

Synthesis of Ionophore from *p-t*-Butyl-(carboxymethoxy)calix[4]arene Substituted Amide**Nasriadi Dali^{1*}, Seniwati Dali², Armadi Chairunnas³, Hilda Ayu Melvi Amalia⁴,
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ABSTRACT. The ionophore has been successfully synthesized from *p-t*-butyl(carboxymethoxy)calix[4]arene substituted amide. The ionophore was obtained in two steps of the synthesis reaction. The first step is the chlorination reaction of *p-t*-butyl(carboxymethoxy)calix[4]arene with thionyl chloride in dry benzene solvent. The product of the chlorination reaction is *p-t*-butyl(chloroacetylmethoxy)calix[4]arene in the form of the light brown viscous liquid with the rendement of 78.25% and TLC (SiO₂, CH₃OH : CH₂Cl₂ = 1 : 1 v/v, R_f = 0.65). The second step is the amidation reaction of *p-t*-butyl(chloroacetylmethoxy)calix[4]arene with dimethylamine in dry tetrahydrofuran solvent. The product of the amidation reaction is *p-t*-butyl(dimethylcarbamoylmethoxy)-calix[4]arene or the DIMECAC4ND3 ionophore in the form of white solid with the rendement of 60.75%, a melting point of 277-279 °C, and TLC (SiO₂, CH₃OH : CH₂Cl₂ = 1 : 1 v/v, R_f = 0.82).

Keywords: amidation, calix[4]arene, chlorination, ionophore**INTRODUCTION**

The separation of metal ions is an important process in analytical and industrial chemistry (Basset et al., 2014; Harrison, 2017; Lo et al., 2013). In the field of analytical chemistry, the purpose of separating metal ions is to remove or concentrate metal ions from a dilute solution before further analysis. In the industrial sector, metal ion separation aims to take, purify, and reduce the concentration of metal ions in liquid waste, especially heavy metal ions before being discharged into the environment. For the purpose of purification or retrieving metal ions from wastewater, a selective separation method is needed for metal ions to be separated.

Industrial wastewater treatment involves the deposition of metals as hydroxides, salts, bases, and sulfides (Harrison, 2017). This method is not effective for wastewater with low dissolved metal ion concentration. One of the separation methods that can be applied for industrial wastewater treatment is liquid membrane transport. This method is favorable because it can be applied even though the dissolved metal ion concentration is low, can transport metal

ions from low to high concentrations, uses little organic solvent, has simple operation, and requires low operating costs. In addition, the separation process takes place continuously (Mulder, 2016).

In the liquid membrane transport method, metal ions are transported from the source phase to the target phase through an organic liquid membrane phase containing ion carrying molecules or ionophore. The success of this method is largely determined by stability of complex between metal ions and ionophore. The stability of complex is determined by the type of donor atom (active group), ring size, and branch length of the hydrophobic group of the ionophore (Bozkurt et al., 2015). Thus, the efficiency and selectivity of transport in various extraction techniques is heavily influenced by the ionophore in the liquid membrane (Qazi et al., 2012).

Efforts to improve the performance of metal ion separation using the liquid membrane transport method continue to be carried out by researchers both from the synthesis aspect and its application to the separation of various metal ions (Suyanta, 2013; Tsurubou et al., 2015; Nijenhuis et al., 2012; Hwang

& Shih, 2010; Tayeb et al., 2017; Kadir, 2014). The interesting part from the synthesis aspect is the emergence of new organic compounds that can be used as selective metal ionophores. Among the compounds that are widely synthesized for this purpose are crown ethers, cryptans, calix[*n*]arenes, and cyclodextrins (Lindoy, 2010; Izatt et al., 2013; Bohmer, 2015; Ikeda & Shinkai, 2017; Kusumaningsih et al., 2010; Arora et al., 2017).

Calix[*n*]arene is one of the macrocyclic compounds that has the potential to be used as an ionophore for the purpose of separating metal ions by the liquid membrane transport method. From the aspect of synthesis, calix[*n*]arene is relatively easy to synthesize from an alkylphenol and formaldehyde in alkaline conditions with varying degrees of condensation [*n*] (Dali et al., 2015). Likewise, calix[*n*]arene derivatives can be synthesized through the replacement of the lower or upper group on the molecular ring (Dali et al., 2016). From the aspect of structure, calix[*n*]arene resembles a bowl and has two groups that can be used to interact with neutral ions and molecules, namely an alkyl group or its derivatives above the ring and a hydroxyl group or its derivatives below the ring (Dali et al., 2012; Dali et al., 2015). From the aspect of solubility, calix[*n*]arene is generally soluble in organic solvents, such as chloroform, dichloroethane, benzene, toluene and other organic solvents (Bohmer, 2015; Gutsche et al., 2013).

Several ionophore have been successfully synthesized from calix[*n*]arene by substituting the lower or upper groups of the molecular ring. Substitution of the bottom hydroxyl (OH) group with ethylester produces the ionophore BEC4ND1 and BEC6ND1 (Dali et al., 2015). Substitution of the lower ethylester group of the ring with carboxylic acid produces the ionophore BCAC4ND2 and BCAC6ND2 (Dali et al., 2020; Dali et al., 2016). Substitution of the bottom carboxylic acid group with ethylesteramide produces the BEAC4ND4 ionophore (Dali et al., 2020).

The ionophore have been used to improve the performance of carbon paste electrodes (CPE). The TiO₂-BEC6ND1 ionophore has been used as a CPE composite to increase selectivity and sensitivity to Pb²⁺ ions. The presence of the BEC6ND1 ionophore can significantly increase the peak current of Pb²⁺ ion with a limit of detection (LOD) value of 0.1756. Similarly, the presence of the TiO₂-BEC6ND1 ionophore composite showed the stability of the measurement current with a relative standard deviation (RSD) of 0.83% (Nurdin et al., 2018). The TiO₂-BEC6ND1 ionophore has been used as a modified CPE nanocomposite (ionophore of BEC6ND1-TiO₂/CPE) for the determination of Cu²⁺ ions by cyclic voltammetry (CV). The results showed that the LOD for Cu²⁺ ions was 0.022 ppm with a RSD of 0.011% (Dali et al., 2022).

One of the derivatives of calix[4]arene that has been successfully synthesized is *p*-*t*-butyl

(carboxymethoxy)calix[4]arene (Dali et al., 2020). In this study, we modified the structure of this compound by substituting -COOH group at the bottom of the ring with *N,N*-dimethylamide [(CON(CH₃)₂) group. It is intended to increase its reactivity, selectivity, and effectiveness as an ionophore in the binding of metal ions. The presence of basic O and N atoms in the amide group can make the binding of metal ions more effective, because the O and N atoms can donate electrons to form coordination bonds with metal ions, especially with metal ions which are soft acids. Therefore, the aim of this study was to synthesize of the ionophore from *p*-*t*-butyl(carboxymethoxy)calix[4]arene substituted amide. The presence of the DIMECAC4ND3 ionophore as a new compound is expected to be used as an ion carrier molecule that can improve the performance of metal ion separation by the liquid membrane transport method.

EXPERIMENTAL SECTION

Materials

The materials used in this research were *p*-*t*-butyl(carboxymethoxy)calix[4]arene (raw material) (synthesized) (Dali et al., 2020), anhydrous sodium sulfate (Na₂SO₄) p.a. (Merck), aquabidest (Onelab Waterone), benzene p.a. (Merck), chloroform p.a. (Merck), dichloromethane p.a. (Merck), ethyl acetate p.a. (Merck), methanol p.a. (Merck), nitrogen gas (commercial), *n*-hexane p.a. (Merck), dimethylamine p.a. (Merck), potassium carbonate (K₂CO₃) p.a. (Merck), pyridine p.a (Merck), tetrahydrofuran (THF) p.a. (Merck), thionyl chloride p.a. (Merck), and TLC plate.

The instruments used in this research were consisted of two kinds, namely instruments for sample preparation and characterization. The instruments used for sample preparation are analytical balance (Explorer Ohaus), ball coolers, chamber, chemical beaker (Pyrex), desiccator, dropper pipette (Pyrex), electrothermal (series IA9100), funnels, heating mantles, magnetic stirrers (1 cm), measuring cup (Pyrex), rotary vacuum evaporator (BUCHI Rotavapor™ series R-300), separating funnel, a set of reflux devices consisting of 100 mL three-neck round bottom flask, stirring rod, and thermometers (100 °C). The instruments used for sample characterization are the FTIR Shimadzu (series Prestige-21) and FTNMR Jeol (series JNM-MY500) spectrometers.

Synthesis of the DIMECAC4ND3 Ionophores

The *p*-*t*-Butyl(carboxymethoxy)calix[4]arene (0.44 g, 0.5 mmol) was dissolved in 25 mL dry benzene. This solution was put into a three-neck flask with a capacity of 100 mL equipped with a ball cooler and then saturated with nitrogen gas. Then, it was added by 5 mL of SOCl₂ and 3 drops of pyridine. This mixture was refluxed for 8 hours while stirring with a magnetic stirrer. The mixture was tested by TLC every 2 hours to control the reaction results. Excess SOCl₂ (bp. 74.6 °C) was separated by distillation. The residue in the form

of the light brown viscous liquid is a *p-t*-butyl (chloroacetylmethoxy)calix[4]arene or acid chloride solution (Dali et al., 2020; Dali et al., 2016).

The acid chloride solution (0.23 g, 0.2409 mmol) was dissolved in 50 mL dry THF. The hydrochloric acid solution was put into a separating funnel. The acid chloride solution was dripped slowly into a cold solution (-5 °C) of dimethylamine (0.30 g, 4 mmol) in 30 mL of dry chloroform and 2 g of K₂CO₃ while stirring with a magnetic stirrer for 24 hours. Every 8 hours the mixture was tested by TLC to control the reaction results. The mixture was filtered. Then, the filtrate was washed with water and then dried with Na₂SO₄. The solvent was evaporated with an evaporator at 39.6 °C. The solid was recrystallized with ethyl acetate and *n*-hexane. The white solid obtained is the DIMECAC4ND3 ionophore. The DIMECAC4ND3 ionophore was dried in a desiccator. The DIMECAC4ND3 ionophore was characterized by TLC, melting point apparatus, FTIR, and FTNMR (¹H, ¹³C) (Dali et al., 2020; Dali et al., 2016).

Determination of the DIMECAC4ND3 Ionophore Structure

The structure of the DIMECAC4ND3 ionophore was determined using FTIR and FTNMR (¹H, ¹³C) spectroscopy. Physical data: yield 60.75%; mp 277-279 °C; TLC (SiO₂, CHCl₃ : C₂H₅OH = 1 : 1 v/v, R_f = 0.80). FTIR (KBr) ν_{max} (cm⁻¹) data: 2962.5, 2904.6, and 2869.9 (CH stretch of (CH₃)₃C saturated

aliphatic), 1666.4 (C=O stretch of tertiary amides), 1581.5 (C=C aromatic ring stretching), 1477.4 (CH stretch of CH₂ aliphatic), 1431.1 (CH stretch of CH₃ aliphatic), 1361.7 (CH₃ deformation of amides), 1265.2 and 1199.6 (C-O aromatic ring stretching), 1242.1 (C-O-C stretch in alkyl aryl ethers), 1126.4 (C-O-C stretch in dialkyl ethers), 1064.6 (R-C-O stretch in alkyl aryl ethers), 871.8 and 794.6 (C-H out-of-plane deformation of 1,4-disubstituted *para*), 574.7 (N-C=O bend of amides), 559.3 (C=O out-of-plane bend of amides), 470.6 (C-C=O bend of amides). ¹H-NMR (500 MHz, CDCl₃) δ_H (ppm) data: 6.8342 [(s, 1H) (ArH-22/24)], 4.7128 [(s, 2H) (CH₂O-2'')], 4.2739 [(d, 2H, J = 13.5 Hz) (ArCH₂Ar-2_a, 2_b)], 3.3312 [(d, 2H, J = 13.5 Hz) (ArCH₂Ar-20_a, 20_b)], 3.3177 [(m, 3H, J = 7.3 Hz) (CON(CH₃)₂-1_a)], 1.0413 [(m, 3H, J = 7.4 Hz) (CON(CH₃)₂-1_b)], 1.1164 [(s, 9H) (C(CH₃)₃-2')]. ¹³C-NMR (500 MHz, CDCl₃) δ_C (ppm) data: 169.5406 [(CON(CH₃)₂) (C-1'')], 72.0208 [(ArOCH₂-) (C-2'')], 40.9449 [(CON(CH₃)₂) (C-1_a)], 33.9815 [(CON(CH₃)₂) (C-1_b)], 154.3175 [(CO aryl) (C-25)], 144.3976 [(C-*para* aryl) (C-23)], 133.7528 [(C-*ortho* aryl) (C-1/C-21)], 125.4545 [(C-*meta* aryl) (C-22/C-24)], 33.5974 [(C(CH₃)₃) (C-1')], 31.5974 [(ArCH₂Ar) (C-2/C-20)], and 31.5211 [(C(CH₃)₃) (C-2')]. The position of the chemical shift value of ¹H and ¹³C-NMR in the carbon framework of the DIMECAC4ND3 ionophore can be seen in **Figure 1**.

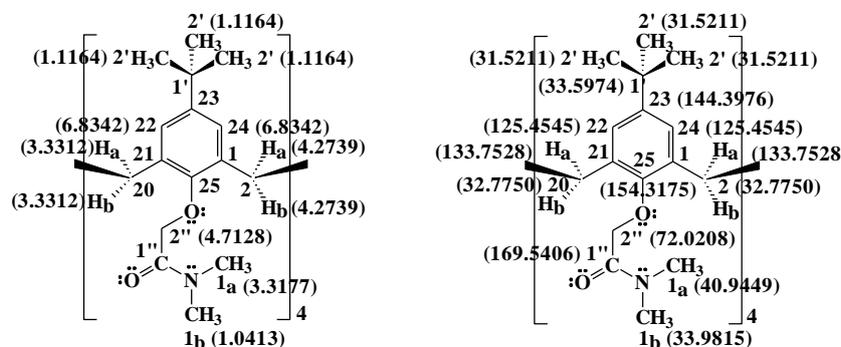


Figure 1. The position of chemical shift value of ¹H-NMR (left) and ¹³C-NMR (right) in the carbon framework of the DIMECAC4ND3 ionophore

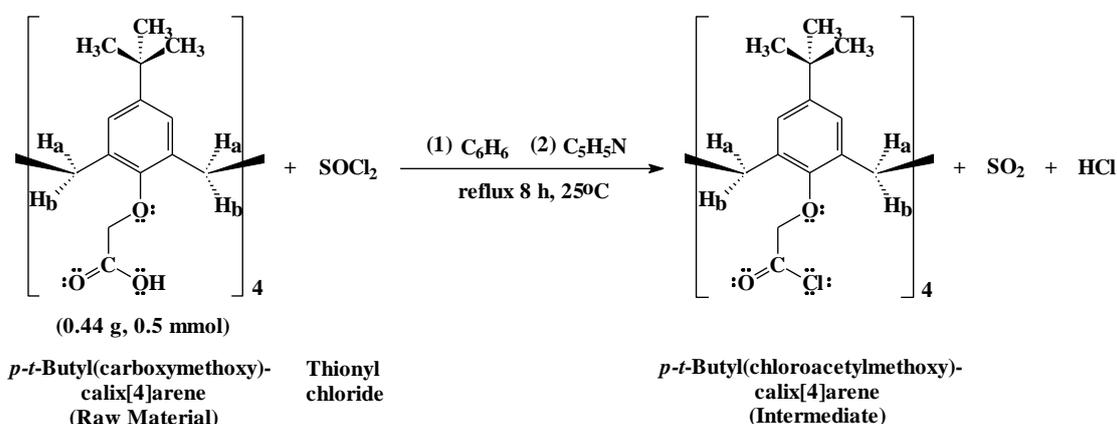


Figure 2. The chlorination reaction of *p-t*-butyl(carboxymethoxy)calix[4]arene with thionyl chloride to form of *p-t*-butyl(chloroacetylmethoxy)calix[4]arene

RESULTS AND DISCUSSION

The DIMECAC4ND3 ionophore was obtained through a two step synthesis reaction. The first step is the chlorination reaction of *p*-*t*-butyl(carboxymethoxy)calix[4]arene with thionyl chloride in dry benzene solvent (**Figure 2**). The product of the chlorination reaction is *p*-*t*-butyl(chloroacetylmethoxy)calix[4]arene in the form of the light brown viscous liquid with the TLC (SiO₂, CH₃OH : CH₂Cl₂ = 1 : 1 v/v, R_f = 0.65). The efficiency of this reaction expressed as percent yield is calculated as follows:

$$\begin{aligned} \% \text{ yield} &= \frac{\text{final weight (product)}}{\text{initial weight (raw material)}} \times 100\% \\ &= \frac{0.3443 \text{ g}}{0.44 \text{ g}} \times 100\% = 78.25\% \end{aligned}$$

The second step is the amidation reaction of *p*-*t*-butyl(chloroacetylmethoxy)calix[4]arene with dimethylamine in dry tetrahydrofuran solvent (**Figure 3**). The product of the amidation reaction is *p*-*t*-butyl(dimethylcarbamoylmethoxy)calix[4]arene or the DIMECAC4ND3 ionophore in the form of white solid with a melting point of 277-279 °C, TLC (SiO₂, CH₃OH : CH₂Cl₂ = 1 : 1 v/v, R_f = 0.82). The efficiency of this reaction expressed as percent yield is calculated as follows:

$$\begin{aligned} \% \text{ yield} &= \frac{\text{final weight (product)}}{\text{initial weight (intermediate)}} \times 100\% \\ &= \frac{0.13973 \text{ g}}{0.23 \text{ g}} \times 100\% = 60.75\% \end{aligned}$$

Table 1 shows the FTIR spectrum data of the DIMECAC4ND3 ionophore. Very strong absorption bands from the vibrations of the OH stretch appeared at 3166.9 cm⁻¹ and C=O stretch at 1747.4 cm⁻¹ in the spectrum of the raw material is no longer visible in the spectrum of the DIMECAC4ND3 ionophore. This indicates that the OH and C=O groups of the

carboxylic acid (-COOH) have changed during the synthesis reaction process. The change in the -COOH functional group was confirmed by the presence of a very strong absorption band from the amide type C=O vibration that appeared at 1666.4 cm⁻¹ which was very different from the acid type C=O absorption. The presence of C=O vibrational absorption at 1666.4 cm⁻¹ indicates that the -COOH group of the raw material has reacted with dimethylamine to form an amide [CON(CH₃)₂].

Table 1 also shows that the DIMECAC4ND3 ionophore has tertiary amide absorption bands that are not found in the raw material. The absorption bands of tertiary amides are 1666.4 cm⁻¹ (C=O stretch of tertiary amides), 1361.7 cm⁻¹ (CH₃ deformation of amides), 574.7 cm⁻¹ (N-C=O bend of amides), 559.3 cm⁻¹ (C=O out-of-plane bend of amides), and 470.6 cm⁻¹ (C-C=O bend of amides). From the **Table 1**, it can be concluded that the C=O and OH groups of the -COOH in the raw material have changed to tertiary amide groups [CON(CH₃)₂] in the DIMECAC4ND3 ionophore during the synthesis reaction.

Table 1 also showed the presence of several similar absorption bands between the starting material and the synthesis product. The FTIR spectrum of the synthetic product showed an aromatic ring absorption band that appeared at 1581.5 cm⁻¹ (C=C stretch), 1265.2 and 1199.6 cm⁻¹ (C-O stretch), 871.8 and 794.6 cm⁻¹ (C-H out-of-plane). Saturated aliphatic absorption bands appeared at 2962.5, 2904.6, 2869.9 cm⁻¹ [C-H stretch of (CH₃)₃C-], 1477.4 cm⁻¹ (C-H stretch of -CH₂-), and 1431.1 cm⁻¹ (C-H stretch of CH₃-). The ether absorption bands appeared at 1242.1 cm⁻¹ (C-O-C stretch in alkyl aryl ethers), 1126.4 cm⁻¹ (C-O-C stretch in dialkyl ethers), and 1064.6 cm⁻¹ (R-C-O stretch in alkyl aryl ethers). Thus, the DIMECAC4ND3 ionophore is a compound containing amide, aromatic, methyl, methylene and ether carbonyl groups.

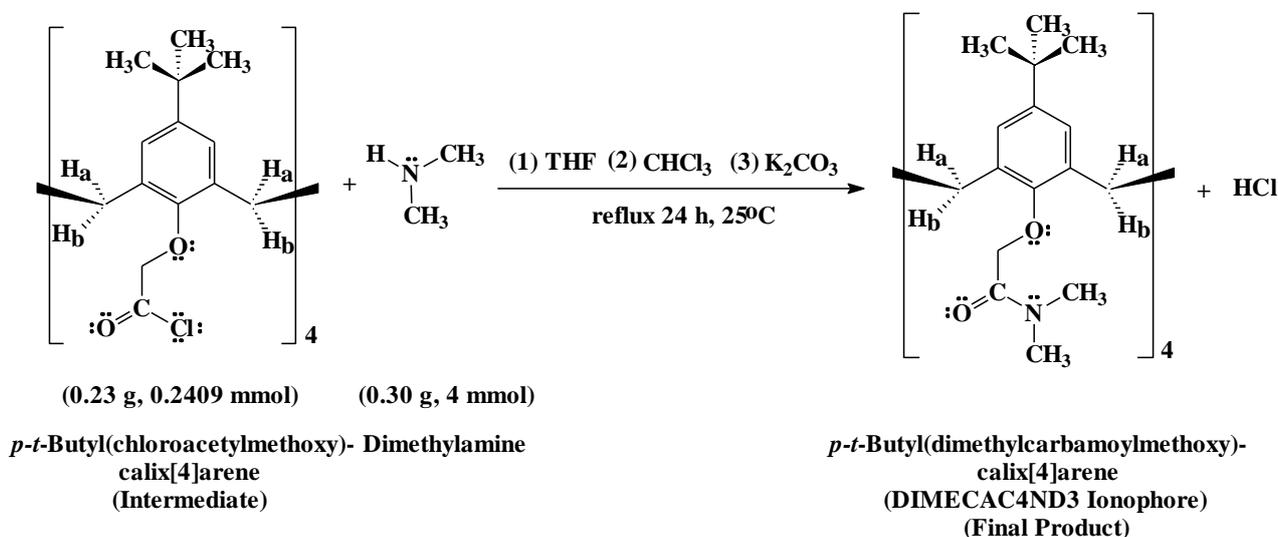
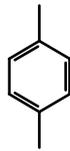


Figure 3. The amidation reaction of *p*-*t*-butyl(chloroacetylmethoxy)calix[4]arene with dimethylamine to form of the DIMECAC4ND3 ionophore

Table 1. Interpretation of the FTIR spectrum of the *p*-*t*-butyl(carboxymethoxy)calix[4]arene (raw material) and the DIMECAC4ND3 ionophore (product)

No	Frequency (cm ⁻¹) and Intensities		Frequency Ranges (cm ⁻¹) and Intensities*	Group or Class	Remarks
	Raw Material®	DIMECAC4ND3 Ionophore			
1	3166.9 (vs)	-	3400-2400 (s)	Carboxylic Acids RCOOH	OH stretch
2	1747.4 (vs)	-	1730-1700 (vs)		C=O stretch
3	1238.2 (s)	1242.1 (s)	1280-1220 (s)	Ethers ROR'	C-O-C stretch in alkyl aryl ethers
4	1126.4 v(s)	1126.4 (vs)	1140-1110 (vs)		C-O-C stretch in dialkyl ethers
5	1060.8 (s)	1064.6 (s)	1075-1020 (s)		R-C-O stretch in alkyl aryl ethers
6	1604.7 (w)	1581.5 (w)	1630-1430 (v)	Aromatic ArH 	C=C aromatic ring stretching
7	1299.9 (s)	1265.2 (s)	1300-1000 (s)		C-O aromatic ring stretching
8	1195.8 (vs)	1199.6 (vs)			Out-of-plane C-H deformation 1,4-disubstituted <i>para</i>
9	871.8 (s)	871.8 (s)	900-650 (s)		
10	798.5 (w)	794.6 (s)			
11	-	1666.4 (vs)	1670-1640 (vs)	Amides CONR ₂	C=O stretch of tertiary amides
12	-	1361.7 (s)	1400-1360 (m)		CH ₃ deformation
13	-	574.7 (m)	630-570 (s)		N-C=O bend
14	-	559.3 (s)	615-535 (s)		C=O out-of-plane bend
15	-	470.6 (m)	520-430 (m-s)		C-C=O bend
16	2958.6 (vs)	2962.5 (vs)	2970-2850 (s)	Aliphatic RH	C-H saturated stretching from (CH ₃) ₃ C-
17	2908.5 (s)	2904.6 (s)			
18	2869.9 (s)	2869.9 (s)			
19	1481.2 (vs)	1477.4 (vs)	1485-1450 (m)	Methylene -CH ₂ - <i>t</i> -Butyl (CH ₃) ₃ C-	C-H stretch from -CH ₂ -
20	1431.2 (vs)	1431.1 (vs)	1450-1375 (s)		C-H stretch from CH ₃ -

• Notes: vs = very strong; v = variable; s = strong; m = medium; w = weak.

® Sources: (Dali et al., 2020)

* Sources: (Kemp, 1991; Lambert et al., 2011; Sastrohamidjojo, 1994)

Table 2 shows the NMR (¹H, ¹³C) spectrum data of the DIMECAC4ND3 ionophore. **Table 2** shows that proton absorption signals appeared in the four main chemical shift regions, namely around δ_H 1, 3, 5, and 7 ppm. Signals around δ_H 1 ppm were from protons methyl amide [(CON(CH₃)₂-1_b)] and methyl *t*-butyl [(C(CH₃)₃-2¹)] which appeared at δ_H 1.0413 and 1.1164 ppm, respectively. Signals around δ_H 3 ppm were from proton methyl amide [(CON(CH₃)₂-1_a)] and methylene bridge [(ArCH₂Ar-20_a, 20_b)] which appeared at δ_H 3.3177 and 3.3312 ppm, respectively. Signals around δ_H 5 ppm were from the protons methylene methoxy [(CH₂O-2²)] and methylene bridge [(ArCH₂Ar-2_a, 2_b)] which appeared at δ_H 4.7128 and 4.2739 ppm, respectively. The signal around δ_H 7 ppm comes from the aryl proton [(ArH-22/24)] which appears at δ_H 6.8342 ppm.

The ¹H-NMR spectrum data also support the success of the synthesis reaction. This can be seen from the proton hydroxyl (OH) signal of the -COOH at δ_H 10.2771 ppm which no longer appears in the ¹H-NMR spectrum of the DIMECAC4ND3 ionophore. **Table 2** also shows the presence of proton methyl amide [CON(CH₃)₂] which appears at δ_H 3.3177 and 1.0413 ppm, where these two proton signals are not found in the ¹H-NMR spectrum of carboxylic acids (raw material). This indicates that the hydroxyl (OH) group of the -COOH has changed to an amide [CON(CH₃)₂] group during the synthesis reaction.

The success of the synthesis reaction was also supported by the ¹³C-NMR spectrum data (**Table 2**). This can be seen from the presence of two different carbon signals between the starting material and the synthesis product. First, there is a change in the

carbonyl carbon (C=O) signal from the starting material and synthesis product. The C=O signal of the -COOH (starting material) that appears at δ_c 170.0000 ppm has changed to carbonyl amide carbon [(CON(CH₃)₂) (C-1'')] (synthesis product) which appears at δ_c 169.5406 ppm. Second, the appearance of a carbon signal from the two methyl groups bound to N-amide (synthesis product) which was not found in the starting material. The carbons of the two methyl groups bonded to the N-amide show different absorption signals from one the another. Methyl carbon [(CON(CH₃)₂) (C-1_a)] and [(CON(CH₃)₂) (C-1_b)] appeared at δ_c 40.9449 and 33.9815 ppm, respectively. The appearance of these two different methyl carbon absorption signals is due to the different positions in the bond to the oxygen atom of the carbonyl (C=O) group of the amide. One methyl group is located in the *cis* position and the other as *trans*. The *cis* and *trans* positions are related to the conjugation effect in the [CON(CH₃)₂] bond and the

anisotropy of carbonyl (C=O) (Sastrohamidjojo, 1994). The carbon absorption signal from the methyl group at the *cis* position is more upfield than the *trans* position. The effect of the bond conjugation system and anisotropy on the difference in δ_c values of the two methyl groups also affects the δ_H value of each group, namely δ_H 3.3177 [(CON(CH₃)₂-(H-1_a))] and 1.0413 [(CON(CH₃)₂-(H-1_b))].

The ¹³C-NMR spectrum data (Table 2) also showed some similar carbon signals between the starting material and the synthesis product. The aryl carbon absorption signals of the synthesis product appeared in four δ_c values, namely 154.3175, 144.3976, 133.7528, and 125.4545 ppm. Aryl carbon which binds directly to oxygen [(CO aryl) (C-25)] is more downfield (δ_c 154.3175 ppm) compared to the other C-aryls. C-aryl absorption signals at δ_c 144.3976, 133.7528, and 125.4545 ppm, respectively, came from the *para* (C-23), *ortho* (C-1/C-21), and *meta* (C-22/C-24) positions.

Table 2. Interpretation of the NMR (¹H, ¹³C) spectrum of the *p-t*-butyl(carboxymethoxy)-calix[4]arene (raw material) and the DIMECAC4ND3 ionophore (product)

C Position	δ_c (ppm)		Groups	H Position	δ_H (ppm)		Groups
	Raw Material*	DIMECAC4 ND3 Ionophore			Raw Material	BEAC4ND4 Ionophore	
1, 21	125.6563	133.7528	C-o aryl		-	-	-
22, 24	125.5990	125.4545	C-m aryl	22, 24	6.9819 (1H, s)	6.8342 (1H, s)	ArH
23	132.7242	144.3976	C-p aryl		-	-	-
25	146.8027	154.3175	CO aryl		-	-	-
1'	34.1837	33.5974	C(CH ₃) ₃		-	-	-
2'	31.4844	31.5211	C(CH ₃) ₃	2'	1.1407 (9H, s)	1.1164 (9H, s)	C(CH ₃) ₃
2, 20	31.1887	32.7750	ArCH ₂ Ar	2 _a , 2 _b	4.1866 (2H, d, J = 13.5 Hz)	4.2739 (2H, d, J = 14.7 Hz)	ArCH ₂ Ar
				2 _{0a} , 2 _{0b}	3.4263 (2H, d, J = 13.5 Hz)	3.3312 (2H, d, J = 13.5 Hz)	ArCH ₂ Ar
1''	-	169.5406	C=O amides		-	-	-
	170.0000	-	C=O carboxylic acids	1''	10.2771 (1H, s)	-	CO ₂ H
2''	72.9952	72.0208	ArOCH ₂ -	2''	4.6090 (2H, s)	4.7128 (2H, s)	CH ₂ O
1 _a	-	40.9449	CON(CH ₃) ₂	1 _a	-	3.3177 (3H, m, J = 7.3 Hz)	CON(C H ₃) ₂
1 _b	-	33.9815	CON(CH ₃) ₂	1 _b	-	1.0413 (3H, m, J = 7.4 Hz)	CON(C H ₃) ₂

• Notes: o = *ortho*; m = *meta*; p = *para*; s = *singlet*; d = *doublet*; m = *multiplet*; J = *coupling constant*.

* Sources: (Dali et al., 2020).

The carbon signal that appears at δ_c 72.0208 ppm comes from C-methylene [(ArOCH₂-) (C-2'')] which is more downfield than other methylene because this C-methylene binds directly to oxygen and carbonyl (C=O) amide. Three strong absorption signals at δ_c 33.5974, 32.7750, and 31.5211 ppm were from tertiary carbon [C(CH₃)₃ (C-1')], methylene bridge [ArCH₂Ar(C-2/C-20)], and methyl carbon [(C(CH₃)₃)(C-2')], respectively. This order is based on the effect of the electronegativity of the atoms bonded by each carbon atom on the δ_c value and the relative abundance of the absorption signal in the ¹³C-NMR spectrum.

Based on the melting point data and the results of the analysis of the synthesis reaction product with FTIR and FTNMR spectrometers (¹H, ¹³C), the chlorination reaction to *p-t*-butyl(carboxymethoxy)calix[4]arene and amidation to *p-t*-butyl(chloroacetyl-methoxy)-calix[4]arene with dimethylamine gives *p-t*-butyl(dimethyl-carbamoylmethoxy)calix[4]arene (DIMECAC4ND3 ionophore) with a cone conformation (Figure 4). The cone conformational shape of the DIMECAC4ND3 ionophore (Figure 4) was identified by the proton chemical shift patterns of the aryl, methylene bridge, and *t*-butyl groups. According to Gutsche, Levine, & Sujeeth (2013), cone conformers exhibit a singlet signal from an aryl group proton, a doublet pair ($J = 12$ Hz) from a methylene bridge proton group, and a singlet signal from a *t*-butyl proton. The ¹H-NMR spectrum data of the DIMECAC4ND3 ionophore (Table 2) shows that there is a singlet signal of an aryl proton (ArH) at δ_H 6.8342 ppm [(s, 1H) (ArH-22/24)], a doublet pair of proton methylene bridged (ArCH₂Ar) on δ_H 4.2739 ppm [(d, 2H, $J = 13.5$ Hz) (ArCH₂Ar-2_a, 2_b)] and 3.3312 ppm [(d, 2H, $J = 13.5$ Hz) (ArCH₂Ar-20_a, 20_b)], and one singlet of the proton *t*-butyl [C(CH₃)₃] at δ_H 1.1164 ppm [(s, 9H) (C(CH₃)₃-2')]. Thus, the conformational shape of the DIMECAC4ND3 ionophore is cone.

The cone conformation of the DIMECAC4ND3 ionophore (Figure 4) was also identified by the proton

and carbon shift chemical patterns of the methylene bridge groups. The cone conformer exhibits a doublet pair of proton methylene bridged groups around (4.2 ± 1 ppm) and (3.4 ± 1 ppm) (De Mendoza et al., 2019; Arora, 2016; Gutsche et al., 2013; Gutsche et al., 2019). The ¹H-NMR spectrum data of the DIMECAC4ND3 ionophore (Table 2) showed the presence of a doublet pair of proton methylene bridge (ArCH₂Ar) on δ_H 4.2739 ppm [(d, 2H, $J = 13.5$ Hz) (ArCH₂Ar-2_a, 2_b)] and 3.3312 ppm [(d, 2H, $J = 13.5$ Hz) (ArCH₂Ar-20_a, 20_b)]. The pattern of these absorption bands indicates that the conformation of the DIMECAC4ND3 ionophore is a cone (Figure 4). If the chemical shift for the methylene carbon is near 31 ppm, two adjacent aryl groups are in a *syn* orientation to each other (De Mendoza et al., 2019; Arora, 2016; Gutsche et al., 2013; Gutsche et al., 2019). The spectral data ¹³C-NMR of the DIMECAC4ND3 ionophore (Table 2) shows that carbon absorption band from the methylene bridge group [(ArCH₂Ar) (C-2/C-20)] appears at δ_c 31.5974 ppm. This means that the orientation of two adjacent aryl groups is *syn* to each other (Figure 4).

CONCLUSIONS

The DIMECAC4ND3 ionophore has been successfully synthesized from *p-t*-butyl(carboxymethoxy) calix[4]arene. The DIMECAC4ND3 ionophore was obtained in the form of white solid with the rendement of 60.75%, a melting point of 277-279 °C, and TLC (SiO₂, CH₃OH : CH₂Cl₂ = 1 : 1 v/v, R_f = 0.82).

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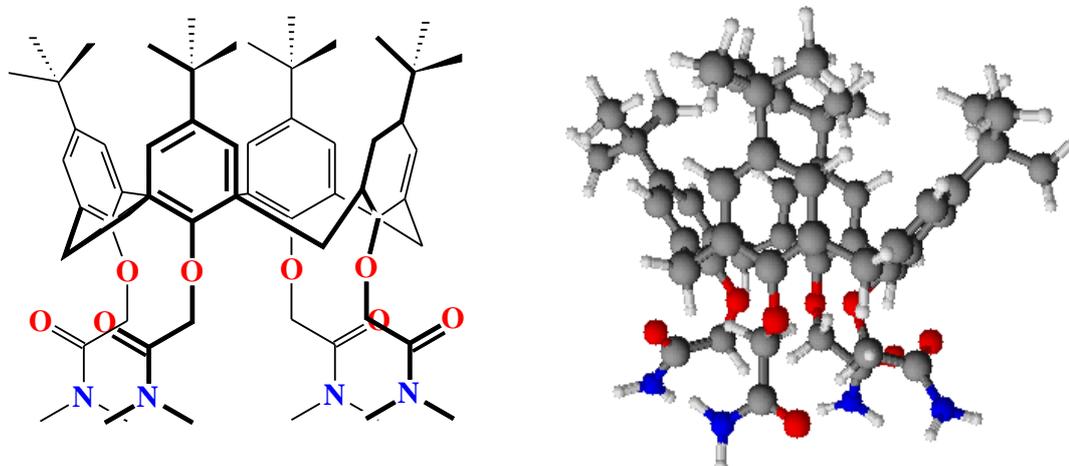


Figure 4. Cone conformation 2D and 3D structure of the DIMECAC4ND3 ionophore

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