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Regioselective Addition of *N*-(4-Thiocyanatophenyl)pyrrolidine Addends to Fullerenes

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The regioselectivity of 1,3-dipolar cycloaddition reactions between *N*-(4-thiocyanatophenyl)glycine and tetrakis[bis-(ethoxycarbonyl)methylene]-C_{60} (**7**) was studied. The mono-addition resulted in two penta-adduct isomers (**8** and **9**) in a 1:1 ratio. A second addition to each compound led to, in the case of **8**, two hexa-adduct isomer products (**10** and **11**), whereas addition to **9** led to **11** and **12**. Finally, reaction of **11** and the glycine afforded a third addition, giving rise to hepta-adduct isomers **13** and **14**. Preparative TLC and column chromatography were used to separate and purify these compounds. The structures were assigned based on their molecular symmetries as analyzed by ^{1}H, ^{13}C, and 2D NMR spectra and MALDI-TOF MS.

Introduction

Since Krätschmer, Huffman, and co-workers[1] discovered a bulk fullerene preparation method in 1990, the adducts of C_{60} have been studied extensively. One area that has interested researchers is the use of fullerenes in molecular electronics applications. There are reports of C_{60} being used as a single-molecule transistor by inducing nanomechanical oscillations between two gold electrodes,[2a,2b] tunneling of electrons through a C_{60} compound between two magnetic nickel electrodes[2c] and a field-sensitive double-tunnel junction with C_{60} embedded in SiO_2 for nonvolatile memory applications.[2d] Morita and Lindsay[2e] presented the first example of a C_{60} derivative as a single-molecule transistor. Two bis-adducts *trans*-1 and *trans*-2 with amino-terminated linkers exhibited enhanced electron-tunneling conductance upon accepting electrons, with the dianion being the best conductor and the neutral species the worst.[2e]

The presence of 30 equiv. of [6,6] double bonds on the surface of C_{60}, all of which exhibit identical reactivity, results in low regioselectivity under conditions resulting in multiaddition products.[3] After the formation of the mono-adduct, successive additions of one, two, and three symmetrical addends yield 8, 46, and 262 possible regioisomers, respectively.[4] Hirsch and co-workers published an extensive study on the isolation and characterization of the multiple adducts from cyclopropanation of C_{60} with diethyl bromomalonate. These included the first tris-adducts, which were called C_3 and D_3.[5] It should be noted that the isolation of these isomers was only achieved after laborious chromatographic separation and was not a trivial endeavor.

Hirsch also proposed a nomenclature for the positional relationships of the eight different double bonds in bis-(ethoxycarbonyl)methylene-C_{60} [6,6]-bis-adducts with respect to the bond carrying the first addend. The most favorable positions for subsequent cyclopropanation of a mono-adduct were found to be the equatorial and *trans*-3 positions (**1**, Figure 1).[5b]

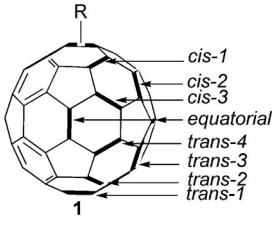

Figure 1. Hirsch nomenclature of the eight double bonds in C_{60} [6,6]-bis-adducts with respect to the bond having the first addend R.

The distribution of the eight possible bis-adducts depends not only on the steric demands of the addends but also on the type of cycloaddition reaction employed. Another cycloaddition[6] that has been extensively studied is the 1,3-dipolar cycloaddition of azomethine ylides to C_{60}, first reported by Prato and co-workers.[7] This reaction yields a fullerene product with a pyrrolidine ring attached. Wilson and co-workers found that 1,3-dipolar cycloadditions are less chemoselective than the corresponding cyclopropanations of C_{60}.[6] The reaction resulted in all eight possible regioisomers if the azomethine ylide was symmet-

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ric. The yield of *trans*-1 bis-adducts is only 1–6% of the total yield and is the isomer formed in the lowest amount.[8] Additionally, the isolation of isomerically pure bis-adducts is challenging because bis- and tris-adducts co-elute during chromatography due to their similar polarities.[9] One way in which the regiochemistry of multiple additions to fullerenes has been controlled is the tether-directed remote multifunctionalization approach.[11] Specifically, a covalent template is used to functionalize the fullerene with reversibly removable addends. Diels–Alder reaction and cyclopropanation are the two most common routes that have been used in this approach.[11] One of the advantages is that the regiochemistry of bis-adducts can be controlled by the length, geometry and rigidity of the tether. In some examples equatorial,[10] *cis*-2,[11] *trans*-2[12a] or *trans*-1,[12b,12c] structures could be obtained almost exclusively.

In 1999, T_h- and D_3-hexakis-adducts of fulleropyrrolidine hexanitroxide were reported by Rubin and co-workers.[13a] In 2006, Rubin and co-workers also reported a *cis*-1 bis-adduct temporarily blocked by a tethered 1,3-diene, which activated the LUMO orbital coefficients at the [*trans*-4,*trans*-4,*trans*-4] positions. Later, the tether was removed thermally.[13b] In closely related works Kräutler and co-workers reported the first example of an approach they named "orthogonal transposition" in which C_{60} was protected with two thermally labile anthracene groups in the *trans*-1 positions followed by symmetric addition of four malonate groups to the equatorial belt of C_{60}. The anthracene moieties were then removed by a thermal retro-Diels–Alder reaction.[14] Using Kräutler's approach,[14] in 2006 we reported the synthesis of *trans*-1 bis(terpyridylyl)pyrrolidine C_{60}-tetramalonate **2** and *trans*-1 pyridylpyrrolidine/terpyridylylpyrrolidine C_{60}-tetramalonate **3**.[15] The malonates were subsequently removed by controlled potential electrolysis (CPE) to give the desired *trans*-1 bis(terpyridylyl) compound **4** (Figure 2).[15] An interesting result was that the electrochemistry became reversible upon removal of the malonates. In the present work, we present a study of multiple additions of the thiocyanatophenyl group (C_6H_4SCN) to tetrakis[bis(ethoxycarbonyl)methano]-C_{60}, (**7**). We report a family of compounds that can potentially complex different metal ions such as Cu^{II},[16a] Ag, Pt, and Au upon cleavage of the S–CN bond, giving rise to species identical to those seen in free thiol assemblies.[16b,16c]

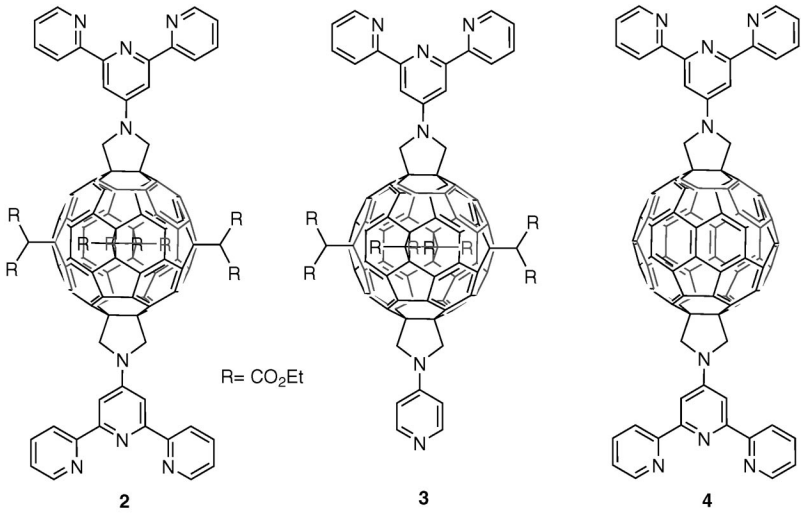
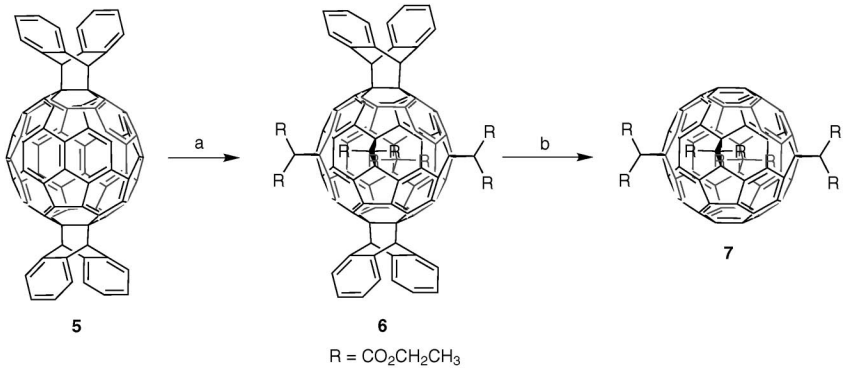


Figure 2. Structures of compounds **2**, **3**, and **4**.



Scheme 1. Synthesis of C_{60}-tetramalonate **7**.

The crux of the orthogonal transposition approach involves a protection/deprotection scheme in order to prepare an equatorially protected C_{60} compound containing four addends, which leave the antipodal hemispheres of the fullerene available for further reaction.[14] This is done by first preparing *trans*-1 bis(anthracene) adduct **5** of C_{60} in a solid-state reaction,[17] followed by multiple Bingel reactions in order to prepare hexakis-adduct **6**.[14] Finally, thermally induced retro-Diels–Alder reaction to remove the anthracene moieties gives compound **7** (Scheme 1).[14] The protection/deprotecion scheme was further extended by treating compound **7** with terpyridylylglycine and paraformaldehyde, which resulted in mono- and bis-addition to yield **2**.[15]

On the basis of the results obtained in preparing **2**–**4**, further studies to develop this strategy for the regioselective synthesis of pentakis-, hexakis-, and heptakis-adducts of C_{60}-fullerene were designed, and the results are presented in the present work.

Results and Discussion

Synthesis of 8, 9 and 10

Compound **7**, *N*-[(4-thiocyanato)phenyl]glycine and paraformaldehyde were allowed to react in a 1,3-dipolar cycloaddition reaction to give hexakis-adducts **10** and **11** in a single step. This is different from the protocol used previously[15] where the pentakis-adduct products were recovered, purified and allowed to react again under the same conditions to obtain the hexakis-adducts (Scheme 2).

After 30 min, three molecular ion peaks corresponding to pentakis-, hexakis- and heptakis-adducts of C_{60}-fullerene were observed by MALDI-TOF MS. The crude reaction mixture was subjected to column chromatography with CH_2Cl_2 as eluant, and six fractions were isolated (Scheme 2). The first two fractions had the same molecular mass (S25, Supporting Information) corresponding to the pentakis-adducts **8** and **9**, and the subsequent three fractions had the same molecular mass corresponding to hexakis-adducts **10**, **11** and **12**. The last fraction was a mixture of heptakis-adducts. The first two pentakis fractions were characterized by means of ^1H and ^{13}C NMR spectroscopy and were determined to be the isomeric compounds **8** and **9**, respectively. The addition of the C_6H_4SCN group occurs at two different positions. It can either add to the unique double bond on a hemisphere (called symmetric in Figure 3) or to one of the other four equivalent double bonds located on the same hemisphere (called unsymmetric in Figure 3). If the addition reaction occurred statistically the product ratio should be 1:4 in favor of the unsymmetrical product **9** vs. **8**. Since the observed ratio was 1:1, the reaction at the unique double bond is favored fourfold, probably due to steric hindrance of the malonates around the unsymmetric bonds. Thanks to electronic effects as well,[3,18] the symmetric double bond (Figure 3) will be favored because it is an equatorial position with respect to each cyclopropane ring.

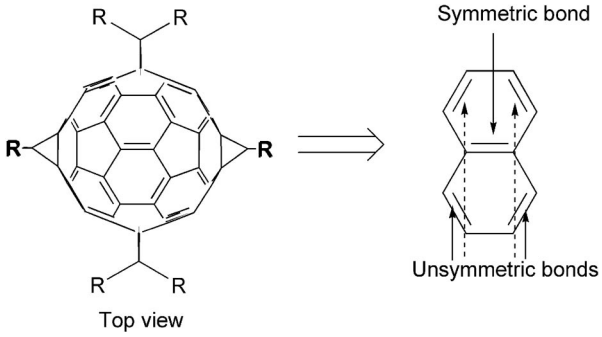
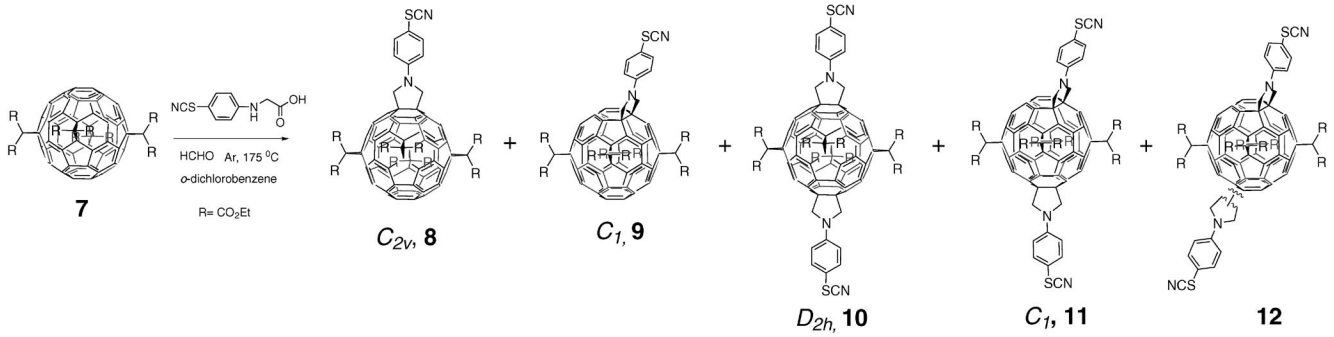


Figure 3. Two different sites of addition to **7** leading to symmetric (**8**) or unsymmetric (**9**) pentakis-adducts.

The (C_{2v} and C_1) symmetries of **8** and **9** were determined by NMR spectroscopy. The ^1H NMR spectrum of **8** (Figure 4) showed three sets of triplets for CH_3 protons, with integration ratios of 6:6:12, between δ = 1.40 and 1.30 ppm. These were assigned to the malonate groups for compound **8**. The signals of the methylene protons from the malonate groups overlapped with those of the protons from the pyrrolidine ring. Two doublets integrating for two protons each were observed for the four aromatic protons. The C_{2v} symmetry of compound **8** was also corroborated by the ^{13}C NMR spectrum (S14, Supporting Information). Three signals for carbonyl groups and three for methyl groups indicated that two groups were in different chemical environments and two were equivalent. Twelve sp^2-C signals of the fullerene cage were observed between δ = 154 and 117 ppm. Seven sp^3-C signals were also observed, three between δ = 69.85 and 61.40 ppm, assigned to the sp^3-fullerene carbon



Scheme 2. Synthesis of fullerene derivatives with 4-thiocyanatophenyl groups.

atoms. One of these signals was from the two carbon atoms of the pyrrolidine ring, and the other two were from the two different carbon atoms of the four cyclopropane rings. The remaining four sp^3-C signals left in this region were assigned to methylene groups, where one signal was for the pyrrolidine ring and three were for the four malonate groups.

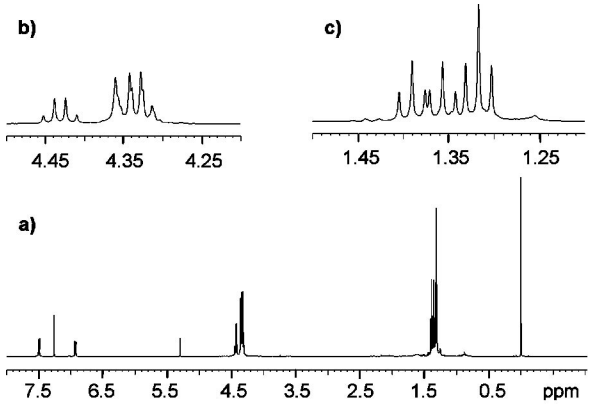


Figure 4. (a) ^{1}H NMR spectrum of symmetric pentakis-adduct **8** (500 MHz, $CDCl_3$) and expanded parts from (b) δ = 4.5 to 4.2 ppm and (c) δ = 1.5 to 1.2 ppm.

The analysis of **9** by ^{1}H NMR spectroscopy (Figure 5) showed the expected lower symmetry (Figure 5). The aromatic proton signals were shifted downfield when compared to those of **8**. Seven triplets were observed between δ = 1.52 and 1.31 ppm due to eight different methyl groups (one triplet had twice the intensity of the others) and multiplets for the methylene protons indicated NMR non-equivalency. The ^{13}C NMR spectrum (S16, Supporting Information) of **9** indicated C_1 symmetry with 49 sp^2-C signals from the fullerene cage appearing between δ = 151 and 111 ppm, 7 signals for carbonyl groups and seven for methyl groups. Nine signals between δ = 72.22 and 62.00 ppm were assigned to the sp^3-C atoms of the fullerene cage, whereas seven signals were assigned to the cyclopropane rings, and two were assigned to the pyrrolidine ring. Finally, nine signals were assigned to the methylene moieties of the malonate groups.

The next three fractions (**a**, **b**, and **c**), with a mass ratio of 1:2.2:1.3, were purified by preparative TLC on silica gel using dichloromethane as eluant. The plate was dried multiple times and new eluant used until an optimal separation was obtained. Fraction **a** was identified as hexakis-adduct **10** after characterization by ^{1}H NMR spectroscopy (Figure 6, a), ^{13}C NMR spectroscopy, COSY, and MALDI-TOF. The ^{1}H NMR spectrum (Figure 6, a) exhibited two doublets integrating for four protons each. A sharp peak at δ = 4.59 ppm was assigned to the eight equivalent pyrrolidine protons. Two quartets at δ = 4.35–4.30 and 4.30–4.26 ppm integrating for eight protons each were assigned to the two sets of methylene moieties in the malonate groups. Two of the triplets at δ = 1.35–1.32 and 1.28–1.25 ppm corresponded to twelve protons each and were assigned to the two different methyl groups from the malonate groups.

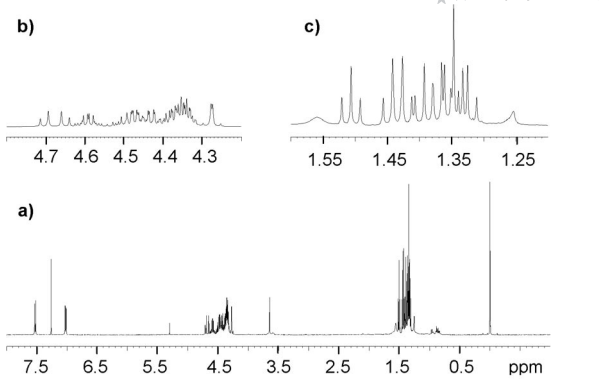


Figure 5. (a) ^{1}H NMR spectrum of asymmetric pentakis-adduct **9** (500 MHz, $CDCl_3$) and expanded parts from (b) δ = 4.8 to 4.2 ppm and (c) δ = 1.6 to 1.2 ppm.

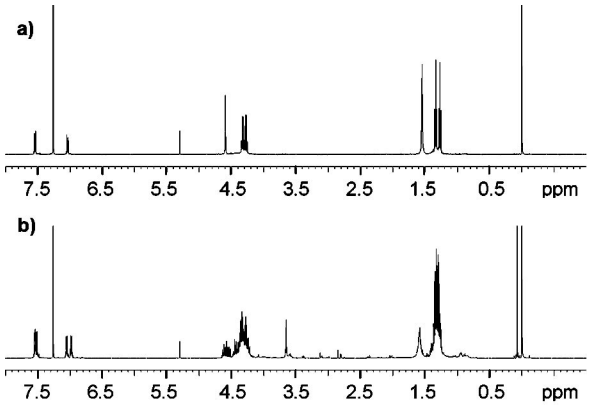
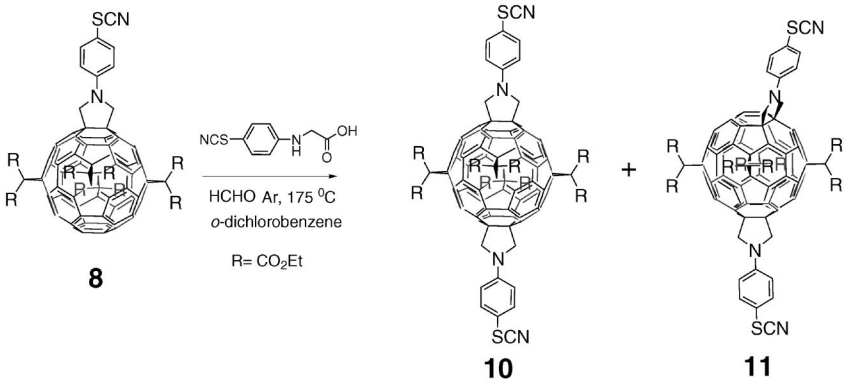


Figure 6. ^{1}H NMR spectrum of (a) compound **10**, (b) compound **11** ($CDCl_3$).

Similar ^{1}H NMR results were previously obtained for **2**, which possesses the same D_{2h} symmetry as **10**.[15] The ^{13}C NMR spectrum of **10** showed two peaks for carbonyl groups, two peaks for methyl groups, and six sp^2-C peaks for the fullerene cage. Finally, four signals between δ = 66.87 and 61.00 ppm for the sp^3-C atoms of the fullerene cage and methylene groups were observed (see Supporting Information). The NMR spectrum of **10** indicated D_{2h} symmetry because all of the addends are located at the pseudo-octahedral positions on the fullerene. The structures of the other two hexakis-adducts from fractions **b** and **c** were difficult to assign by ^{1}H and ^{13}C NMR spectroscopy and COSY because of their structural complexity and lack of symmetry. Hence, their structures were elucidated by using an alternate synthetic route, discussed below.

Synthesis of 10, 11, and 12

After allowing **8**, *N*-(4-thiocyanatophenyl)glycine, and paraformaldehyde to react for 15 min (Scheme 3), two hexakis-adducts and one heptakis-adduct were detected by TLC. Three fractions were isolated by preparative TLC using dichloromethane as eluant. The first two fractions were characterized as hexakis-adducts **10** and **11**, respectively.



Scheme 3. Synthesis of [*N*-(4-thiocyanatophenyl)pyrrolidino]fullerene derivatives **10** and **11**.

Not surprisingly, **10** and **11** were obtained in a ratio of 1:2.4 instead of the expected 1:4 ratio (see Figure 3).

Two sets of doublets for each ring were observed in the ^{1}H NMR spectrum of **11** (Figure 6, b), two of them overlapped and integrated to four protons. The other doublets correspond to two protons each, for a total of four different aromatic protons. The protons of the pyrrolidine ring and the malonate groups overlapped and gave rise to a multiplet.

Figure 7 shows the COSY spectrum for **11**. Three correlations were observed between (1) CH_2 and CH_3 of the malonate groups, (2) the protons of the pyrrolidine ring, and (3) the protons of the C_6H_4SCN ring. The lack of symmetry results from addition at one of the four unsymmetric bonds on the unoccupied hemisphere of **8**. The controlled synthesis of the hexakis-adducts by using **8** as the starting material confirmed the hypothesis that an addition to the same side of the first symmetric addend was not feasible and does not occur. Thus, two possible isomers can be obtained when the synthesis starts with this pentakis-adduct (Figure 8, a). The NMR spectra and the R_f value of fraction **b** are consistent with those expected for **11**. This confirmed that fraction **b** corresponds to compound **11**. The reaction between **9**, *N*-(4-thocyanatophenyl)glycine, and paraformaldehyde (Scheme 4) was stopped after 10 min when heptakis-adducts were observed by TLC. After purification, two hexakis-adducts were isolated (**11** and **12**) in a mass ratio of 1:1.4. The NMR spectra and the R_f value of fraction **c** are consistent with those of **12**. When compound **12** was subjected to HPLC by using toluene as the mobile phase in a Buckyprep column, seven peaks were observed, the retention time of one of them matching that of **11**. From the seven isomers, two of them had an area three times larger than those of the other five products (S22, Supporting Information). The next addition of the C_6H_4SCN group to **9** during the synthesis of **12** resulted in up to seven isomers (Figure 8, b).

From these reactions (Schemes 3 and 4) it is possible to conclude that **9** is more reactive than **8**. After 10 min of reaction, **9** gave rise to more products than **8**. Also, the amount of **9** recovered after the reaction was much less than in the case of **8**. This means that every time an addition occurs on an unsymmetric double bond, the resulting compound is more reactive, which decreases the yield. Thus, the reactivity order is **11** > **10** > **9** > **8**, with **11** being the most reactive.

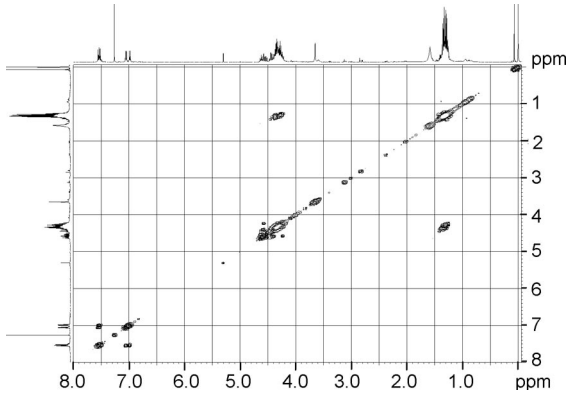


Figure 7. COSY spectrum of **11** (500 MHz, $CDCl_3$).

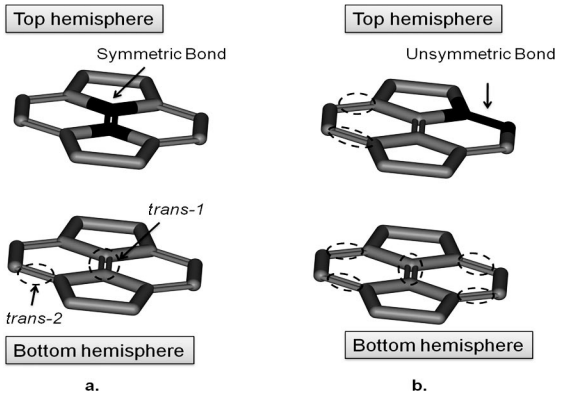
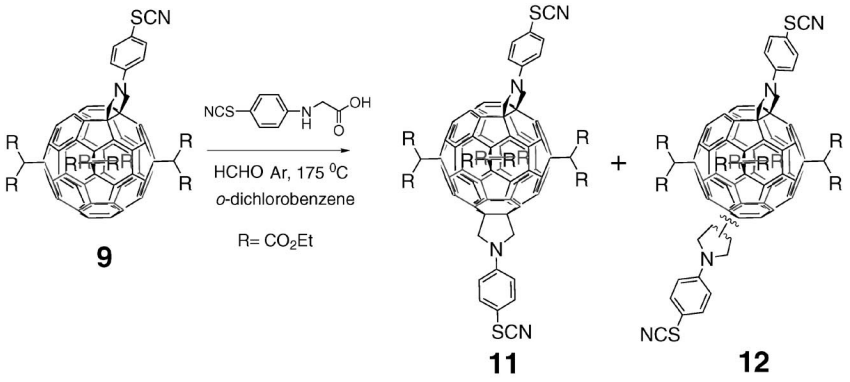


Figure 8. (a) Schematic representation of two possible isomers for a second addition to compound **8** (mono-symmetric adduct). (b) Schematic representation of seven possible isomers for a second addition to compound **9** (mono-unsymmetric adduct). Dotted circles represent possible addition sites, and bold-faced bonds represent adduct positions.



Scheme 4. Synthesis of [*N*-(4-thiocyanatophenyl)pyrrolidino]fullerene derivatives **11** and **12**.

Synthesis of 13 and 14

After purification and characterization of **11**, the synthesis of heptakis-adducts was pursued by using **11** as the starting material. According to the previous results, the addition of a new group should not occur on the same six-membered ring that already has a group attached. This leads to the possibility of just two regioisomers (Figure 9).

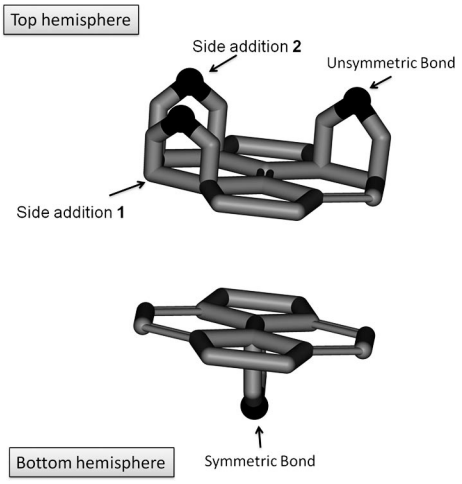


Figure 9. Two different bonds available for the heptakis-adducts of compound **11**.

The reaction of **11**, *N*-(4-thiocyanatophenyl)glycine, and paraformaldehyde in *o*-dichlorobenzene resulted in a mixture of heptakis-adducts (Figure 9). After 30 min of reaction, the crude material was subjected to preparative TLC with CH_2Cl_2 as eluant, giving two fractions. The first two fractions had the molecular ion peak corresponding to heptakis-adducts, defined as heptakis-1 and heptakis-2, respectively. The ^{1}H NMR spectrum of heptakis-1 (Figure 10, a) showed two doublets in the aromatic region which integrated for two protons each, and two "triplets" corresponding to four protons each (which were two overlapped doublets) for a total of six different aromatic protons.

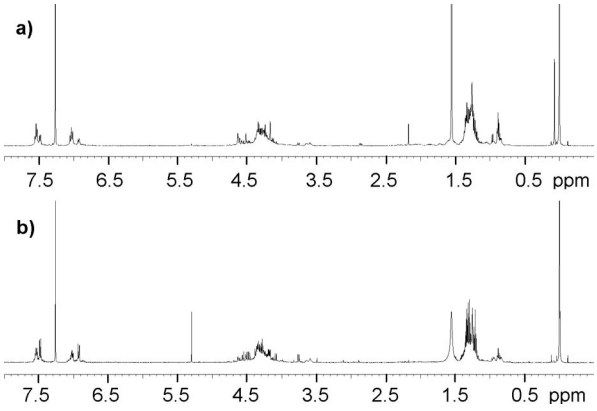


Figure 10. ^{1}H NMR spectrum of (a) compound **13** and (b) compound **14** (500 MHz, $CDCl_3$).

In an attempt to determine the position of the third addition of the C_6H_4SCN group, HMBC (Heteronuclear Multiple Bond Correlation) experiments were performed (Figure 11), to determine whether any correlations between the pyrrolidine protons and the sp^2-hybridized carbon atoms were present. Figure 11 shows that in the HMBC one set of the pyrrolidine protons correlated with one sp^2 carbon

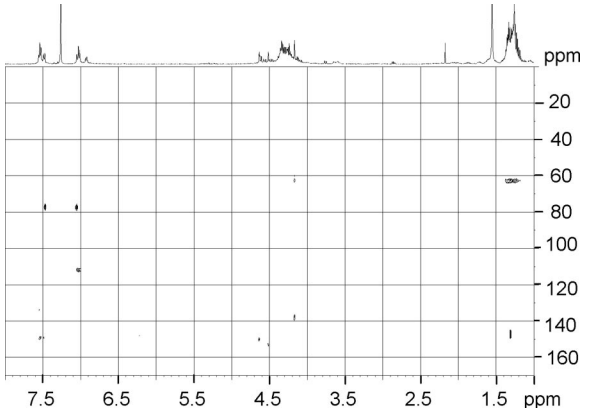


Figure 11. HMBC NMR spectrum of **13** (500 MHz, $CDCl_3$).

atom as well as with an sp^3 carbon atom of the fullerene. However, the two isomers did not show significant differences in their correlations.

Although the identity of the two regioisomers cannot be established at this point, if the polarity of the molecules is considered, **13** (side addition 1) should be less polar than **14** (side addition 2), since the third addend is opposite the *trans*-2 position (Figure 9). Therefore, heptakis-1 can be tentatively assigned as **13** and heptakis-2 as **14**.

Conclusions

Herein we described the regioselective synthesis and characterization of mono-, bis-, and tris(4-thiocyanatophenyl)pyrrolidino-C_{60}-tetramalonate adducts, that are potentially useful compounds for molecular electronic applications. The syntheses were achieved by using a selective protection/deprotection strategy. The low yield (mass ratio 1:1) and reaction time for unsymmetric pentakis-adduct **9** indicate that it is more reactive than symmetric heptakis-adduct **8**. The hexakis-adducts isomers *trans*-1 **10** and *trans*-2 **11** were obtained in a ratio of 1:2.4, which indicated the preference of addition at the unsymmetric positions. Formation of two heptakis-adducts, **13** and **14**, from hexakis-adduct *trans*-2 **11** was detected in a ratio of 1:1.3, which indicated that competition was no longer present. Therefore, the addition of a new group seems to be disfavored on the same six-membered ring that already has a group attached.

Experimental Section

Synthesis of *N*-(4-Thiocyanatophenyl)glycine: Ethyl bromoacetate (1.10 mL, 9.99 mmol) was added to a solution of 4-aminophenyl thiocyanate[19] (3.0 g, 19.97 mmol) in anhydrous 1,4-dioxane (6 mL). The mixture was heated to reflux for 1 h. After the solution had cooled, water (10 mL) was added, and the mixture was extracted with chloroform. The organic layer was removed and washed with saturated $NaHCO_3$ twice, brine, dried with $MgSO_4$, then concentrated. The resulting product was purified by column chromatography on silica gel (chloroform/acetone, 9:1 as eluant) to give ethyl *N*-(4-thiocyanatophenyl)glycinate (4.0 g, 60%). ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 7.41 (m, 2 H, ArH), 6.60 (m, 2 H, ArH), 4.64 (br., 1 H, NH), 4.26 [q, ^3J(H,H) = 7.1 Hz, 2 H, -$COCH_2$-], 3.90 (d, 2 H, -CH_2CO-), 1.32 (t, $^3J_{H,H}$ = 7.1 Hz, 3 H, CH_3) ppm. ^{13}C NMR (500 MHz, $CDCl_3$, 25 °C): δ = 170.30 (C=O), 148.81, 134.58, 114.05, 112.28, 109.21, 61.69, 45.19, 14.19 ppm. MALDI-MS: *m*/*z* = 237 [MH^+]. Ethyl *N*-(4-thiocyanatophenyl)glycinate (2.5 g, 10.6 mmol) was dissolved in 5 M HCl/dioxane[20] (11 mL) and heated to reflux under Ar for 15 min. After the solution had cooled, the *N*-(4-thiocyanotophenyl)glycine precipitated, was filtered and washed with dioxane to give a white solid (2.8 g, 76%). ^{1}H NMR (500 MHz, [D_6]DMSO, 25 °C): δ = 12.65 (br., 1 H, CO_2H), 7.39 (m, 2 H, ArH), 6.66 (m, 2 H, ArH), 3.86 (s, 2 H, -CH_2-), 3.50 (br., 1 H, NH) ppm. ^{13}C NMR ([D_6]-DMSO, 500 MHz): δ = 172.5 (C=O), 151.0, 135.1, 114.0, 113.0, 106.3, 44.55 ppm. MALDI-MS: *m*/*z* = 209 [MH^+].

Pentakis-Adducts 8, 9 and Hexakis-Adducts 10 and 11: A solution of **7** (1 g, 0.74 mmol), *N*-(4-thiocyanatophenyl)glycine (385 mg, 1.85 mmol), and paraformaldehyde (111 mg, 3.7 mmol) in 1,2-dichlorobenzene (300 mL) was heated to 175 °C under Ar for 30 min. The resulting mixture was cooled and concentrated with an N_2 stream. Separation of the **7** (200 mg, material recovered), **8** (71 mg, 6.3%), **9** (70 mg, 6.2%), **10** (24.4 mg, 2.2%), and **11** (51.9 mg, 4.6%) was achieved by column chromatography on silica gel using dichloromethane as eluant. Better purification of **10** and **11** was achieved by preparative TLC on silica gel using dichloromethane as eluant. **8:** ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 7.50 (d, $^3J_{H,H}$ = 8.9 Hz, 2 H, ArH), 6.93 (d, $^3J_{H,H}$ = 8.9 Hz, 2 H, ArH), 4.45–4.41 (q, 4 H, -CH_2-), 4.36–4.31 (m, 16 H, -CH_2-), 1.40–1.30 (m, 24 H, CH_3) ppm. ^{13}C NMR (500 MHz, $CDCl_3$, 25 °C): δ = 163.83, 163.73, 163.64, 153.64, 152.36, 149.41, 147.17, 146.14, 145.98, 145.47, 145.30, 144.26, 143.41, 143.15, 142.29, 138.58, 138.20, 133.83, 117.01, 111.80, 69.85, 69.11, 68.22, 67.75, 62.98, 62.94, 61.40, 45.39, 44.88, 14.17, 14.09, 14.06 ppm. UV/Vis: λ_{max} = 291, 309, 339, 476, 545 nm. MS (MALDI): *m*/*z* = 1527 [M^+ – 1], 1369, 1352. **9:** ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 7.53 (d, $^3J_{H,H}$ = 8.9 Hz, 2 H, ArH), 7.02 (d, $^3J_{H,H}$ = 8.9 Hz, 2 H, ArH), 4.71–4.27 (m, 20 H, -CH_2-), 1.52–1.31 (8 t, 24 H, CH_3) ppm. ^{13}C NMR (500 MHz, $CDCl_3$, 25 °C): δ = 164.21, 164.11, 163.86, 163.70, 163.65, 163.15, 150.88, 149.45, 149.28, 149.00, 148.66, 148.34, 147.74, 147.44, 147.07, 147.02, 146.95, 146.08, 145.78, 145.47, 145.13, 144.42, 144.30, 144.23, 144.15, 143.78, 143.47, 143.32, 143.27, 142.99, 142.82, 142.74, 142.52, 142.34, 142.11, 141.95, 141.90, 141.74, 141.61, 141.30, 141.11, 140.99, 140.87, 140.79, 140.45, 140.33, 140.25, 140.07, 138.69, 138.64, 138.34, 138.19, 135.18, 133.89, 131.81, 130.60, 125.81, 116.98, 111.86, 111.51, 72.22, 70.77, 70.50, 69.17, 69.05, 68.71, 66.34, 66.07, 65.08, 63.27, 63.13, 63.05, 63.03, 62.98, 62.78, 62.65, 62.39, 62.00, 46.33, 43.94, 43.31, 41.37, 14.29, 14.25, 14.20, 14.18, 14.11, 14.09, 14.08 ppm. UV/Vis: λ_{max} = 271, 330, 548 nm. MS (MALDI): *m*/*z* = 1528 [M^+], 1369, 1352.

Hexakis-Adducts 10 and 11: A solution of **8** (20 mg, 0.013 mmol), *N*-(4-thiocyanatophenyl)glycine (14 mg, 0.065 mmol), and paraformaldehyde (4 mg, 0.130 mmol) in 1,2-dichlorobenzene (2 mL) was heated at 175 °C under Ar for 15 min. The mixture was cooled, and the solvents were evaporated. Separation of **8** (6 mg, material recovered), **10** (2 mg, 9%) and **11** (5 mg, 22%) was achieved by preparative TLC on silica gel using dichloromethane as eluant. **10:** ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 7.54 (d, $^3J_{H,H}$ = 9.0 Hz, 4 H, ArH), 7.04 (d, $^3J_{H,H}$ = 9.0 Hz, 4 H, ArH), 4.59 (s, 8 H, NCH_2-), 4.35–4.30 (q, $^3J_{H,H}$ = 7.1 Hz, 8 H, -CH_2-), 4.30–4.26 (q, $^3J_{H,H}$ = 7.1 Hz, 8 H, -CH_2-), 1.35–1.32 (t, $^3J_{H,H}$ = 7.1 Hz, 12 H, CH_3), 1.28–1.25 (t, $^3J_{H,H}$ = 7.1 Hz, 12 H, CH_3) ppm. ^{13}C NMR (500 MHz, $CDCl_3$, 25 °C): δ = 163.87, 163.83, 152.34, 149.45, 146.11, 145.79, 145.53, 145.40, 143.88, 143.66, 143.47, 141.62, 141.13, 140.99, 140.33, 139.72, 133.89, 117.19, 111.82, 70.83, 69.38, 69.08, 66.87, 66.11, 62.85, 61.99, 61.12, 46.11, 45.44, 45.38, 44.71, 14.27, 14.06 ppm. UV/Vis: λ_{max} = 275, 332, 546 nm. MS (MALDI): *m*/*z* = 1704 [M^+], 1669, 1596, 1511, 1352. **11:** ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 7.55 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, ArH), 7.52 (d, $^3J_{H,H}$ = 9.0 Hz, 2 H, ArH), 7.06 (d, $^3J_{H,H}$ = 8.8 Hz, 2 H, ArH), 6.98 (d, $^3J_{H,H}$ = 8.9 Hz, 2 H, ArH), 4.64–4.51 (m, 4 H, -CH_2-), 4.47–4.21 (m, 20 H, -CH_2-), 1.34–1.26 (m, 24 H, CH_3) ppm. ^{13}C NMR (500 MHz, $CDCl_3$, 25 °C): δ = 164.00, 163.95, 163.86, 163.83, 163.50, 163.20, 163.03, 153.84, 153.17, 152.06, 151.60, 151.13, 149.45, 149.32, 148.66, 147.80, 146.92, 146.66, 146.61, 146.51, 146.42, 146.29, 146.21, 145.99, 145.90, 145.79, 145.71, 145.51, 145.33, 145.25, 144.37, 144.12, 143.50, 143.18, 143.00, 142.48, 142.39, 142.34, 142.25, 142.04, 141.85, 141.43, 141.32, 140.94, 140.68, 139.71, 138.82, 138.53, 136.75, 136.68, 136.59, 136.18, 136.12, 133.93, 133.88, 130.27, 125.23, 117.09, 117.02, 111.89, 111.75, 111.52, 70.55, 70.37, 70.20, 69.15, 68.89, 67.86,

67.74, 67.56, 67.37, 66.99, 64.84, 63.76, 62.98, 62.92, 62.89, 62.84, 62.80, 62.75, 62.56, 62.52, 61.85, 61.57, 61.50, 61.34, 45.55, 43.77, 43.46, 42.03, 14.14, 14.09, 14.06, 14.04 ppm. UV/Vis: λ_{max} = 286, 482, 525 nm. MS (MALDI): *m*/*z* = 1706 [M^+ + 2], 1671, 1553 [$M^+ - C_6H_4SCN$], 1354 [$M^+ - 2\ C_6H_4SCN$].

Heptakis-Adducts 13 and 14: A solution of **11** (11 mg, 0.064 mmol), *N*-(4-thiocyanatophenyl)glycine (19 mg, 0.093 mmol), and paraformaldehyde (6 mg, 0.190 mmol) in 1,2-dichlorobenzene (1 mL) was heated at 175 °C under Ar for 30 min. The mixture was cooled, and the solvents were evaporated. Separation of **11** (4.7 mg, material recovered), **13** (2.2 mg, 18%) and **14** (1.7 mg, 14%) was achieved by preparative TLC on silica gel using dichloromethane as eluant. **13:** ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 7.55 (m, 4 H, ArH), 7.48 (d, $^3J_{H,H}$ = 8.1 Hz, 2 H, ArH), 7.05 (m, 4 H, ArH), 6.93 (d, $^3J_{H,H}$ = 8.1 Hz, 2 H, ArH), 4.65–4.10 (m, 28 H, -CH_2-), 1.42–1.05 (m, 24 H, CH_3) ppm. UV/Vis: λ_{max} = 274, 520 nm. MS (MALDI): *m*/*z* = 1881 [M^+ + 1], 1723, 1705 [$M^+ - C_6H_4SCN$], 1547, 1529 [$M^+ - 2\ C_6H_4SCN$], 1371. **14:** ^{1}H NMR (500 MHz, $CDCl_3$, 25 °C): δ = 7.54 (m, 4 H, ArH), 7.48 (d, $^3J_{H,H}$ = 8.8 Hz, 2 H, ArH), 7.03 (m, 4 H, ArH), 6.93 (d, $^3J_{H,H}$ = 8.8 Hz, 2 H, ArH), 4.64–4.10 (m, 28 H, -CH_2-), 1.37–1.15 (m, 24 H, CH_3) ppm. UV/Vis: λ_{max} = 287, 497, 529 nm. MS (MALDI): *m*/*z* = 1880 [M^+], 1722, 1704 [$M^+ - C_6H_4SCN$], 1546, 1529 [$M^+ - 2\ C_6H_4SCN$], 1367.

Supporting Information (see footnote on the first page of this article): MALDI mass spectra, UV/Vis spectra and NMR spectra of new compounds.

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