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Synthesis, characterization and ion transportation studies of some novel cyclophane amides

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Abstract—Various novel cyclophane amides with a large cavity have been synthesized. The structures of cyclophane amides **14** and **15** were resolved using XRD studies. Cyclophane amide **28** shows a shift in λ_{max} in the UV/Vis. spectra when treated with Cu (II) ion as well as with Pb (II) ion. Ion transportation studies were carried out with cyclophane amide **14** which proved that the Na^+ ion passes through the cavity while K^+ ions are retained.
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1. Introduction

The synthesis of new supramolecules for studying biomolecular interactions stimulates the imaginative skill of synthetic chemists. Synthesis of amide based supramolecular system has been reported in the literature.[1–17] Cyclic peptides[18] with open pores are useful as transport vehicles for biologically important ions or neutral molecules[19] or as catalysts[20] and for studying host-guest chemistry. Synthesis and complexation studies with tyrosinophanes has been reported earlier.[21] Cystine based cyclic peptide has the ability to form a double—helical structure.[22] The self-assembly of acyclic peptides and hence their ability to form beta-sheet structures has also been demonstrated.[23,24] The conformational aspects and molecular recognition ability of cystinophanes are well known.[25] Adamantane based systems also form double-helical cyclic structures.[24,26] The ability of cyclic peptides to form nanotubes has been well documented.[27,28] Serinophanes form a tubular structure due to aromatic π–π interactions.[29]

The ion transport properties of macrocycles are biologically relevent[30] and ion transport through membranes has been characterized with adamantane based cyclophanes[31] and with norbornene based cyclic peptides.[32] Thus cyclic amides play an important role in various biological systems and hence, by varying the size of the cavity, cyclic amides can be used for the transport of a particular ion in preference to the other ions. Once the synthesis of the targeted cyclic amide is carried out, the cyclic amide can be impregnated into a membrane and can be used for ion transport.[33] Intramolecular hydrogen bonding can collapse the cyclic peptide to a minimum accompanied by folding of the backbone.[34] However, due to intermolecular hydrogen bonding the cyclic amide can show self assembling properties that would eventually lead to tubular structure and hence have potential to be used as nano material devices. Furthermore such cyclic amides can form complexes with metal ions like Cd (II),[35] Fe (III)[20] and Cu (II) and hence they can be used for selective metal ion complexation studies[36] and also as a neutral host for anion complexation.[37] Amides are also used as molecular receptors[38] and in the molecular recognition[39] of biologically interacting substrates including anti-HIV active macrocyclic amides.[40] With such views in mind we focused our attention on the synthesis of various cyclic amides. Herein we report the synthesis and characterization of various cyclic amides with varied cavity size. Furthermore we describe herein the ion transport studies of some of the cyclic amides.

2. Results and discussion

Diacid chlorides **1–5** were prepared and used for the synthesis of cyclophane amides.

Keywords: Cyclophane amides; Adamantane; Macrocyclic amides.
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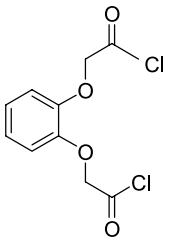

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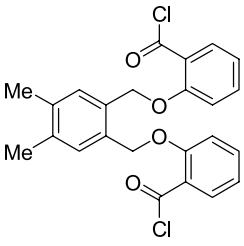

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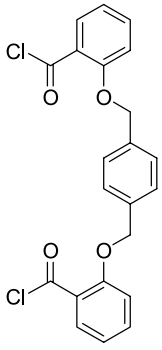

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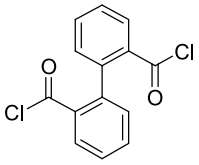

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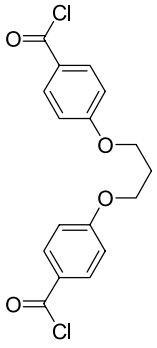

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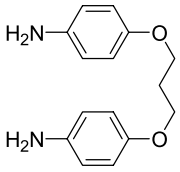

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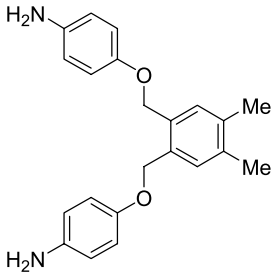

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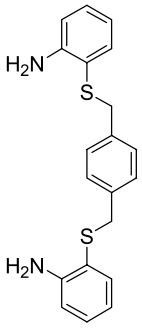

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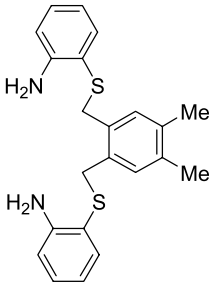

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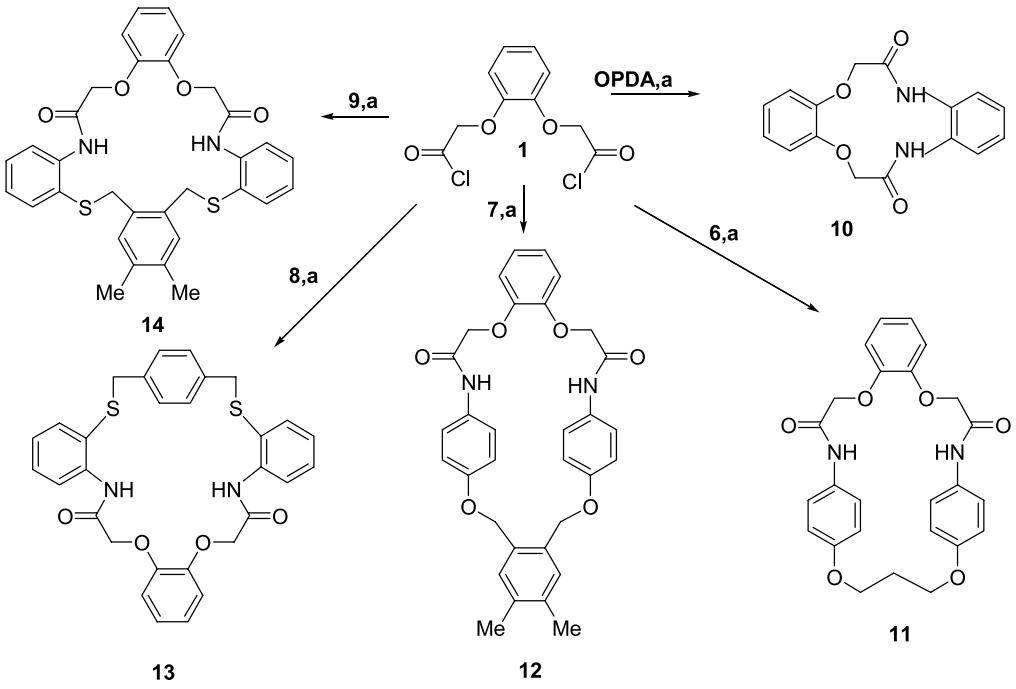
Reaction of catechol with 2.1 equiv of ethyl chloroacetate in the presence of potassium carbonate followed by the hydrolysis of the resulting diethyl ester gave the corresponding diacid, which was then reacted with thionyl chloride to give diacid chloride **1**.[41] The diacid derived for diacid chloride **1** was also prepared from the respective diol.[42] Reaction of 4,5-bis (chloromethyl)-*o*-xylene[43] with 2.1 equiv of methyl salicylate followed by hydrolysis of the resulting dimethyl ester and subsequent reaction with thionyl chloride gave diacid chloride **2**. Diacid chloride **3** was obtained from the corresponding dicarboxylic acid. The respective dicarboxylic acid was reported earlier[44] in 55% overall yield by the reaction of *p*-xylylene dibromide with methyl salicylate in the presence of NaH in THF followed by hydrolysis. However in the present investigation the diacid was obtained in 95% overall yield by the alkylation of *p*-xylylene dibromide with methyl salicylate in the presence of anhydrous potassium carbonate and KI in acetonitrile followed by hydrolysis of the resulting diester. Reaction of the corresponding dicarboxylic acid with thionyl chloride in methylene chloride gave diacid chloride **3** in quantitative yield. Diphenic acid chloride **4** was prepared by the reaction of diphenic acid and thionyl chloride. The diacid chloride **5** was obtained from the corresponding diacid which was reported earlier.[45] The diacid was also prepared from 1,3-dibromopropane and *p*-hydroxybenzoic acid in presence of NaOH in DMSO.[46] By another method, 1,3-dibromopropane was reacted with methyl *p*-hydroxybenzoate and the resulting diester was hydrolyzed to give the dicarboxylic acid.[47] In the current investigation the later method was employed and the resulting dicarboxylic acid was reacted with thionyl chloride to give diacid chloride **5**.

Diamines **6–9** were prepared and used for the synthesis of cyclophane amides.

Diamine **6** has been used previously for polymerization.[48] In the earlier method[49] 1,3-dibromopropane was treated with *p*-nitrophenol and the resulting dinitro compound was then reduced to give diamine **6**. In a later method[50] 1,3-dibromopropane was treated with 4-hydroxy acetanilide and resulting product was hydrolyzed to give **6**. However, in both the references cited above detailed experimental procedure was not available as the reported methods were patented. Hence, in the present investigation 1,3-dibromopropane was treated with 2.1 equiv of *p*-nitrophenol in acetonitrile in the presence of anhydrous potassium carbonate and KI and the resulting dinitro compound was reduced with hydrogen in the presence of Pd/C to give the diamine **6** in 65% overall yield. Similarly diamine **7** was also prepared by the reaction of 4,5-bis (chloromethyl)-*o*-xylene with *p*-nitrophenol by the usual procedure to give dinitro compound, which was reduced with hydrogen in the presence of Pd/C to give diamine **7**. Though diamine **8** was reported recently,[51] in the present investigation 2.1 equiv of *o*-aminothiophenol were treated with *p*-xylylene dibromide to give diamine **8** in 90% yield. Diamine **9** was also prepared by a similar method from the reaction of 4,5-bis (chloromethyl)-*o*-xylene with *o*-aminothiophenol.

The diester derived from diacid chloride **1** has been extensively used for the formation of macrocyclic amides.[52] Diacid chloride **1** has been also used for the preparation of macrocyclic amides.[53] Similarly the reaction of diacid chloride **1** with arylamines has also been studied.[54] In the current investigation, diacid chloride **1** was used for the synthesis of cyclophane amides. Reaction of diacid choride **1** with *o*-phenylenediamine (OPDA) in chloroform and in the presence of triethylamine afforded cyclophane amide **10** in 50% yield. Cyclophane amide **10** in the ^{1}H NMR showed the OCH_2 and NH protons at δ 4.76, at δ 9.71 in addition to



Scheme 1. (a) Triethyl amine, $CHCl_3$, rt, 6 h.

aromatic protons at δ 7.04 to 7.63 and in the mass spectrum the molecular ion appeared at *m/z* 298. Similarly acid chloride **1** with various diamines **6**, **7**, **8** and **9** gave cyclophane amides **11**, **12**, **13** and **14** in 45%, 50%, 40% and 45% yield respectively. The reaction sequence is given in Scheme 1.

Compound **11** in the ^{1}H NMR displayed the OCH_2CH_2-CH_2O protons at δ 1.83 and δ 4.15 and OCH_2CO protons appeared as a singlet at δ 4.59 and the NH proton appeared at δ 9.55 in addition to the aromatic protons. Compound **12** in the ^{1}H NMR displayed the aromatic methyl protons at δ 2.23 and the two sets of OCH_2 protons appeared at δ 4.56 and δ 5.00 in addition to the aromatic protons. Compound **13** in the ^{1}H NMR displayed the SCH_2 and OCH_2 protons at δ 3.79 and δ 4.55 respectively and the NH protons at δ 9.39 in addition to the aromatic protons. In the ^{1}H NMR, cyclophane **14** displayed signals at δ 1.99, δ 3.91, δ 4.51 and

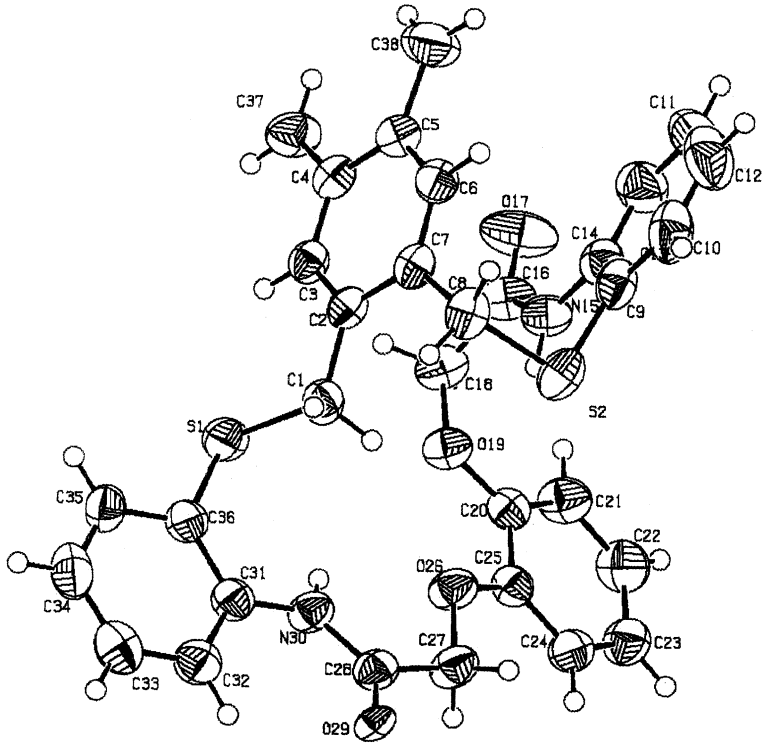


Figure 1. ORTEP diagram for **14**.

δ 9.48 for aromatic methyl, SCH_2, OCH_2 and NH protons, respectively, in addition to the aromatic protons at δ 6.45 to δ 8.39.

X-ray diffraction (XRD) studies on cyclophane **14**[55] showed the presence of intramolecular hydrogen bonding and hence cyclophane **14** is not planar and one of the benzene rings is puckered (Figs. 1 and 2). Though cyclophane **14** can show self-assembling properties and hence can generate channel, XRD showed only intramolecular hydrogen bonding rather than intermoleculer hydrogen bonding.

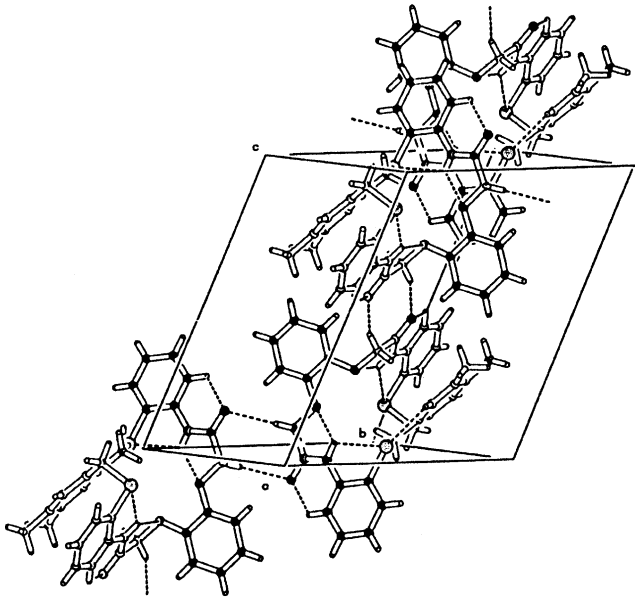
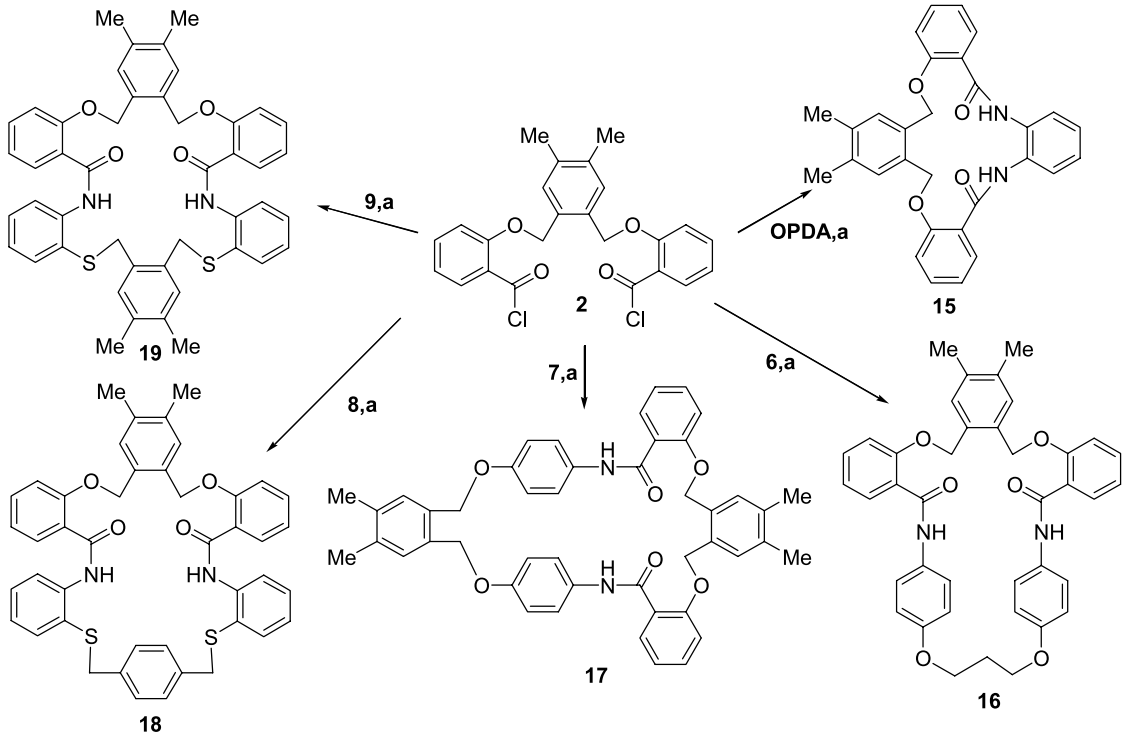


Figure 2. Crystal lattice diagram for **14**.

In order to synthesize large cavity cyclophanes with amide linkages diacid chloride **2** was used. In order to test the suitability of diacid chloride **2** for the formation of cyclophane, diacid chloride **2** was reacted with *o*-phenylenediamine and cyclic diamide **15** was obtained in 50% yield. In the ^{1}H NMR the aromatic methyl, OCH_2 and NH protons appeared at δ 2.23, δ 5.24 and δ 9.64, respectively, in addition to the aromatic protons. In the mass spectrum the molecular ion appeared at *m*/*z* 478. Similarly reaction of diacid chloride **2** with diamines **6**, **7**, **8** and **9** gave cyclophanes **16**, **17**, **18** and **19** in 47, 43, 50 and 50% yield, respectively (Scheme 2).

XRD studies were carried out for cyclophane **15**.[56] One of the benzene rings derived from the *o*-phenylenediamine unit is orthogonal to the xylenyl unit and the molecule is not planar due to intramolecular hydrogen bonding and XRD shows the dimeric structure in crystal packing (Figs. 3 and 4). Cyclophane **16** in the ^{1}H NMR displayed aromatic methyl and OCH_2 protons at δ 2.30 and δ 5.23. The OCH_2 CH_2 CH_2O protons group appeared at δ 1.95 and δ 4.08 and NH protons at δ 9.57. Cyclophane **17** in the ^{1}H NMR displayed two types of aromatic methyl at δ 2.22 and δ 2.29 and two sets of OCH_2 protons appeared at δ 5.04 and δ 5.38 and the NH protons appeared at δ 9.60 in addition to the aromatic protons. Cyclophane **18** in the ^{1}H NMR displayed singlet at δ 2.21, δ 3.94, δ 5.01 and δ 11.07 for aromatic methyl, SCH_2, OCH_2 and NH protons in addition to the aromatic protons and the molecular ion appeared at *m*/*z* 722 in the FAB mass spectrum. Cyclophane amide **19** showed two types of aromatic methyl protons at δ 1.87 and δ 2.02 and SCH_2, OCH_2 and NH protons at δ 3.70, δ 5.26 and δ 10.42, respectively, in the ^{1}H NMR.

Further, we focused attention on the synthesis of cyclophane



Scheme 2. (a) Triethyl amine, $CHCl_3$,rt, 6 h.

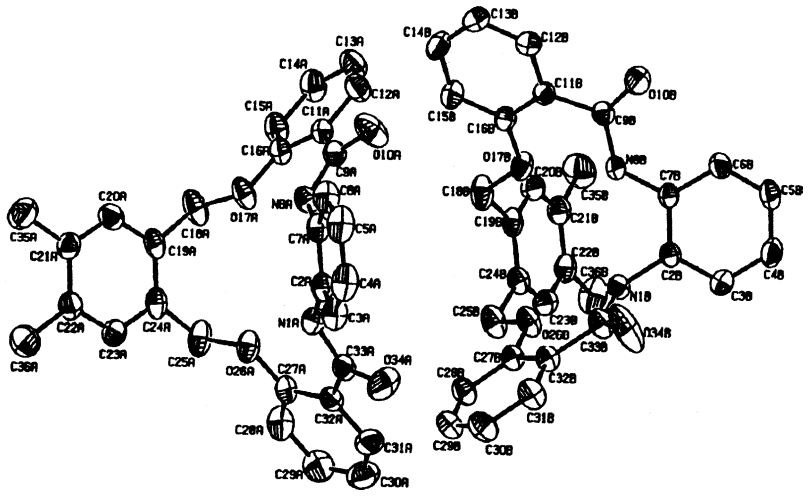


Figure 3. ORTEP diagram for **15**.

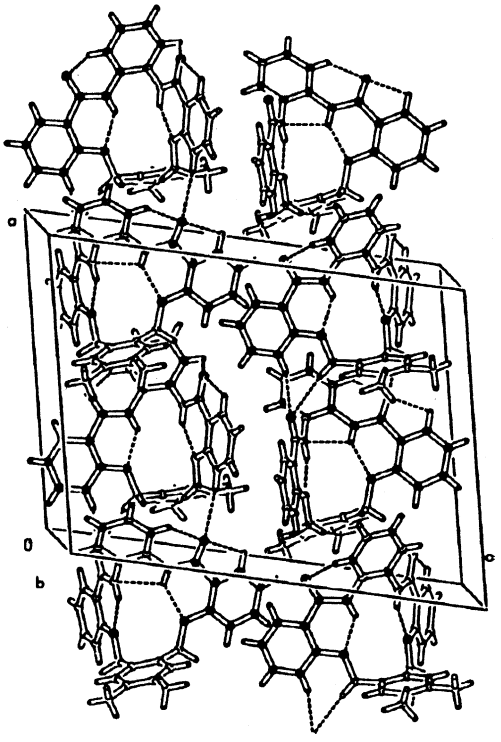


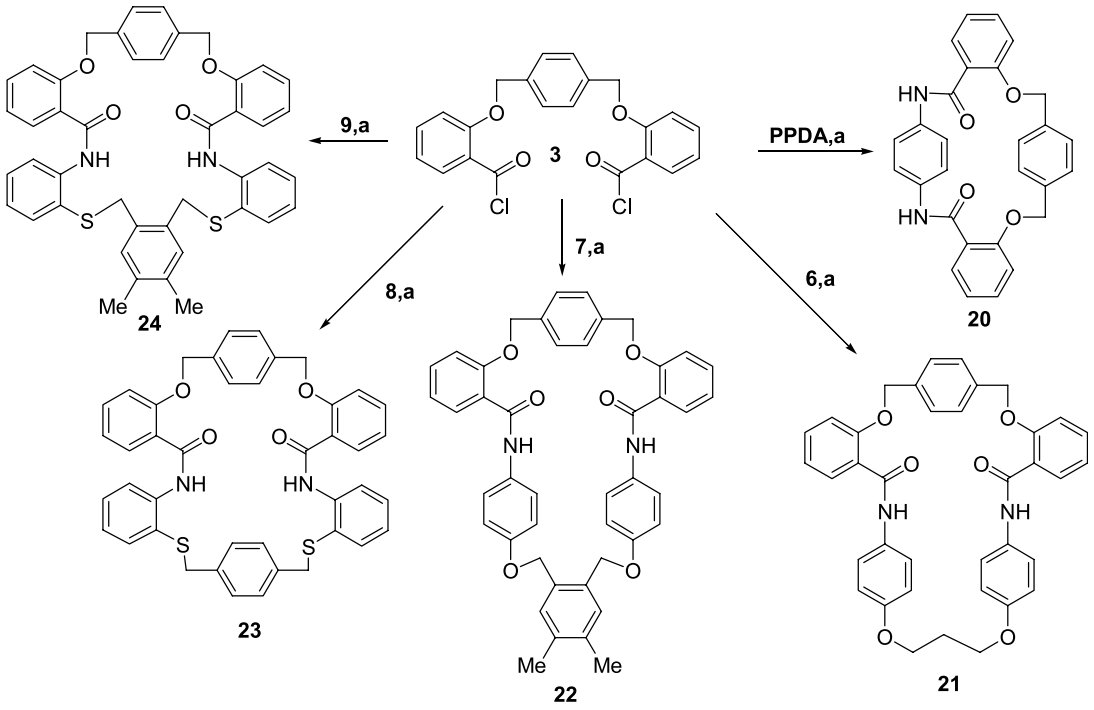
Figure 4. Crystal lattice diagram for **15**.

amides based on diacid chloride **3** because of the fact that the cavity size could still be large due to the *p*-xylenyl spacer. Reaction of diacid chloride **3** with *p*-phenylenediamine and diamines **6**, **7**, **8** and **9** gave cyclophanes **20**, **21**, **22**, **23**, and **24** in 45, 42, 48, 50 and 48% yield, respectively (Scheme 3).

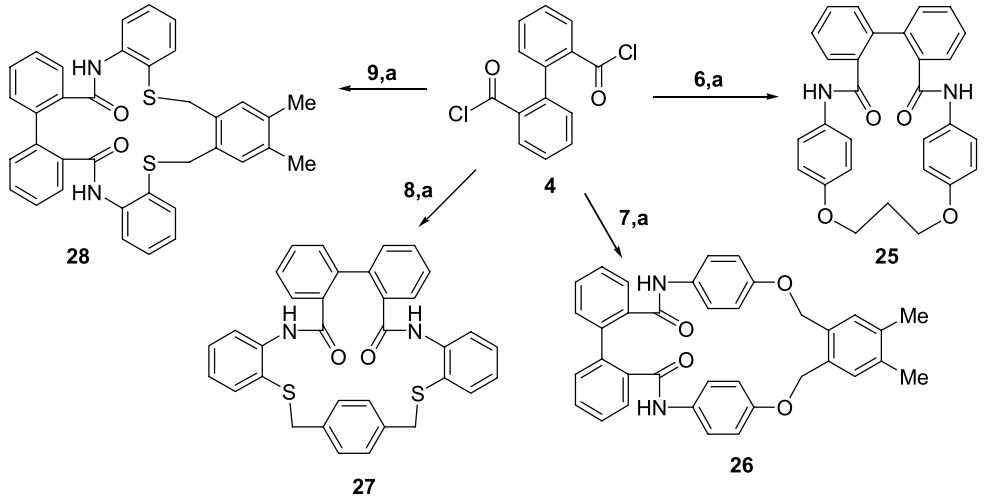
Cyclophane amides **20**, **21**, **22**, **23**, and **24** displayed molecular ions at *m*/*z* 450 (EI), 600 (EI), 690 (EI), 694 (FAB mass spectrum) and 722 (FAB Mass spectrum), respectively. Cyclophane **20** in the ^{1}H NMR displayed singlet at δ 5.01 and δ 9.61 for OCH_2 and NH protons in addition to aromatic protons. Cyclophane **21** in the ^{1}H NMR displayed a two-proton quintet at δ 2.09 and a four-proton triplet at δ 4.17. OCH_2 protons at *p*-xylenyl unit and NH protons appeared as singlets at δ 5.27 and δ 9.79 in addition to the aromatic protons. Cyclophane **22** in the ^{1}H NMR displayed aromatic methyl, two sets of OCH_2 protons and NH protons at δ 2.26, δ 5.05, δ 5.27 and δ 9.80 in addition to the aromatic protons. Diamide **23** in the ^{1}H NMR displayed SCH_2, OCH_2 and NH protons at δ 3.84, δ 5.18 and δ 10.58 in addition to the aromatic protons. Similarly cyclophane amide **24** also showed aromatic methyl, SCH_2, OCH_2 and NH protons at δ 1.93, δ 3.48, δ 5.26 and δ 10.50 in addition to the aromatic protons.

It is of interest to use the acid chloride derived from diphenic acid because biphenyl compounds can show atropisomerism. With this view, various cyclophane amides were synthesized from diphenic acid chloride. Diacid chloride **4** was obtained by the reaction of diphenic acid with thionyl chloride. Diacid chloride **4** on reaction with various amines **6**, **7**, **8** and **9** under the usual condition gave cyclophane amides **25**, **26**, **27** and **28** in 40, 44, 40 and 45% yield, respectively (Scheme 4).

In the mass spectrum cyclophanes **25**, **26**, **27** and **28** displayed molecular ion at *m*/*z* 464 (EI), 554 (EI), 558 (EI) and 586 (EI), respectively. In the ^{1}H NMR cyclophane **25** showed the OCH_2 CH_2 CH_2O protons at δ 1.88 and δ 4.10 for two and four protons in addition to the NH protons at δ 9.90 and aromatic protons at δ 7.30 to δ 7.56. A singlet was observed at δ 6.38 for four protons which apparently indicates that one of the phenyl rings derived from the amine is orthogonal to the other and due to free rotation all the four protons of the benzene ring is continuously shielded in the aromatic π clouds of the other benzene ring and hence four aromatic protons appear at a different region than the other aromatic protons. ^{1}H NMR of cyclophane **26** displayed aromatic methyl, OCH_2 and NH protons at δ 2.27, δ 4.88 and δ 5.01 (ABq, J=10.8 Hz) and δ 9.32 respectively in addition to the aromatic protons. As evidenced earlier one of the benzene rings lies perpendicular to the other and due to shielding effect four aromatic protons are observed as a doublet at δ 6.36 with J=9.3 Hz. Cyclophane **27** in the ^{1}H NMR displayed SCH_2 protons as an AB quartet at δ 3.72 and δ 3.92 with J= 11.7 Hz in addition to the aromatic protons and NH protons

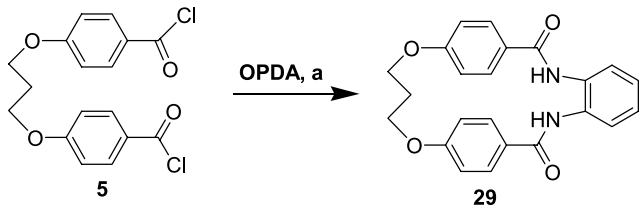


Scheme 3. (a)Triethyl amine, $CHCl_3$, rt, 6 h.



Scheme 4. (a) Triethyl amine, $CHCl_3$,rt, 6 h.

at δ 8.46. Similarly, cyclophane **28** in the ^{1}H NMR displayed aromatic methyl at δ 1.99 and SCH_2 protons appeared as an AB quartet at δ 3.40 and δ 3.56 with $J=$ 12.7 Hz and the NH protons appeared at δ 8.48 in addition to the aromatic protons.



Scheme 5. (a) Triethyl amine, $CHCl_3$, rt, 6 h.

Finally the utilization of acid chloride **5** for the synthesis of cyclophane diamide was explored by employing with *o*-phenylenediamine. Cyclophane diamide **29** was obtained in 35% yield by the reaction of acid chloride **5** with *o*-phenylenediamine (Scheme 5).

In the ^{1}H NMR compound **29** displayed the OCH_2 CH_2 CH_2O protons at δ 1.91 and δ 4.20 and the aromatic protons appeared as an AB quartet at δ 6.67 and δ 7.47 with $J=$ 8.8 Hz for eight protons and the aromatic protons derived from the *o*-phenylenediamine moiety appeared at δ 7.34 as a broad singlet and the NH protons were observed at δ 9.10. Some of the cyclophanes synthesized were tested for their complexation behavior with metal ions like copper (II) and lead (II) as well as for ion transportation studies.

3. X-ray diffraction study

Recrystallisation of the cyclophane **14** in chloroform/hexane afforded a single crystal suitable for the XRD studies. The bond lengths and the bond angles have been reported earlier.[55] The crystal parameters are given in Table 1 and ORTEP diagram as well as crystal lattice diagram are shown in Figures 1 and 2.

Table 1. Crystal data for cyclophane **14**

$C_{32}H_{30}N_2O_4S_2$	$Z=2$
$M_r=570.70$	$D_x=1.314$ Mg m^{-3}
Triclinic, $P\bar{1}$	Mo $K\alpha$ radiation
$a=8.5860$ (7) Å	Cell parameters from 2732 reflections
$b=12.9090$ (10) Å	$\theta=2.7$–$26.3°$
$c=14.7552$ (11) Å	$\mu=0.23$ mm^{-1}
$\alpha=65.065$ (1)°	$T=293$ (2) K
$\beta=84.701$ (1)°	Needle, colourless
$\gamma=76.522$ (1)°	$0.25\times0.19\times0.14$ mm
$V=1442.1$ (2) Å^3	

XRD studies proved that intramolecular hydrogen bonding exists in cyclophane **14** and hence it is not planar though aromatic rings were introduced to make the molecule planar.

Similarly XRD studies were carried out with cyclophane **15** after obtaining a crystal from chloroform/methanol and the crystal parameters are given in Table 2. The ORTEP diagram and lattice crystal diagram are shown in Figures 3 and 4. Again in cyclophane **15** one of the benzene rings is orthogonal to the rest of the molecule. XRD studies of cyclophanes **19** and **23** are currently under investigation.

Table 2. Crystal data for cyclophane **15**

$C_{30}H_{26}N_2O_4$	$D_x=1.288$ Mg m^{-3}
$M_r=478.53$	Mo $K\alpha$ radiation
Monoclinic, $P2_1/n$	Cell parameters from 5463 reflections
$a=15.5767$ (9) Å	$\theta=2.3$–$21.7°$
$b=15.7746$ (9) Å	$\mu=0.09$ mm^{-1}
$c=20.5721$ (12) Å	$T=293$ (2) K
$\beta=102.541$ (1)°	Block, colourless
$V=4934.3$ (5) Å^3	$0.24\times0.20\times0.16$ mm
$Z=8$	

Though intermolecular hydrogen bonding could lead to self-assembling properties, cyclophane **14** and **15** did not exhibit such properties. Thus from the X- ray diffraction studies, it is clear that intramolecular hydrogen bonding predominates over intermolecular hydrogen bonding under solid state conditions.

4. UV/Vis spectral studies

Cyclophane amide **14**, **19** and **24** in CH_3CN showed λ_{max} in the UV/Vis. spectrum at 209, 206 and 290, 208 and 287 nm, respectively. However, no shift in λ_{max} was observed even after the addition of required amount of either Cu (II) acetate or Pb (II) acetate to cyclophane amide **14**, **19** and **24** in CH_3CN. Cyclophane amide **28** shows λ_{max} at 221 nm in CH_3OH in the UV spectrum and after the addition of Cu (II) acetate, λ_{max} was observed at 273 nm. Similarly when Pb (II) acetate was added to the solution of cyclophane amide **28** in CH_3OH, λ_{max} was observed at 235 nm. The shift in λ_{max} observed by the addition of Cu (II) acetate as well as Pb (II) acetate in the case of cyclophane amide **28**, could be due to the formation of metal receptor complex. However the complexes could not be thoroughly characterized, due to their instability, insolubility in usual NMR solvents and further because of paramagnetic behavior.

5. Ion transportation studies

In the current investigation, a glass vessel as depicted in Figure 5 was fabricated in order to test the ability of cyclophane amides towards ion transporting phenomenon. Though cyclophane amides **14** and **15** do not exhibit self-assembling characteristics in solid phase as evidenced by XRD studies, it is of interest to test the ion transport property in solution phase.

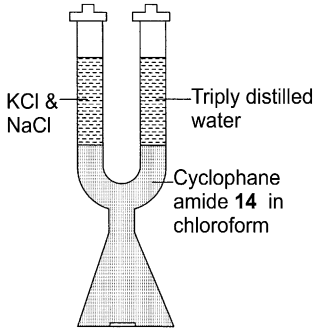


Figure 5. Apparatus used for ion transport study by cyclophane amide **14**.

Cyclophane amide **14** was dissolved in chloroform and kept in a conical flask fitted with a U tube as shown in Figure 5. One arm of the U tube is filled with water in which NaCl and KCl were dissolved and the other arm is filled with triply distilled water. The chloroform layer was stirred for 5 days. The arm that was filled with triply distilled water showed the presence of Na^+ ion and K^+ ion level was below the detecting limit (less than 0.4 mg/l). Thus the experiment proved that Na^+ ions were transported by cyclophane amide **14** from one arm to the other. The size of Na^+ ion (ionic radius: 0.95 Å) and the cavity dimension of cyclophane **14** (4.4×6.1 Å^2) are complementary to each other, whereas the size of K^+ ion (ionic radius: 1.33 Å) does not match with cavity size. Hence cyclophane amide **14** could be used as a potential ion filtering system for retaining the biologically important K^+ ion and eliminating Na^+ ion. It is noteworthy to mention that K^+ ion play a vital role in blood brain barrier. A blank experiment was also performed in chloroform without cyclophane amide and no such ion mobility was observed. Currently, we are investigating such preferential ion mobility of other cyclophane amides. Further, impregnation of the cyclophane amide **14** on membrane and ion transport studies over such membranes are under further investigation.

6. Conclusion

We have synthesized 20 cyclophane diamides, and fully characterized by spectral, physical and analytical data. XRD

studies were carried out for cyclophane amides **14** and **15**, which proved the existence of intramolecular hydrogen bonding. Cyclophane amide **14** shows preference for transportation of Na^+ ion over K^+ ion and hence can be used as ion filter in biological system.

7. Experimental

7.1. General

All ^1H NMR and ^{13}C NMR were recorded in $CDCl_3$ and DMSO-d_6 with JEOL Model: GSX 400. EI-MS spectra were recorded using JEOL DX-303 mass spectrometer and FAB MS spectra were recorded using JEOL SX 102/DA-6000 mass spectrometer using a *m*-nitro benzyl alcohol (NBA) matrix. Melting points were recorded with Gallenkamp melting point apparatus. UV/Vis spectra were recorded with Jasco-V550. FT-IR spectra were recorded with Perkin–Elmer. Atomic absorption spectra were recorded using DEP-Vision (model: 381E). Pre-coated silica gel plates from Merck were used for TLC. Column chromatography was carried out using silica gel (60–120 mesh) purchased from Acme.

7.1.1. Diacid chloride 1. A mixture of catechol (11.0 g, 0.10 mol), ethyl chloroacetate (27.0 g, 0.22 mol), anhydrous potassium carbonate (16.5 g, 0.25 mol) and KI (0.5 g) in acetonitrile (100 mL) was refluxed for 12 h. After completion of the reaction, the reaction mixture was poured into ice water (300 mL) and then added NaOH solution (10% w/v, 100 mL). The gelatinous precipitate formed was filtered and the clear filtrate was acidified with dil HCl (6 M, 150 mL). The precipitated diacid was filtered, washed with cold water and air dried as an off-white solid (14.7 g, 65%). Mp 179–181 °C.[42] A mixture of the diacid (0.113 g, 0.5 mmol), thionyl chloride (0.5 mL) triethylamine (0.1 mL) in methylene chloride (25 mL) was refluxed for 3 h. The solvent and excess thionyl chloride were removed under vacuum to give diacid chloride **1** as a light brown solid.[41]

7.1.2. Diacid chloride 2. A mixture of 4,5-bis (chloromethyl)-*o*-xylene (2.0 g, 9.8 mmol), methyl salicylate (3.5 g, 23 mmol), anhydrous potassium carbonate (1.3 g, 23 mmol) and KI (0.1 g) in acetonitrile (25 mL) was refluxed for 8 h. The reaction mixture was cooled to rt and then quenched into ice water (100 mL) and the solid diester obtained was filtered with suction. The diester was washed with cold water and dried with suction as a white solid (4.2 g, 97%). Mp 121–123 °C; IR (KBr, cm^{-1}) 1732, 1600; ^1H NMR (400 MHz, $CDCl_3$) δ 2.29 (s, 6H), 3.84 (s, 6H), 5.26 (s, 4H), 6.97–7.81 (m, 10H). Mass spectrum: *m*/*z* 434 (M^+). Elemental analysis calcd for $C_{26}H_{26}O_6$: C, 71.88; H, 5.99. Found: C, 71.79; H, 5.98. The diester (2.0 g, 4.5 mmol) was treated with ethanolic KOH (5% w/v, 50 mL). The reaction mixture was then filtered and the clear filtrate was acidified with dil HCl (6 M, 30 mL) to give the diacid, which was filtered with suction and washed with water. The diacid was dried in vacuum as a white solid (1.7 g, 90%). Mp 178–180 °C; IR (KBr, cm^{-1}) 2917, 1695, 1600; ^1H NMR (400 MHz, $CDCl_3$) δ 2.31 (s, 6H), 5.32 (s, 4H), 7.10–8.21 (m, 10H). Mass spectrum: *m*/*z* 406 (M^+). Elemental analysis calcd for $C_{24}H_{22}O_6$: C, 70.93; H, 5.41. Found: C, 70.85; H, 5.42. The diacid (0.204 g, 0.5 mmol) in methylene chloride (25 mL) was refluxed with thionyl chloride (0.5 mL) and triethylamine (0.1 mL). After refluxing for 2 h, the solvent and excess thionyl chloride were removed under vacuum to give diacid chloride **2** as a pale yellow solid.

7.1.3. Diacid chloride 3. A mixture of *p*-xylylene dibromide (2.0 g, 7.5 mmol) methyl salicylate (2.6 g, 17 mmol), anhydrous potassium carbonate (2.5 g, 18 mmol) and KI (0.1 g) in acetonitrile (30 mL) was refluxed for 8 h. After completion of the reaction, the reaction mixture was poured into ice water (100 mL). The precipitated diester was filtered, washed with cold water and dried as an off-white solid (2.8 g, 90%). Mp 125–127 °C.[44] The diester (2.0 g, 4.9 mmol) was treated with ethanolic KOH (5% w/v, 50 mL). The reaction mixture was filtered and the clear filtrate was acidified with dil HCl (6 M, 30 mL) to give the diacid, which was filtered with suction and washed with water. The diacid was dried in vacuum as a white solid (1.76 g, 95%). Mp 238–240 °C.[44] The diacid (0.189 g, 0.5 mmol), thionyl chloride (0.5 mL) and triethylamine (0.1 mL) in methylene chloride (25 mL) was refluxed for 2 h. The solvent and excess thionyl chloride were removed under vacuum to give diacid chloride **3** as a light brown solid.

7.1.4. Diacid chloride 4. A mixture of diphenic acid (0.121 g, 0.5 mmol), thionyl chloride (0.5 mL), triethylamine (0.1 mL) and methylene chloride (25 mL) was refluxed for 2 h. The solvent and excess thionyl chloride were removed under vacuum to get the diacid chloride **4** as a light brown solid.

7.1.5. Diacid chloride 5. A mixture of 1,3-dibromopropane (2.56 g, 12.7 mmol), methyl *p*-hydroxybenzoate (4.0 g, 26.3 mmol), anhydrous potassium carbonate (4.0 g, 29 mmol) and KI (0.1 g) in acetonitrile (25 mL) was refluxed for 20 h. The reaction mixture was then poured into ice water and extracted with methylene chloride (2× 75 mL). The combined organic layer was washed with NaOH solution (5% w/v, 25 mL) till no methyl *p*-hydroxybenzoate was present and after washing with water (25 mL), dried over magnesium sulphate. Methylene chloride was concentrated to 25 mL and cooled with freezing mixture for 3 h. The diester was filtered at suction and dried as an off-white solid (3.27 g, 75%). Mp 134–136 °C. The diester (2.0 g, 5.8 mmol) was refluxed with ethanolic KOH (5% w/v, 50 mL) for 1 h. The reaction mixture was then filtered and to the clear filtrate dil HCl (6 M, 30 mL) was added to give the diacid, which was filtered with suction and washed with water. The diacid was dried in vacuum as a white solid (1.65 g, 90%). Mp >295 °C.[45–47] The diacid (0.158 g, 0.5 mmol) was refluxed in methylene chloride (25 mL) with thionyl chloride (0.5 mL) and triethylamine (0.1 mL) for 3 h. The solvent and excess thionyl chloride were removed under vacuum to give the diacid chloride **5** as a light brown solid.

7.1.6. Diamine 6. A mixture of 1,3-dibromopropane (2.0 g, 10 mmol), *p*-nitrophenol (4.0 g, 32 mmol), anhydrous potassium carbonate (4.0 g, 29 mmol) and KI (0.1 g) in

acetonitrile (40 mL) was refluxed for 48 h. The reaction mixture was poured into ice water (100 mL) and made alkaline with NaOH solution (5% w/v, 25 mL). The solid dinitro compound was filtered and washed with water (2× 20 mL) and recrystallised from chloroform and hexane (1:1) to give pure dinitro compound as a pale yellow solid (2.2 g, 80%). Mp 128–130 °C.[49] A mixture of dinitro compound (0.57 g, 2 mmol) and 10% Pd/C (25 mg) in methanol (100 mL) was warmed to 40 °C and hydrogen gas was bubbled through the reaction mixture. Immediately after the completion of the reaction, the reaction mixture was filtered and the filtrate was concentrated to approximately 10 mL and cooled to 0–10 °C to give diamine **6** as a beige solid after washing with cold methanol, (0.41 g, 80%). Mp 109–111 °C.[49,50]

7.1.7. Diamine 7. A mixture of 4,5-bis (chloromethyl)-*o*-xylene (2.0 g, 10 mmol), *p*-nitrophenol (3.5 g, 28 mmol), anhydrous potassium carbonate (4.0 g, 29 mmol) and KI (0.1 g) in acetonitrile (25 mL) was refluxed for 4 h. Then the reaction mixture was poured into ice water (100 mL). The solid was filtered, washed with cold water and dried to give the dinitro compound as a pale yellow solid in almost pure and quantitative yield. Mp 211–213 °C; IR (KBr, cm^{-1}) 1500, 1330; ^{1}H NMR (400 MHz, DMSO-d_6) δ 2.25 (s, 6H), 5.30 (s, 4H), 7.16–8.15 (m, 10H). Mass spectrum: *m*/*z* 408 (M^+). Elemental analysis calcd for $C_{22}H_{20}N_2O_6$: C, 64.70; H, 4.90; N, 6.86. Found: C, 64.59; H, 4.91; N, 6.87. A mixture of dinitro compound (0.6 g, 1.6 mmol) and 10% Pd/C (20 mg) in methanol (100 mL) was warmed to 40 °C. Hydrogen gas was bubbled through the reaction mixture for 1 h. The reaction mixture was filtered and the filtrate was concentrated to 15 mL. On cooling, diamine **7** crystallized, which was filtered and washed with cold methanol as a light brown solid (0.5 g, 90%). Mp 190–192 °C; IR (KBr, cm^{-1}) 3425, 1620; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.25 (s, 6H), 3.25 (br s, 4H) 5.00 (s, 4H), 6.60–7.24 (m, 10H). Mass spectrum: *m*/*z* 348 (M^+). Elemental analysis calcd for $C_{22}H_{24}N_2O_2$: C, 75.86; H, 6.89; N, 8.04.Found: C, 75.79; H, 6.88; N, 8.03.

7.1.8. Diamine 8. To a solution of KOH (1.3 g, 19.7 mmol) in methanol (40 mL) was added *o*-aminothiophenol (2.4 g, 19.2 mmol) followed by *p*-xylylene dibromide (2.0 g, 7.5 mmol) at 30 °C with stirring. After stirring for 2 h, the solid obtained was filtered with suction and washed with methanol (25 mL). Then the solid was washed with water (50 mL) and dried with suction to give pure diamine **8**, brown solid (2.4 g, 90%). Mp 141–143 °C.[51]

7.1.9. Diamine 9. To a solution of KOH (1.3 g, 19.7 mmol) in methanol (40 mL) was added *o*-aminothiophenol (2.4 g, 19.2 mmol) followed by 4,5-bis (chloromethyl)-*o*-xylene (1.52 g, 7.5 mmol) at 30 °C with stirring. After stirring for 8 h, the solid obtained was filtered with suction, washed with methanol (10 mL), then with water (50 mL) and dried to give diamine **9** as a light violet solid (2.3 g, 80%). Mp 129–131 °C; IR (KBr, cm^{-1}) 3444, 1604; ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.14 (s, 6H), 3.92 (s, 4H), 4.30 (br s, 4H), 6.61–7.26 (m, 10H). Mass spectrum: *m*/*z* 380 (M^+). Elemental analysis calcd for $C_{22}H_{24}N_2S_2$: C, 69.47; H, 6.31; N, 7.36. Found: C, 69.39; H, 6.32; N, 7.35.

7.2. General procedure for the synthesis of cyclophane amides

A solution of the diacid chloride (0.5 mmol) in dry chloroform (100 mL) and a solution of the diamine (0.5 mmol) and triethylamine (1.1 mmol) in dry chloroform (100 mL) were simultaneously added dropwise to a well-stirred solution of chloroform (500 mL) during 6 h. After the addition was complete, the reaction mixture was stirred for another 6 h. The solvent was removed at reduced pressure and the residue obtained was then dissolved in chloroform (300 mL), washed with water (2×100 mL) to remove the triethylammonium chloride and dried over magnesium sulphate. Removal of the chloroform gave the cyclophane as a crude material, which was purified by column chromatography with suitable eluting solvent as mentioned under each cyclophane.

7.2.1. Cyclophane 10. White hairy crystalline solid. Eluent for column chromatography: chloroform to chloroform/methanol (49:1); yield: 50%; R_f 0.65 (chloroform/methanol, 9:1). Mp 220–222 °C; IR (KBr, cm^{-1}) 3312, 1723, 1676; ^{1}H NMR (400 MHz, DMSO-d_6) δ 4.76 (s, 4H), 7.04–7.63 (m, 8H), 9.71 (s, 2H). Mass spectrum: *m*/*z* 298 (M^+). Elemental analysis calcd for $C_{16}H_{14}N_2O_4$: C, 64.42; H, 4.69; N, 9.39. Found: C, 64.48; H, 4.68; N, 9.38.

7.2.2. Cyclophane 11. Off-white solid. Eluent for column chromatography: chloroform to chloroform/methanol (49:1); yield: 45%; R_f 0.55 (chloroform/methanol, 9:1). Mp 238–240 °C; IR (KBr, cm^{-1}) 3375, 1684, 1596; ^{1}H NMR (400 MHz, DMSO-d_6) δ 1.83 (quint, 2H, J=5.9 Hz), 4.15 (t, 4H, J=5.9 Hz), 4.59 (s, 4H), 6.57–7.16 (m, 12H), 9.55 (s, 2H). Mass spectrum: *m*/*z* 448 (M^+). Elemental analysis calcd for $C_{25}H_{24}N_2O_6$: C, 66.96; H, 5.35; N, 6.25.Found: C, 66.89; H, 5.29; N, 6.18.

7.2.3. Cyclophane 12. Off-white solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); yield: 50%; R_f 0.80 (chloroform/methanol, 9:1). Mp 304–306 °C; IR (KBr, cm^{-1}) 3382, 1684, 1597; ^{1}H NMR (400 MHz, DMSO-d_6) δ 2.23 (s, 6H), 4.56 (s, 4H), 5.00 (s, 4H), 6.51–8.04 (m, 14H), 9.22 (s, 2H). Mass spectrum: *m*/*z* 538 (M^+). Elemental analysis calcd for $C_{32}H_{30}N_2O_6$: C, 71.37; H, 5.57; N, 5.20.Found: C, 71.42; H, 5.56; N, 5.19.

7.2.4. Cyclophane 13. Lemon yellow solid. Eluent for column chromatography: hexane to hexane/chloroform (1:1); yield: 40%; R_f 0.55 (toluene/ethyl acetate, 9:1). Mp 204–208 °C; IR (KBr, cm^{-1}) 3350, 1684, 1577; ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.79 (s, 4H), 4.55 (s, 4H), 6.86–8.46 (m, 16H), 9.39 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 29.9, 43.0,70.2, 117.5, 120.5, 123.4, 124.1, 125.1, 129.3, 130.7, 136.6, 136.8, 140.0, 148.6, 166.5. Mass spectrum: *m*/*z* 542 (M^+). Elemental analysis calcd for $C_{30}H_{26}N_2O_4S_2$: C, 66.42; H, 4.79; N, 5.16. Found: C, 66.37; H, 4.78; N, 5.17.

7.2.5. Cyclophane 14. Off-white crystalline solid. Eluent for column chromatography: hexane to hexane/chloroform (1:1); yield: 45%; R_f 0.60 (toluene/ethyl acetate, 9:1). Mp 226–228 °C; IR (KBr, cm^{-1}) 3378, 1685, 1595. ^{1}H NMR

(400 MHz, $CDCl_3$) δ 1.99 (s, 6H), 3.91 (s, 4H), 4.51 (s, 4H), 6.45–8.39 (m, 14H), 9.48 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 19.0, 38.5, 68.8, 113.9, 120.2, 122.8, 123.5, 124.6, 129.9, 131.0, 131.8, 135.3, 136.2, 139.2, 147.2, 166.2. Mass spectrum: *m/z* 570 (M^+). Elemental analysis calcd for $C_{32}H_{30}N_2O_4S_2$; C, 67.36; H, 5.26; N, 4.91.Found; C, 67.31; H, 5.27; N, 4.92.

7.2.6. Cyclophane 15. Beige crystalline solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); Yield: 50%; R_f 0.75 (chloroform/methanol, 9:1). Mp 278–281 °C; IR (KBr, cm^{-1}) 3353, 1663, 1597; ^1H NMR (400 MHz, $CDCl_3$) δ 2.23 (s, 6H), 5.24 (s, 4H), 6.91–8.21 (m, 14H), 9.64 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 19.4, 29.6, 70.4, 112.8,121.6, 121.8, 124.3, 125.1, 129.7, 131.4, 132.2, 132.9, 133.1, 138.2, 156.3, 163.8. Mass spectrum: *m/z* 478 (M^+). Elemental analysis calcd for $C_{30}H_{26}N_2O_4$: C, 75.31; H, 5.44; N, 5.85. Found: C, 75.39; H, 5.45; N, 5.86.

7.2.7. Cyclophane 16. White solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); yield: 47%; R_f 0.80 (chloroform/methanol, 9:1). Mp 234–236 °C; IR (KBr, cm^{-1}) 3340, 1658, 1598; ^1H NMR (400 MHz, $CDCl_3$) δ 1.95 (quint, 2H, $J=5.8$ Hz), 2.30 (s, 6H), 4.08 (t, 4H, $J=5.8$ Hz), 5.23 (s, 4H), 6.44–8.06 (m, 18H), 9.57 (s, 2H); FAB Mass spectrum: *m/z* 628 (M^+). Elemental analysis calcd for $C_{39}H_{36}N_2O_6$: C, 74.52; H, 5.73; N, 4.45. Found: C, 74.57; H, 5.78; N, 4.44.

7.2.8. Cyclophane 17. Off-white solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); yield: 43%; R_f 0.75 (chloroform/methanol, 9:1). Mp >300 °C; IR (KBr, cm^{-1}) 3348, 1662, 1598; ^1H NMR (400 MHz, DMSO-d_6) δ 2.22 (s, 6H), 2.29 (s, 6H), 5.04 (s, 4H), 5.38 (s, 4H), 6.57–8.10 (m, 20H), 9.60 (s, 2H); FAB Mass spectrum: *m/z* 718 (M^+). Elemental analysis calcd for $C_{46}H_{42}N_2O_6$: C, 76.88; H, 5.84; N, 3.89. Found: C, 76.94; H, 5.77; N, 3.81.

7.2.9. Cyclophane 18. Off-white solid. Eluent for column chromatography: hexane to hexane/chloroform (1:1); yield: 50%; R_f 0.50 (toluene/ethyl acetate, 9:1). Mp 254–256 °C (decomp.); IR (KBr, cm^{-1}) 3291, 1658, 1581; ^1H NMR (400 MHz, $CDCl_3$) δ 2.21 (s, 6H), 3.94 (s, 4H), 5.01 (s, 4H), 6.68–8.69 (m, 22H), 11.07 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 19.9, 41.6, 69.4, 114.9, 122.3, 122.7, 123.6, 124.8, 125.4, 129.0, 129.6, 131.1, 133.4, 133.8, 137.1, 137.2, 140.4, 157.1, 164.2; FAB Mass spectrum: *m/z* 722 (M^+). Elemental analysis calcd for $C_{44}H_{38}N_2O_4S_2$: C, 73.13; H, 5.26; N, 3.87. Found: C, 72.95; H, 5.20; N, 3.91.

7.2.10. Cyclophane 19. Off-white solid. Eluent for column chromatography: hexane to hexane/chloroform (1:1); yield: 50%; R_f 0.70 (toluene/ethyl acetate, 9:1). Mp 224–227 °C; IR (KBr, cm^{-1}) 3337, 1661, 1600; ^1H NMR (400 MHz, $CDCl_3$) δ 1.87 (s, 6H), 2.02 (s, 6H), 3.70 (s, 4H), 5.26 (s, 4H), 6.48–8.53 (m, 20H), 10.42 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 18.8, 19.2, 38.3, 69.8, 113.7, 121.5, 121.9, 123.6, 123.8, 124.3, 129.4, 130.4, 131.3, 131.7, 132.4, 132.8, 132.9, 135.1, 135.9, 137.3, 140.2, 156.7, 163.8; FAB Mass spectrum: *m/z* 750 (M^+). Elemental analysis calcd for $C_{46}H_{42}N_2O_4S_2$: C, 73.6; H, 5.60; N, 3.73. Found: C, 73.65; H, 5.55; N, 3.78.

7.2.11. Cyclophane 20. Off-white solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); yield: 45%; R_f 0.62 (chloroform/methanol, 9:1). Mp 268–270 °C (decomp.); IR (KBr, cm^{-1}) 3333, 1702, 1654, 1601; ^1H NMR (400 MHz, DMSO-d_6) δ 5.01 (s, 4H), 7.09–8.26 (m, 16H), 9.61 (s, 2H). Mass spectrum: *m/z* 450 (M^+). Elemental analysis calcd for $C_{28}H_{22}N_2O_4$: C, 74.66; H, 4.88; N, 6.22. Found: C, 74.71; H, 4.73; N, 6.30.

7.2.12. Cyclophane 21. White crystalline solid. Eluent for column chromatography: chloroform to chloroform/methanol (49:1); yield: 42%; R_f 0.84 (chloroform/methanol, 9:1). Mp 251-253 °C; IR (KBr, cm^{-1}) 3354, 1663, 1597; ^1H NMR (400 MHz, DMSO-d_6) δ 2.09 (quint, 2H, $J=5.8$ Hz), 4.17 (t, 4H, $J=5.8$ Hz) 5.27 (s, 4H), 6.80–8.18 (m, 20H), 9.79 (s, 2H). Mass spectrum: *m/z* 600 (M^+). Elemental analysis calcd for $C_{37}H_{32}N_2O_6$: C, 74.0; H, 5.33; N, 4.66. Found: C, 73.8; H, 5.29; N, 4.72.

7.2.13. Cyclophane 22. White solid. Eluent for column chromatography: chloroform to chloroform/methanol (49:1); yield: 48%; R_f 0.86 (chloroform/methanol, 9:1). Mp 292-294 °C; IR (KBr, cm^{-1}) 3348, 1663, 1597, 1542; ^1H NMR (400 MHz, DMSO-d_6) δ 2.26 (s, 6H), 5.05 (s, 4H), 5.27 (s, 4H), 6.86–8.14 (m, 22H), 9.80 (s, 2H); FAB Mass spectrum: *m/z* 690 (M^+). Elemental analysis calcd for $C_{44}H_{38}N_2O_6$: C, 76.52; H, 5.50; N, 4.05. Found: C, 76.65; H, 5.48; N, 4.07.

7.2.14. Cyclophane 23. Off-white crystalline solid. Eluent for column chromatography: hexane to hexane/chloroform (1:1); yield: 50%; R_f 0.66 (toluene/ethyl acetate, 9:1). Mp 200–202 °C; IR (KBr, cm^{-1}) 3335, 1665, 1595, 1576; ^1H NMR (400 MHz, $CDCl_3$) δ 3.84 (s, 4H), 5.18 (s, 4H), 6.85–8.53 (m, 24H), 10.58 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 40.3, 71.2, 113.6, 121.7, 121.8, 122.6, 124.3, 124.8, 127.2, 128.7, 128.8, 132.5, 132.9, 133.1, 135.6, 136.0, 139.1, 156.6, 163.6; FAB Mass spectrum: *m/z* 694 (M^+). Elemental analysis calcd for $C_{42}H_{34}N_2O_4S_2$: C, 72.62; H, 4.89; N, 4.03. Found: C, 72.55; H, 4.79; N, 4.10.

7.2.15. Cyclophane 24. Light brown crystalline solid. Eluent for column chromatography: hexane to hexane/chloroform (1:1); yield: 48%; R_f 0.52 (toluene/ethyl acetate, 9:1). Mp 202-204 °C; IR (KBr, cm^{-1}) 3279, 1668, 1576; ^1H NMR (400 MHz, $CDCl_3$) δ 1.93 (s, 6H), 3.48 (s, 4H), 5.26 (s, 4H), 6.35–8.54 (m, 22H), 10.50 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 19.0, 37.0, 70.9, 112.7, 121.6, 121.7, 122.6, 123.7, 124.2, 128.0, 129.0, 131.8, 132.5, 132.8, 133.2, 134.3, 135.5, 136.2, 139.6, 156.5, 163.5; FAB Mass spectrum: *m/z* 722 (M^+). Elemental analysis calcd for $C_{44}H_{38}N_2O_4S_2$: C, 73.13; H, 5.26; N, 3.87. Found: C, 73.19; H, 5.18; N, 3.89.

7.2.16. Cyclophane 25. White crystalline solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); yield: 40%; R_f 0.72 (chloroform/methanol, 9:1). Mp 300–304 °C; IR (KBr, cm^{-1}) 3343, 2940, 1668, 1532; ^1H NMR (400 MHz, DMSO-d_6) δ 1.88 (quint, 2H, $J=$ 5.8 Hz), 4.10 (t, 4H, $J=5.8$ Hz), 6.38 (s, 4H), 7.30–7.56 (m,

12H), 9.90 (s, 2H). Mass spectrum: *m/z* 464 (M^+). Elemental analysis calcd for $C_{29}H_{24}N_2O_4$: C, 75.0; H, 5.17; N, 6.03. Found: C, 75.07; H, 5.11; N, 6.10.

7.2.17. Cyclophane 26. White solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); yield: 44%; R_f 0.54 (chloroform/methanol, 9:1). Mp 316–318 °C; IR (KBr, cm^{-1}) 3433, 1681, 1530; ^1H NMR (400 MHz, DMSO-d_6) δ 2.27 (s, 6H), 4.88, 5.01 (ABq, 4H, $J=10.8$ Hz), 6.36 (d, 4H, $J=9.3$ Hz), 7.18–7.62 (m, 14H), 9.32 (s, 2H); ^{13}C NMR (100.4 MHz, DMSO-d_6) δ 18.2, 77.9, 78.2, 114.5, 119.7, 126.2, 127.0, 129.0, 132.1, 132.4, 133.2, 135.6, 139.7, 155.0, 168.8. Mass spectrum: *m/z* 554 (M^+). Elemental analysis calcd for $C_{36}H_{30}N_2O_4$: C, 77.97; H, 5.41; N, 5.05. Found: C, 77.89; H, 5.38; N, 5.12.

7.2.18. Cyclophane 27. Pale yellow solid. Eluent for column chromatography: hexane to hexane:chloroform (1:1); yield: 40%; R_f 0.48 (toluene/ethyl acetate, 9:1). Mp 220–224 °C; IR (KBr, cm^{-1}) 3352, 1666, 1577; ^1H NMR (400 MHz, $CDCl_3$) δ 3.72, 3.92 (ABq, 4H, $J=11.7$ Hz), 6.77 (s, 4H), 7.02–8.02 (m, 16H), 8.46 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 41.4, 121.9, 125.0, 125.8, 127.4, 128.3, 128.4, 128.6, 130.1, 130.3, 135.6, 136.5, 138.6, 139.9, 166.9. Mass spectrum: *m/z* 558 (M^+). Elemental analysis calcd for $C_{34}H_{26}N_2O_2S_2$: C, 73.11; H, 4.65; N, 5.01. Found: C, 73.20; H, 4.61; N, 5.10.

7.2.19. Cyclophane 28. Off-white solid. Eluent for column chromatography: hexane to hexane:chloroform (1:1); yield: 45%; R_f 0.46 (toluene/ethyl acetate, 9:1). Mp 226–228 °C; IR (KBr, cm^{-1}) 3321, 1670, 1577; ^1H NMR (400 MHz, $CDCl_3$) δ 1.99 (s, 6H), 3.40, 3.56 (ABq, 4H, $J=12.7$ Hz), 6.39 (s, 4H), 6.83–8.38 (m, 14H), 8.48 (s, 2H); ^{13}C NMR (100.4 MHz, $CDCl_3$) δ 19.0, 37.9, 119.5, 121.9, 123.9, 128.2, 129.3, 129.8, 130.3, 130.8, 130.9, 131.3, 135.2, 135.9, 136.3, 136.9, 140.0, 167.6. Mass spectrum: *m/z* 586 (M^+). Elemental analysis calcd for $C_{36}H_{30}N_2O_2S_2$: C, 73.72; H, 5.11; N, 4.77. Found: C, 73.68; H, 5.08; N, 4.81.

7.2.20. Cyclophane 29. White solid. Eluent for column chromatography: chloroform to chloroform/methanol (99:1); yield: 35%; R_f 0.66 (chloroform/methanol, 9:1). Mp 296–298 °C; IR (KBr, cm^{-1}) 3242, 1646, 1603, 1522; ^1H NMR (400 MHz, DMSO-d_6) δ 1.91 (quint, 2H, $J=$ 5.3 Hz), 4.20 (t, 4H, $J=5.3$ Hz), 6.67, 7.47 (ABq, 8H, $J=$ 8.8 Hz), 7.34 (br s, 4H), 9.10 (s, 2H). Mass spectrum: *m/z* 388 (M^+). Elemental analysis calcd for $C_{23}H_{20}N_2O_4$: C, 71.13; H, 5.15; N, 7.25. Found: C, 71.09; H, 5.10; N, 7.29.

7.3. UV/Vis spectral studies

Cyclophane amides **14/19/24** (0.023 g/ 0.026 g/0.025 g) were dissolved in CH_3CN (50 mL) and UV/Vis spectra were recorded. Cyclophane amide **14** showed λ_{max} at 209 nm, cyclophane amide **19** showed λ_{max} at 206 nm, 290 nm and cyclophane amide **24** had absorption at 208, 287 nm. To a solution of cyclophane amides **14/19/24** (0.023 g/0.030 g/ 0.029 g, 4×10^{-2} mmol) added a solution of Cu (II) acetate (0.008 g, 4×10^{-2} mmol) and left at rt for 5 days under N_2 atm. In the UV/Vis. spectra no appreciable change in λ_{max} could be observed. Similarly by adding Pb (II) acetate no shift in λ_{max} was observed. However, cyclophane amide **28** (0.0234 g) dissolved in methanol (50 mL) displayed absorption at 222 nm. By adding Cu (II) acetate (0.008 g, 4×10^{-2} mmol) to the cyclophane amide **28** (0.0234 g, 4×10^{-2} mmol) new absorption maximum were observed at 209 and 273 nm and similarly by adding Pb (II) acetate (0.0117 g, 4×10^{-2} mmol) λ_{max} was observed at 235 nm.

7.4. Ion transportation studies

A solution of cyclophane amide **14** (65 mg, 11.4×10^{-2} mmol) in chloroform (40 mL) was kept in a conical flask fitted with a U tube (Fig. 5). A solution of NaCl (585 mg, 10 mmol) and KCl (745 mg, 10 mmol) in triply distilled water (10 mL) was kept in one arm of the U tube and the other arm was filled with triply distilled water (10 mL). After properly stoppering the arms of the U tube, the chloroform layer was stirred vigorously for 5 days. The arm, which was filled with triply distilled water showed the presence of NaCl (21.1 mg/l) and K^+ ion level was below the detecting limit (less than 0.40 mg/l).

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