesis of Substituted Thiolanes through Domino Thia-Michael–Henry Dynamic Covalent Systemic Resolution using Lipase Catalysis. *Adv. Synth. Catal.* **2014**, *356*, 987–992. [[CrossRef](#)]
14. Clever, G.H.; Punt, P. Cation–anion arrangement patterns in self-assembled Pd2L4 and Pd4L8 coordination cages. *Acc. Chem. Res.* **2017**, *50*, 2233–2243. [[CrossRef](#)] [[PubMed](#)]
15. Cook, T.R.; Stang, P.J. Recent developments in the preparation and chemistry of metallacycles and metallacages via coordination. *Chem. Rev.* **2015**, *115*, 7001–7045. [[CrossRef](#)] [[PubMed](#)]
16. Fujita, D.; Ueda, Y.; Sato, S.; Mizuno, N.; Kumasaka, T.; Fujita, M. Self-assembly of tetravalent Goldberg polyhedra from 144 small components. *Nature* **2016**, *540*, 563–566. [[CrossRef](#)] [[PubMed](#)]
17. Danon, J.J.; Krüger, A.; Leigh, D.A.; Lemonnier, J.; Stephens, A.J.; Vitorica-yrezabal, I.J.; Woltering, S.L. Braiding a molecular knot with eight crossings. *Science* **2017**, *355*, 159–162. [[CrossRef](#)] [[PubMed](#)]

18. Fernandez, A.; Ferrando-Soria, J.; Pineda, E.M.; Tuna, F.; Vitorica-Yrezabal, I.J.; Knappke, C.; Ujma, J.; Muryn, C.A.; Timco, G.A.; Barran, P.E.; et al. Making hybrid [n]-rotaxanes as supramolecular arrays of molecular electron spin qubits. *Nat. Commun.* **2016**, *7*, 1–6. [[CrossRef](#)] [[PubMed](#)]
19. Zhang, Z.; Wang, H.; Wang, X.; Li, Y.; Song, B.; Bolarinwa, O.; Reese, R.A.; Zhang, T.; Wang, X.; Cai, J.; et al. Supersnowflakes: Stepwise self-assembly and dynamic exchange of rhombus star-shaped supramolecules. *Am. Chem. Soc.* **2017**, *139*, 8174–8185. [[CrossRef](#)] [[PubMed](#)]
20. Nguyen, M.T.; Krzyaniak, M.D.; Owczarek, M.; Ferris, D.P.; Wasielewski, M.R.; Stoddart, J.F. A Boat-Shaped Tetracationic Macrocyclic with a Semiconducting Organic Framework. *Angew. Chem.* **2017**, *129*, 5889–5894. [[CrossRef](#)]
21. Munkhbat, O.; Garzoni, M.; Raghupathi, K.R.; Pavan, G.M.; Thayumanavan, S. Role of aromatic interactions in temperature-sensitive amphiphilic supramolecular assemblies. *Langmuir* **2017**, *32*, 2874–2881. [[CrossRef](#)]
22. Habault, D.; Zhang, H.; Zhao, Y. Light-triggered self-healing and shape-memory polymers. *Chem. Soc. Rev.* **2013**, *42*, 7244–7256. [[CrossRef](#)]
23. Greb, L.; Mutlu, H.; Barner-kowollik, C.; Lehn, J. Photo- and metallo-responsive N-alkyl  $\alpha$ -bisimines as orthogonally addressable main-chain functional groups in metathesis polymers. *J. Am. Chem. Soc.* **2016**, *138*, 1142–1145. [[CrossRef](#)]
24. Ji, Q.; Lirag, R.C.; Miljanic, O.S. Kinetically controlled phenomena in dynamic combinatorial libraries. *Chem. Soc. Rev.* **2014**, *43*, 1873–1884. [[CrossRef](#)] [[PubMed](#)]
25. Kovaricek, P.; Lehn, J.-M.; Samori, P. Dynamic covalent chemistry of bisimines at the solid/liquid interface monitored by scanning tunnelling microscopy. *Nat. Chem.* **2014**, *6*, 1017–1023.
26. Zhang, Y.; Ramström, O. Thiazolidinones Derived from Dynamic Systemic Resolution of Complex Reversible-Reaction Networks. *Chem. Eur. J.* **2014**, *20*, 3288–3291. [[CrossRef](#)] [[PubMed](#)]
27. Zhang, Y.; Hu, L.; Ramström, O. Constitutional dynamic chemistry for bioactive compounds. In *Supramolecular Systems in Biomedical Fields*; Schneider, H.J., Ed.; Springer: Berlin/Heidelberg, Germany, 2013; pp. 397–418.
28. Dhers, S.; Holub, J.; Lehn, J.-M. Coevolution and ratiometric behaviour in metal cation-driven dynamic covalent systems. *Chem. Sci.* **2017**, *8*, 2125–2130. [[CrossRef](#)]
29. Kulchat, S.; Chaur, M.N.; Lehn, J.-M. Kinetic selectivity and thermodynamic features of competitive imine formation in dynamic covalent chemistry. *Chem. Eur. J.* **2017**, *23*, 11108–11118. [[CrossRef](#)]
30. Barboiu, M.; Dumitru, F.; Legrand, Y.; Van Der Lee, A. Self-sorting of equilibrating metallosupramolecular DCLs via constitutional crystallization. *Chem. Commun.* **2009**, *16*, 2192–2194. [[CrossRef](#)]
31. Angelin, M.; Vongvilai, P.; Fischer, A.; Ramström, O. Crystallization-Driven Asymmetric Synthesis of Pyridine- $\beta$ -nitroalcohols via Discovery-Oriented Self-Resolution of a Dynamic System. *Eur. J. Org. Chem.* **2010**, *33*, 6315–6318. [[CrossRef](#)]
32. Kocsis, I.; Dumitrescu, D.; Legrand, Y.; Van Der Lee, A.; Grosu, I.; Barboiu, M. Self-sorting of dynamic metallosupramolecular libraries (DMLs) via metal-driven selection. *Chem. Commun.* **2014**, *50*, 2621–2623. [[CrossRef](#)]
33. Zhang, Y.; Legrand, Y.M.; Van Der Lee, A.; Barboiu, M. Ligand- and Metal-Driven Selection of Flexible Adaptive Dynamic Host Receptors. *Eur. J. Org. Chem.* **2016**, *10*, 1825–1828. [[CrossRef](#)]
34. Gilles, A.; Barboiu, M. Highly selective artificial K<sup>+</sup> channels: An example of selectivity-induced transmembrane potential. *J. Am. Chem. Soc.* **2016**, *138*, 426–432. [[CrossRef](#)]
35. CrysAlisPro. *Rikagu Oxford Diffraction*; Agilent Technologies Inc.: Oxfordshire, UK, 2012.
36. Lee, A. Charge flipping for routine structure solution. *J. Appl. Crystallogr.* **2013**, *46*, 1306–1315.
37. Palatinus, L.; Chapuis, G. SUPERFLIP—a computer program for the solution of crystal structures by charge flipping in arbitrary dimensions. *J. Appl. Crystallogr.* **2007**, *40*, 786–790. [[CrossRef](#)]
38. Betteridge, P.W.; Carruthers, J.R.; Cooper, R.I.; Prout, K.; Watkin, D.J. Crystals suite of programs. *J. Appl. Crystallogr.* **2003**, *36*, 1487. [[CrossRef](#)]