# SYNTHESIS OF TETRA-*p*-PROPENYLTETRAESTERCALIX[4]ARENE AND TETRA-*p*-PROPENYLTETRACARBOXYLICACIDCALIX[4]ARENE FROM *p-t*-BUTYLPHENOL

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*Received December 15, 2009; Accepted January 12, 2010*

## ABSTRACT

*A research has been conducted to synthesize tetra-p-propenyltetraestercalix[4]arene and tetra-p-propenyltetracarboxylicacidcalix[4] arene using p-t-butylphenol as a starting material. The synthesis was carried out in following stages, i.e (1) synthesis of p-t-butylcalix[4]arene from p-t-butylphenol, (2) debutylation of p-t-butylcalix[4]arene, (3) tetraallilation of 25,26,27,28-tetrahydroxycalix[4]arene with NaH and allilbromida in dry tetrahydrofuran, (4) Claissen rearrangement of 25,26,27,28-tetrapropenyloxycalix[4]arene, (5) esterification of tetra-p-propenyltetrahydroxycalix[4]arene, (6) hydrolisis of tetra-p-propenyltetraestercalix[4]arene. The all structures of products were observed by means of melting point, FTIR, and $^{1}$H-NMR spectrometers. Tetra-p-propenyltetraestercalix[4]arene compound was obtained as yellow liquid product in 55.08% yield. Tetra-p-propenyltetracarboxylicacidcalix[4]arene compound was obtained as white solid product with the melting point 135-137 °C at decomposed and in 70.05% yield.*

***Keywords***: *calix[4]arene, Claissen rearrangement, esterification, hydrolisis*

## INTRODUCTION

Calixarenes have been well established as one of the major structural motifs in supramolecular chemistry. Calixarenes are cyclic oligomer of phenols linked by methylene bridges [1]. They exist in a 'cup' like shape with a defined upper and lower rim and a central annulus. Their rigid conformation enables calixarenes to act as host molecules as a result of their performed activities. By functionally modifying either the upper and/or lower rims it is possible to prepare various derivatives with differing selectivity for various guest ions and small molecules. Calixarenes lend themselves well too many applications because of the multiplicity of options for such structural elaboration [2].

Calixarenes can be used to various applications because of the number of geometry variation and its functional groups. The use of calixarenes as adsorbent [3-5]. Other applications of calixarenes are as heavy metal extractant and liquid membrane transport [6-9], trapping molecule and ion [10], ionophore [11], buffer [12], ion selective electrode [13], drugs [14], chemosensor for $F^-$ anion [15-16] and carboxylic acid [17].

The synthesis of calixarenes can be carried out by base inducing processes. The inducing processes usually applied for calixarenes synthesis are *p*-alkylphenol, especially *p-t*-butylphenol through one phase reaction with formaldehyde and NaOH or KOH [3]. The Yield of the reactions is generally high (60-90%). This process is much more cheap and easy to be done.

General and efficient procedures for the selective alkylation of calix[4]arenes at the smaller (lower) rim have been reported allowing the synthesis of tetralkoxycalixarenes. Incorporation of the tetra-*p*-propenyl functionality was achieved by treatment of tetrahydroxycalix[4]arene with NaH and allilbromida in dry tetrahydrofuran affording the lower rim functionalized p-propenyl derivative. *Claissen rearrangement* in the presence of N,N-diethylamine [18-19] furnished the desired *p*-allylcalix[4]arene.

There is a wealth of literature in chemical journals and in specialised books concerning the synthesis and properties of calixarenes [20]. Our laboratory has been active in designing and synthesizing calixarenes for adsorbent. It has been discovered in our previous research that tetrasulfonatotetraalkoxy calix[4]arenes, *p*-alkenylcalixarenes, and *p*-haloalkylcalixarenes significantly efficient for trapping of heavy metal cations [21], c-4-methoxyphenylcalix[4]resorcinarene significantly

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efficient to adsorb Pb (II) and Cr(III) metal cations in a batch or fixed bed column system [22].

The use of calixarenes for heavy metal ion adsorbent may not dissolve in water. By functionally modifying either the upper and/or lower rims it is possible to prepare of calixarenes to be dissolve in water. This can be done by modify its functional groups using polar (hydrophilic groups) such as carboxylic, sulphonate, nitro, amino, amida, halide, and phosphate.

In this paper, we report the synthesis of tetra-*p*-propenyltetraestercalix[4]arene, and tetra-*p*-propenyl-tetracarboxilicacidcalix[4]arene from *p-t*-butylphenol.

## EXPERIMENTAL SECTION

### Materials

*p-tert*-Butylcalix[4]arene and tetrahydroxycalix[4]-arene were prepared from *p-t*-butylphenol according to the procedures reported previously [3]. All the chemicals were purchased from Merck or Sigma-Aldrich.

### Instrumentation

IR spectra were recorded on a Shimadzu Prestige-21 FTIR spectrometer as KBr pellets. $^1$H-NMR spectrums were recorded on a JEOL 500 MHz spectrometer.

### Procedure

#### *Synthesis of 25,26,27,28-tetrapropenyloxycalix[4]-arene*

Tetrahydroxycalix[4]arene 2 g (4.8 mmol), 2 g (83.3 mmol) NaH, 12.5 mL (195 mmol) allylbromida, and 50 mL dry THF were added into a three-necked flask equipped with a reflux condenser. The mixture was refluxed for 7 h. The resulting mixture was allowed to cool and THF was evaporated. The precipitated was filtered off and recrystallized with chloroform-methanol and then characterized by means of FTIR and $^1$H-NMR.

#### *Synthesis of tetra-p-propenylcalix[4]arene*

A solution of 1 mmol 25,26,27,28-tetraallyloxycalix[4]arene in diethylaniline (10 mL) was refluxed for 2 h in an inert atmosphere. The mixture was cooled, poured into 50 mL of ice water, triturated with 50 mL of concentrated HCl and the resulted solid was filtered off. The solid was recrystallized, dried and then characterized by means of FTIR and $^1$H-NMR.

#### *Synthesis of tetra-p-propenyltetraestercalix[4]arene*

Into a three-necked flask equipped with a reflux condenser, it was added 0.25 mmol tetra-*p*-propenylcalix[4]arene, 0.2875 g (2.35 mmol) ethyl-2-chloroacetic, 0.355 g (2.35 mmol) NaI, 0.425 g (3.25 mmol) $K_2CO_3$ and 50 mL dry acetone. The mixture was refluxed for 24 h. The resulting mixture was allowed to cool, $K_2CO_3$ was filtered off and acetone was evaporated. The residu was dissolved in chloroform, and then washed with 3 x 25 mL HCl 1 M and 1 x 25 mL saturated NaCl. The solution was dried with $Na_2SO_4$ anhydrous and chloroform was evaporated. The product was characterized by means of FTIR and $^1$H-NMR.

#### *Synthesis of tetra-p-propenyltetracarboxylic-acidcalix[4]arene*

Estercalix[4]arene (2 g) and KOH (0.5 g) in 100 mL ethanol 95% were added into a three-necked flask equipped with a reflux condenser. The mixture was reluxed for 24 h. The resulting mixture was allowed to cool and acidified with HCl 1 M. The precipitated was filtered off and then washed with 2 x 25 mL HCl to be followed with 3 x 25 mL water. Furthermore the product was dried in a desicator and recrystallized with ethanol. The product was characterized by means of FTIR and $^1$H-NMR.

## RESULT AND DISCUSSION

### Synthesis of 25,26,27,28-tetrapropenyloxycalix[4]-arene

Synthesis of 25,26,27,28-tetrapropenyloxycalix[4]-arene was carried out by refluxing 1.1 equivalent of allyl bromide and 0.6 equivalent of $K_2CO_3$ in acetone at 56 °C for 48 h under a nitrogen atmosphere. The product obtained for this reaction was white solid having m.p. 217-218 °C (literature 216-217 °C). Structure identifications were performed using FTIR and $^1$H-NMR spectrometers.

Structural analysis based on FTIR spectrum shows absorption band at 3166.9 cm$^{-1}$ of the hydroxyl group (OH) disappeared indicating that the allilation reaction has taken place. The existence of propenyloxy is showed at 3065 and 3021 from vibration absorption $C_{sp2}$-H, bands 2923-2850 cm$^{-1}$ from $C_{sp3}$-H, 1647 cm$^{-1}$ from C=C aliphatic and 1454 cm$^{-1}$ from $CH_2$.

$^1$H-NMR spectrum of the synthesized product shows 4 signals depicting 4 different types of protons. Signals at δ = 5.0-5.5 ppm refer to terminal proton resonance of allyloxy (=$CH_2$) group. Signals at δ = 5.9-6.4 ppm are predicted from one proton in the middle carbon (-CH=) group. The O-$CH_2$- group protons are estimated to resonate at δ = 4.3-4.1 ppm. The existence of methylene bridge of calixarene (-$CH_2$-) protons are shown at δ = 4.1-3.8 ppm.

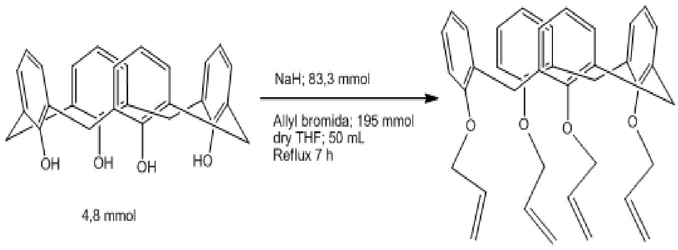


**Fig 1.** Synthesis of 25, 26, 27, 28-tetrapropenyloxycalix [4]arene

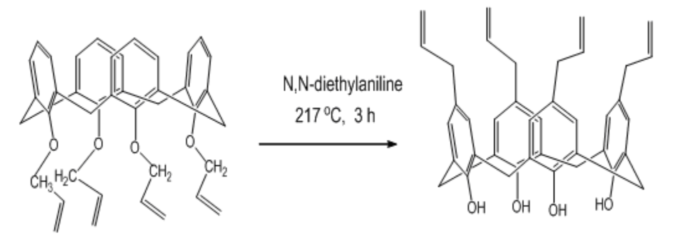


**Fig 2.** *Claissen rearrangement* of 25, 26, 27, 28–tetraallyloxycalix[4]arene

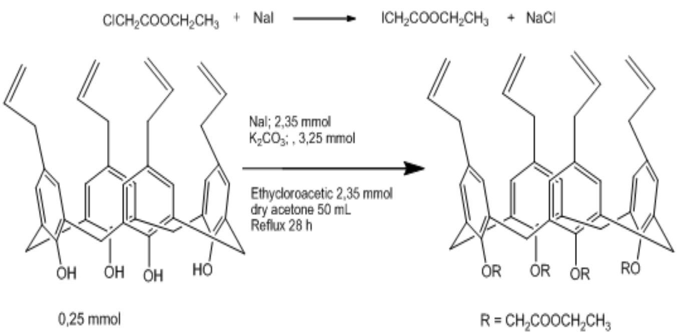


**Fig 3.** Esterification of tetra-*p*-propenylcalix[4]arene

Based on FTIR, and $^1$H-NMR analyses and melting point measurement, it can be concluded that the synthesis of 25,26,27,28-tetrapropenyloxycalix[4]arene was successfully produced. The synthesis of the product is schematically illustrated in Fig. 1.

**Claissen rearrangement of 25,26,27,28-tetra-propenyloxycalix[4]arene**

*Claissen rearrangement* of 25,26,27,28-tetrapropenyloxycalix[4]arene was carried out at 217 °C for 3 h in the presence of *N,N*-diethylaniline. The solid was precipitated after the addition of excess HCl in order to remove the remaining *N,N*-diethylaniline. The obtained product was then recrystallized using dichloromethane-methanol to give tetra-*p*-propenylcalix [4]arene. Result of tetra-*p*-propenylcalix[4]arene is presented in Table 1.

FTIR spectrum shows broad absorption band at 3170.8 cm$^{-1}$ indicating a hydroxyl group (OH). Spectrum was not showed absorption from C-O-C which in tetrapropenyloxycalix[4]arene is showed at 1087-1195 cm$^{-1}$.

The success of the reaction can also be proved from the $^1$H-NMR spectrum. Signal at δ = 10.17 ppm is predicted from -OH protons. The existence of aryl (ArH) protons are estimated to appear at δ = 6.851 ppm. The propenyl group protons (-CH=) are estimated to resonate at δ = 6.3-5.5 ppm. The resonance of methylene bridge protons are predicted to occur at δ = 4.0-3.6 ppm. The propenyl group protons (-$CH_2$) are estimated to resonate at δ = 3.1 ppm.

Regarding FTIR, and $^1$H-NMR analyses, it can be concluded that the *Claissen rearrangement* of 25, 26, 27, 28–tetrapropenyloxycalix[4]arene gave tetra-*p*-propenylcalix[4]arene. The reaction scheme of the product formation is schematically illustrated in Fig. 2.

**Esterification of tetra-*p*-propenylcalix[4]arene**

Esterification of tetra-*p*-propenylcalix[4]arene was performed using $K_2CO_3$, NaI, and 2-ethylchloroacetate reagents. This ester synthesis is shown schematically in Fig. 3.

Result of tetra-*p*-propenylcalix[4]arene esterification is presented in Table 1.

FTIR spectrum of the resulted product shows that the absorption band at 3166.9 cm$^{-1}$ of the hydroxyl group (OH) disappeared indicating that the esterification reaction has taken place. Another strong evidence for the success of the reaction is the appearance of strong absorption band at 1759 cm$^{-1}$ from carbonyl group (-C=O) and absorption band at 1200–1100 cm$^{-1}$ which is characteristic for C-O-C ester.

The next analysis was done using $^1$H-NMR spectrometer. The existence of aryl (ArH) protons are estimated to appear at δ = 6.47-6.5 ppm. The propenyl group protons (-CH=) are estimated to resonate at δ = 6.3-5.5 ppm. The resonance of methylene bridge protons are predicted to occur at δ = 4.21-4.19 ppm. The propenyl group protons (-$CH_2$) are estimated to resonate at δ = 3.06-3.17 ppm.

**Synthesis of tetra-*p*-propenyltetracarboxylicacid-calix[4]arene**

Synthesis of carboxylic acid from calixarene was done by hydrolysis reaction of tetra-*p*-propenyltetra estercalix[4]arene. Scheme and result of the hydrolysis reaction are shown in Fig. 4 and Table 1, respectively.

FTIR spectrum of the resulted product shows the appearance absorption band at 3387.08 cm$^{-1}$ from hydroxyl group (OH) vibration indicating that the hydrolysis has taken place. This indicated that the ester group was hydrolyzed to carboxylic acid. Absorption at 1701.33 cm$^{-1}$ expresses carbonyl (C=O) group vibration.

**Table 1.** Results of the synthesized products

| Compounds | Results | | | |
|---|---|---|---|---|
| | m.p (°C) | Color | Shape | Yield (%) |
| 25,26,27,28-tetrapropenyloxycalix[4]arene | 183-185 °C | white | solid | 49.99 |
| tetra-p-propenyltetrahydroxycalix[4]arene | 235-237 °C | white | solid | 40.02 |
| tetra-*p*-propenyltetraestercalix[4]arene | - | yellow | liquid | 55.08 |
| Tetra-*p*-propenyltetracarboxylicacidcalix[4]arene | 135-137 °C | white | solid | 70.05 |

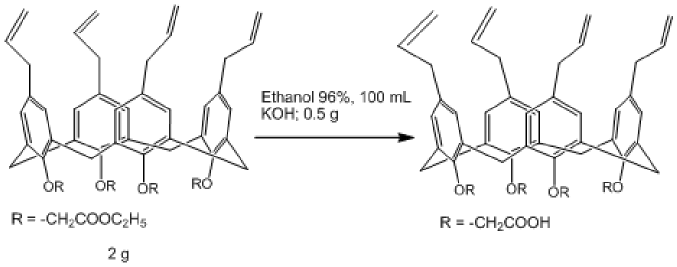


**Fig 4**. Hydrolysis of tetra-*p*-propenyltetraestercalix[4] arene

Absorption at 1604.47 $cm^{-1}$ refers to the C=C vibration. The existence of methylene groups are showed at 1433.04 $cm^{-1}$.

The success of the reaction can also be proved from the $^{1}$H-NMR spectrum. The resonance of 4 H from -OH are predicted to occur at δ = 7.1995-6.9002 ppm. The existence of aryl (ArH) protons are estimated to appear at δ = 6.4137-6.1668 ppm. The resonance of methylene bridge protons are predicted to occur at δ = 3.2346-3.1051 ppm. The propenyl group protons are estimated to resonate at δ = 5.2562-5.2342 ppm.

Results of the synthesized products are presented in Table 1.

## CONCLUSION

The synthesis of tetra-*p*-propenyltetraestercalix[4] arene and tetra-*p*-propenyltetracarboxylicacidcalix [4]arene have been succesfully produced from *p-t*-butylphenol via five and six stages reactions. The stages were synthesis of *p-t*-butylcalix[4]arene from *p-t*-butylphenol, debutylation of *p-t*-butylcalix[4]arene, tetraallilation of 25,26,27,28-tetrahydroxycalix[4]arene, *Claissen rearrangement* of 25,26,27,28-tetrapropenyloxycalix[4]arene, esterification of tetra-*p*-propenyltetrahydroxycalix[4]arene, and hydrolisis of tetra-*p*-propenyltetraester-calix[4]arene.

## ACKNOWLEDGEMENT

We thank the Incentive Research Projects Foundation from the Ministry of Science and Technology, Indonesia for financial support of this work.

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