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tele Nucleophilic Substitutions of Hydrogen in *m*-(Trichloromethyl)-nitrobenzenes with Cyano and Ester Carbanions

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Stabilized carbanions of malonates, 2-phenylacetonitrile, or isopropyl 2-phenylacetate add to *m*-(trichloromethyl)nitrobenzene derivatives to form σ^H adducts that lose a chloride ion to give intermediate *exo*-dichloromethylene nitrocyclohexadienes. These undergo re-aromatization through 1,5-hydrogen shift to yield *tele* substitution mono adducts. Depending on the stoichiometry of the nitroarene to the carbanion, further addition of the nucleophile to the *tele* mono adduct can yield a mixture of products that are either double or triple adducts. At low temperature, the σ^H adducts undergo direct 1,2-addition in competition with chloride ion elimination/1,5-hydrogen shift.

Introduction

There are two major reactions between nucleophilic agents and electron-deficient arenes; that is, addition in positions occupied by leaving groups X such as halogens to form anionic σ^X adducts and addition in positions occupied by hydrogen to form anionic σ^H adducts. As a rule, formation of anionic σ^H adducts proceeds much faster than anionic σ^X formation. Rapid departure of X^- from anionic σ^X adducts leads to the well-recognized S_NAr reaction,[1] whereas formation of anionic σ^H adducts by spontaneous departure of hydride anions does not proceed. Rapid formation of anionic σ^H adducts are of interest due to their conversion into products of nucleophilic substitution of hydrogen, S_NH. As a result, several methods have been developed in which anionic σ^H adducts are converted into products of S_NH.[2] The inability of the hydride anion to depart spontaneously from the anionic σ^H adducts is prevented by the addition of an external oxidant. Indeed, oxidation of anionic σ^H adducts is the most straightforward way of converting these intermediates into S_NH products.[3] Numerous examples of oxidative nucleophilic substitution of hydrogen (ONSH) in nitroarenes and other electron-deficient arenes have been reported.[2,3] An alternative and perhaps the most general and practically useful variant of S_NH is vicarious nucleophilic substitution (VNS), which proceeds when the nucleophile contains a leaving group L. Addition of the nucleophile to the arene and formation of the anionic σ^H adduct is followed by rapid base-induced β-elimination of HL to give the final S_NH product.[4] There are two other possible paths that anionic σ^H adducts follow to give products. In both cases, hydrogen atom transfer takes place from the position of nucleophilic attack to a position occupied previously by a leaving group. Reactions in which leaving groups are vicinal or more than one bond length from the site of nucleophilic addition to the arene are known as *cine* or *tele* substitutions, respectively. A general discussion and numerous examples of these processes are presented in a recent review by Suwiński and Świerczek.[5] Since the publication of this review, nine papers have reported *tele* substitution between nucleophiles and electron-deficient arenes. These arenes are 6-(1,2-dibromo-2-phenylethyl)pteridinediones, dichloropyrazines, *N*-fluoropyridinium fluoride, 2-(1-chloropropyl)imidazole hydrochlorides, 3-trichloromethyl-1,2,4-triazines, [(η^6-arene)tricarbonyl]chromium or tricarbonyl(η^5-cyclohexadienyl)manganese complexes, and halogenomethylnitrobenzenes.[6]

Our work on *tele* nucleophilic substitution has been focused on the reaction of 3-(trichloromethyl)pyridines with O, N, and S nucleophiles; 1-nitro-3- and 1,3-dinitro-5-(trichloromethyl)benzene and 3-(trichloromethyl)benzonitrile with O and S nucleophiles; and *tele* versus oxidative substitution of hydrogen in 1-nitro-3-(trichloromethyl)benzene and 1-(chloro or dichloromethyl)-3-nitrobenzenes with Grignard reagents.[7]

Results and Discussion

Continuing our previous work with Grignard reagents,[7d] we now present some results of *tele* substitution in 1-nitro-3-(trichloromethyl)benzene (**1a**) and 1-chloro-4-nitro-2-(trichloromethyl)benzene (**1b**) with stabilized carbanions derived from diethyl malonate, diethyl 2-methyl-

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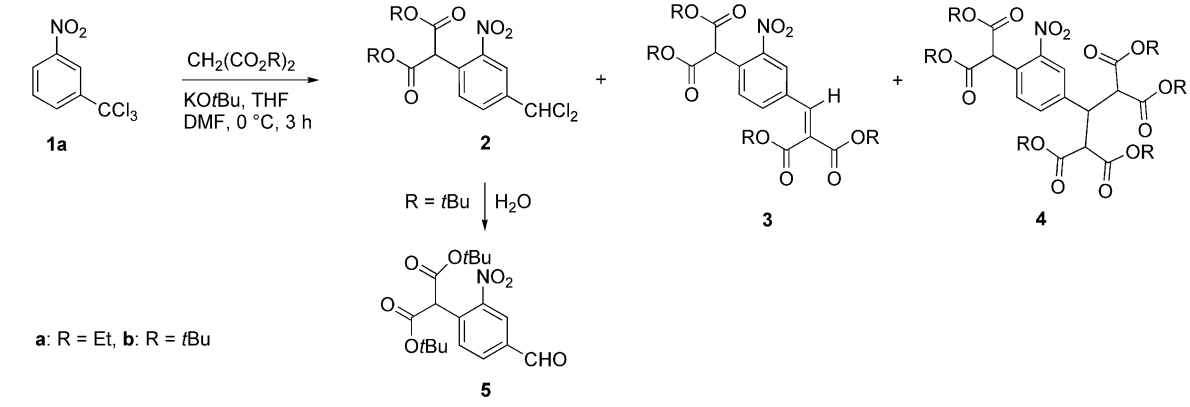
malonate, di-*tert*-butyl malonate, diethyl 2-bromomalonate, phenylacetonitrile, or isopropyl phenylacetate with KO*t*Bu as a base. Reaction of **1a** with diethyl malonate (1.5 equiv.) and KO*t*Bu (2.5 equiv.) in THF/DMF at 0 °C under an atmosphere of argon gave a mixture of three *tele* substitution products: mono adduct **2a**, double adduct **3a**, and triple adduct **4a** in 23, 17, and 22% yield, respectively. Unreacted **1a** was also recovered in 17% yield (Table 1, Entry 1; Scheme 1). When the reaction was repeated with a smaller ratio of diethyl malonate (3 equiv.) and KO*t*Bu (4 equiv.), the sole product was **4a**, which was obtained in 54% yield (Table 1, Entry 2). However, when THF was used as the solvent in this reaction, only starting material was recovered. This suggests that the use of DMF as cosolvent solvates the potassium ions, rendering the carbanions more nucleophilic. The reaction of **1a** with di-*tert*-butyl malonate/KO*t*Bu gave analogous results. Thus, when **1a** was treated with di-*tert*-butyl malonate (1.5 equiv.) and KO*t*Bu (2.5 equiv.) compounds **5**, **3b**, and **4b** were obtained in 26, 18, and 20% yield, respectively, together with 34% of unreacted **1a** (Table 1, Entry 3). It is postulated that aldehyde **5** is a result of the hydrolysis of **2b** during workup. Furthermore, the reaction of **1a** with di-*tert*-butyl malonate (3 equiv.) and KO*t*Bu (4 equiv.) gave **4b** in 48% yield as the only product (Table 1, Entry 4). The yield of **4b** is comparable to that of **4a** (Table 1, Entry 2), which indicates that steric factors due to the bulkiness of the nucleophile are not significant in this reaction.

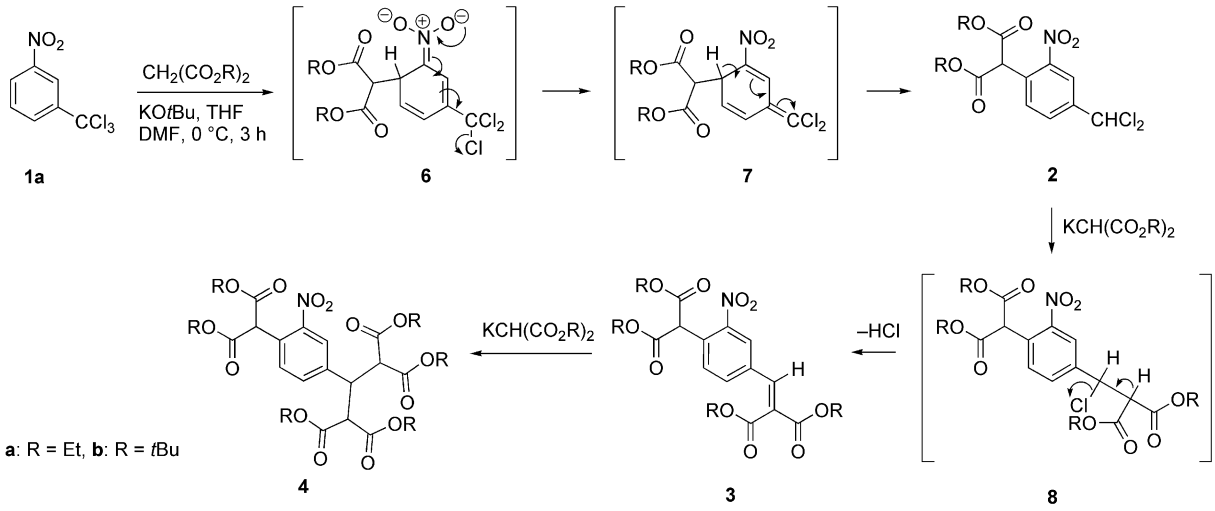
Table 1. Nucleophilic reaction of dialkyl malonates with **1a**.

Entry	R	**1a**/KO*t*Bu/ malonate	Product, Yield [%] **2**[c]	**3**	**4**
1[a]	Et	1:2.5:1.5	**2a**, 23	**3a**, 17	**4a**, 22
2	Et	1:4.0:3.0	–[b]	–[b]	**4a**, 54
3[c]	*t*Bu	1:2.5:1.5	**2b**[d] → **5**, 26	**3b**, 18	**4b**, 20
4	*t*Bu	1:4.0:3.0	–[b]	–[b]	**4b**, 48

[a] Unreacted **1** was isolated in 17% yield. [b] Not detected in the reaction mixture. [c] Unreacted **1** was isolated in 34% yield. [d] Compound **2b** not detected but its hydrolysis during workup gave **5** in 26% yield.



Scheme 1.



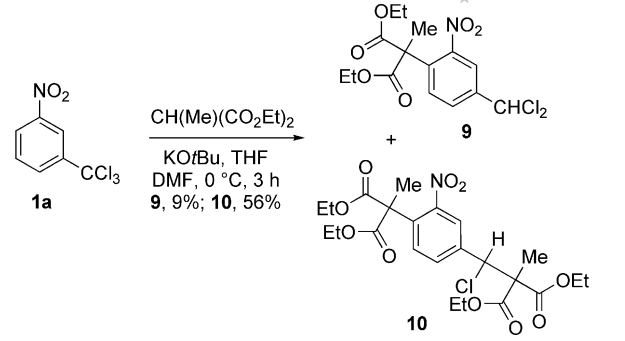
Scheme 2.

These observations are further elaborated in Scheme 2. In accord with our previous work,[7] compound **2a** is an initial product of *tele* substitution formed by addition of the malonate carbanion to the electron-deficient ring of **1a** in the 6-position to give intermediate σ^H adduct **6**, which

undergoes elimination of chloride to form *exo*-dichloromethylene cyclohexadiene **7**. Intermediate **7** undergoes rearomatization through a 1,5-hydrogen shift from the 6-position to the exocyclic carbon atom, leading to 6-substituted-3-(dichloromethyl)benzene **2**. Compound **2** further reacts with the nucleophile to give normal S_N2-type substitution of chloride from the $CHCl_2$ group to give intermediate **8**. The β-elimination of HCl affords α,β-unsaturated double adduct **3**, apparently according to an E1 conjugate-base (E1 cb) mechanism. Compound **3** being an active Michael acceptor, reacts with the malonate carbanion to yield triple adduct **4**. When a threefold excess of the nucleophile and **1a** react, mono adduct **2**, double adduct **3**, and the starting material were not detected; triple adduct **4** was the only product. The isolation of aldehyde **5** instead of dichloromethyl derivative **2b** (Table 1, Entry 3) might be due to hydrolysis of the latter due to prolonged exposure to 1 N hydrochloric acid during workup.

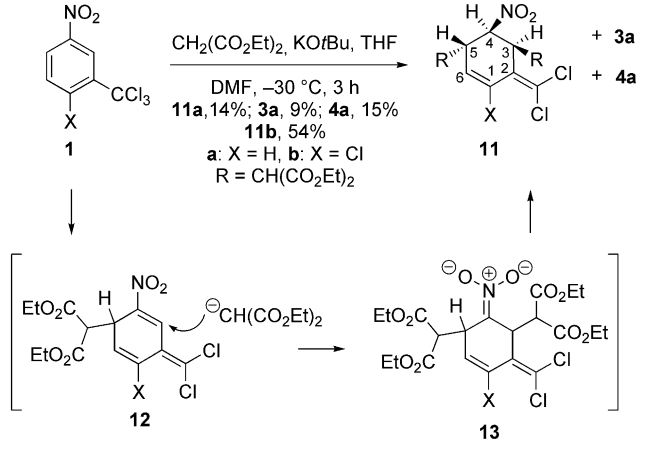
Support for the first three steps of this mechanism can be sought in our previous work on *tele* nucleophilic substitutions.[7] However, the last three steps, that is, conversion of **2** into **4**, may also occur by two consecutive nucleophilic substitutions of chloride. This is highly unlikely because it is known that CH acidic centers located in the α-positions and halogens located in the β-positions with respect to electron-withdrawing groups undergo facile base-induced β-elimination. This supposition was supported by an experiment in which **1a** was treated with diethyl methylmalonate (3 equiv.) and KO*t*Bu (4 equiv.) under conditions identical to those used for the reaction of diethyl malonate and di-*tert*-butyl malonate. *tele* Mono adduct **9** and double adduct **10** resulting from addition of a second equivalent of diethyl malonate to **9** were obtained in 9 and 56% yield, respectively (Scheme 3). Because elimination of HCl from **10** is not possible, the formation of the triple adduct was not detected, and as such, it is reasonable to assume that the formation of triple adducts **4a**,**b** (Scheme 2) is the result of Michael addition of the nucleophile to double adduct **3**. From observations so far regarding the reaction of **1a** with an excess amount of diethyl malonate or di-*tert*-butyl malonate, the substantial quantity of recovered **1a** and the isolation of **3** and **4** as major products indicate that the rates of further transformation of **2** are higher than the rate of its formation. Another observation is that in the two-step reaction involving addition of malonate carbanions to nitroarenes **1a**,**b** to produce σ^H adducts followed by *tele* elimination of chloride from the CCl_3 group of the σ^H adducts, it is the addition step that is rate limiting; hence, the slowest step of the overall transformation is the addition reaction.

Interestingly, when the reaction of **1a** or **1b** with diethyl malonate (3 equiv.) and KO*t*Bu (4 equiv.) was carried out at –30 °C, different products were formed (Scheme 4) compared to the analogous reaction performed at 0 °C (Table 1, Entry 2; Scheme 1). Compound **1a** gave cyclohexene adduct **11a**, double adduct **3a**, and triple adduct **4a** in 14, 9, and 15% yield, respectively, whereas compound **1b** gave cyclohexene **11b** in 54% yield as the only product. Products **11a** and **11b** were strikingly nonaromatic, and their ^1H NMR



Scheme 3.

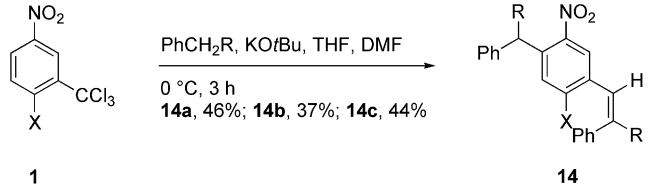
spectra showed certain similarities to those reported for 3-(dichloromethylene)-4,6-dimethyl-5-nitrocyclohex-1-ene isomers.[6] The structures of **11a** and **11b** were confirmed by ^1H NMR, NOE, and COSY spectroscopy and selective decoupling techniques. The hydrogen atoms 1-H and 2-H of **11a** are on the same side of the cyclohexene ring ($J_{1H,2H}$ = 3.6 Hz), whereas hydrogen atom 3-H is located on the opposite side ($J_{2H,3H}$ = 10.8 Hz). Similarly for **11b**, hydrogen atoms 1-H and 2-H ($J_{1H,2H}$ = 3.9 Hz) are located on the opposite side of hydrogen atom 3-H ($J_{2H,3H}$ = 10.2 Hz). In the course of these reactions (Scheme 4), we expected that addition of diethyl potassiomalonate to electrophilic **1a** or **1b** proceeds as described in Scheme 2 to give first the requisite σ^H adduct, which then undergoes elimination of chloride to form *exo*-dichloromethylene cyclohexadiene **12**. Because there are two equal substituents in the 3- and 5-positions of **11a**,**b** and because only one diastereoisomer was isolated, protonation of anion **13** must occur with high diastereoselectivity. It is noteworthy that in the reaction leading to **11b** no side products were detected and the yield was much higher than that obtained with analog **11a**. A likely explanation stems from the fact that the chlorine atom at the 1-position of compound **12b** forces the *exo*-dichloromethylene group to twist out of the plane of the ring so that 1,5-hydrogen shift is slower than 1,2-addition to the ring. In the case of **1a** where the chlorine atom at the



Scheme 4.

1-position is missing, 1,5-hydrogen shift competes with 1,2-addition, which results in a mixture of **11a**, **3a**, and **4a**.

Furthermore, reactions of **1a** and **1b** with phenylacetonitrile and isopropyl phenylacetate were examined (Scheme 5). The *tele* substitution reactions proceeded by treatment of **1a** and **1b** each with phenylacetonitrile (3.0 equiv.) and KO*t*Bu (4 equiv.) in THF/DMF at 0 °C under an atmosphere of argon to give the corresponding α,β-unsaturated double adducts **14a** and **14b** in 46 and 37% yield, respectively. Under similar reaction conditions, *tele* substitution of **1b** by isopropyl potassiophenylacetate afforded α,β-unsaturated double adduct **14c** in 44% yield. This result offers further confirmation towards the assumption that triple adducts **4a**,**b** in Scheme 2 are products of nucleophilic addition to α,β-unsaturated double adducts **3a**,**b**. An explanation as to why the reactions shown in Scheme 5 gave only α,β-unsaturated double adducts **14a**–**c** even in the presence of nucleophiles derived from phenylacetonitrile and isopropyl phenylacetate, which are stronger than the nucleophiles derived from diethyl malonate and di-*tert*-butyl malonate (Scheme 1), cannot be given.



Scheme 5.

Conclusions

We have shown that the reactions of 1-nitro-3-(trichloromethyl)benzene and 1-chloro-4-nitro-2-(trichloromethyl)benzene with the potassium salts of the carbanions of diethyl and di-*tert*-butyl malonates depend on the stoichiometry of the reagents and the temperature of the reaction. At 0 °C, the carbanions add to the 6-position of the substrates (*ortho* to the nitro group and *para* to the trichloromethyl group) to give anionic σ^H adducts. Departure of the chloride ion from the trichloromethyl group of these adducts followed by re-aromatization through 1,5-hydrogen shift gives diesters, the result of *tele* substitution. These diesters react with another equivalent of the carbanion present in the reaction mixture and replace the halogen in the dichloromethyl group; this is then followed by elimination of HCl to give unsaturated tetraesters. The unsaturated group of these tetraester intermediates is an active Michael acceptor to a third equivalent of the carbanion, leading to hexaester derivatives. The use of less than three equivalents of the carbanion gives mixtures of di-, tetra-, and hexaesters. When three equivalents or more of the carbanion were used, the hexaester was the only product. It should be noted that when the reaction was carried out at –30 °C with three equivalents of the carbanion, re-aromatization of the initially formed nitrocyclohexadiene adducts was slow, so that Michael addition of a second carbanion took place to give new, stable cyclohexadiene derivatives. *tele*-Substitution reactions with carbanions of phenylacetonitrile and isopropyl phenylacetate at 0 °C stop when two molecules of the carbanion have been added.

Experimental Section

General Remarks: Melting points were recorded with a Büchi 510 apparatus and are uncorrected. Infrared spectra were recorded with a Perkin–Elmer FTIR spectrometer, solids as Nujol mulls and liquids as thin films between sodium chloride discs. NMR spectra were measured at 400 MHz with a Mercury-400BB or a Bruker AMX 400 spectrometer, or at 200 MHz with a Gemini-200BB spectrometer. Chemical shifts are reported in ppm relative to tetramethylsilane as internal standard. Mass spectra were obtained by use of an AMD 604 Inectra GmbH spectrometer in EI or ESI mode. Mass spectra are given for ions containing ^{35}Cl; appropriate isotope patterns were observed. Flash chromatography was performed at medium pressure by using slurry packed Merck silica gel 230–400 mesh with the specified eluent. Analytical TLC was carried out with Merck alufolien sheets Kieselgel 60 F254. Solvents and reagents were used as received from the manufacturers except for THF and DMF, which were distilled from potassium benzophenone ketyl and calcium hydride, respectively.

General Procedure for the Treatment of 1-Nitro-3-(trichloromethyl)-benzene (1a) or 1-Chloro-4-nitro-2-(trichloromethyl)benzene (1b) with Cyano- and Ester-Stabilized Carbanions: To a stirred solution of potassium *tert*-butoxide (2.5 or 4.0 mmol) in tetrahydrofuran (10 mL) at room temperature, 0, or –30 °C under an atmosphere of argon was added dropwise a solution of **1a** or **1b** (1 mmol) and the appropriate dialkyl malonate, 2-phenylacetonitrile, or isopropyl 2-phenylacetate (1.5 or 3.0 mmol) in DMF (2 mL) over a period of ca. 1 min. After 3 h, the solution was poured into 1 N hydrochloric acid (100 mL) and extracted with dichloromethane (4 × 20 mL). The combined organic extracts were dried (Na_2SO_4), and the solvent was evaporated under reduced pressure. The resulting crude residue was purified by flash chromatography (hexane/EtOAc, 1:6) to afford the corresponding product.

Diethyl [4-(Dichloromethyl)-2-nitrophenyl]malonate (2a): Yield: 11 mg, 3%; yellow oil. ^1H NMR (400 MHz, $CDCl_3$): δ = 8.04 (d, J = 2.4 Hz, 1 H, 3-H), 7.70 (dd, J = 8.8, 2.4 Hz, 1 H, 5-H), 7.11 (d, J = 8.8 Hz, 1 H, 6-H), 6.70 (s, 1 H, $CHCl_2$), 4.23 (q, J = 7.1 Hz, 4 H, 2 CH_2), 3.37 [s, 1 H, CH], 1.30 (t, J = 7.1 Hz, 6 H, 2 CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 166.7 (2 C), 153.1 (C), 132.4 (C), 131.7 (C, CH), 123.7 (CH), 114.7 (CH), 69.8 (CH), 65.7 (CH_2), 61.5 (CH_2), 41.7 (CH), 14.4 (CH_3), 14.0 (CH_3) ppm. HRMS (ESI): calcd. for $C_{14}H_{15}{}^{35}Cl_2NNaO_6$ $[M + Na]^+$ 386.0174; found 386.0182. $C_{14}H_{15}Cl_2NO_6$ (364.18): calcd. C 46.17, H 4.15, N 3.85; found C 46.28, H 4.24, N 3.96.

Diethyl {4-[2-Ethoxy-1-(ethoxycarbonyl)-2-oxoethyl]-3-nitrobenzylidene}malonate (3a): Yield: 77 mg, 17%; yellow oil. ^1H NMR (400 MHz, $CDCl_3$): δ = 8.18 (d, J = 1.9 Hz, 1 H, 2-H), 7.71 (dd, J = 8.2, 1.9 Hz, 1 H, 5-H), 7.70 (s, 1 H, CH=), 7.57 (d, J = 8.2 Hz, 1 H, 6-H), 5.30 (s, 1 H, CH), 4.41–4.23 (m, 8 H, 4 CH_2), 1.37–1.21 (m, 12 H, 4 CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$) δ = 166.7 (C), 166.5 (C), 165.6 (C), 163.3 (C), 148.8 (C), 135.1 (CH), 134.2 (C), 133.7 (CH), 131.9 (CH), 129.7 (C), 129.5 (C), 125.5 (CH), 62.6 (CH_2), 62.2 (CH_2), 62.1 (CH_2), 62.0 (CH_2), 54.3 (CH), 14.0 (CH_3), 13.9 (CH_3), 13.8 (CH_3), 13.7 (CH_3) ppm. HRMS (ESI): calcd. for

$C_{21}H_{25}NNaO_{10}$ [M + Na]$^+$ 474.1376; found 474.1417. $C_{21}H_{25}NO_{10}$ (451.42): calcd. C 55.87, H 5.58, N 3.10; found C 55.83, H 5.43, N 3.17.

Tetraethyl 2-{4-[2-Ethoxy-1-(ethoxycarbonyl)-2-oxoethyl]-3-nitrophenyl}propane-1,1,3,3-tetracarboxylate (4a): Yield: 331 mg, 54%; colorless microcrystals; m.p. 62–64 °C (EtOH). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.09 (d, J = 2.0 Hz, 1 H, 2-H), 7.71 (dd, J = 8.1, 2.0 Hz, 1 H, 5-H), 7.40 (d, J = 8.1 Hz, 1 H, 6-H), 5.22 (s, 1 H, CH), 4.31–4.13 (m, 11 H, 4 CH_2, 2 CH, CH), 4.00 (q, J = 7.1 Hz, 4 H, 2 CH_2), 1.27 (t, J = 7.1 Hz, 6 H, 2 CH_3), 1.23 (t, J = 7.1 Hz, 6 H, 2 CH_3), 1.05 (t, J = 7.1 Hz, 6 H, 2 CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 167.4 (2 C), 167.1 (2 C), 166.9 (2 C), 148.1 (C), 139.1 (C), 134.9 (CH), 130.8 (CH), 127.4 (C), 126.3 (CH), 62.1 (2 CH_2), 62.0 (2 CH_2), 61.7 (2 CH_2), 54.3 (2 CH), 54.2 (CH), 43.0 (CH), 13.9 (2 CH_3), 13.8 (2 CH_3), 13.6 (2 CH_3) ppm. MS (EI): *m*/*z* (%) = 611 (12.3), 593 (21.1), 566 (32.6), 538 (21.4), 520 (30.9), 502 (25.4), 492 (34.6), 464 (64.4), 446 (72.7), 429 (53.0), 406 (83.1), 356 (67.8), 260 (100.0). HRMS (ESI): calcd. for $C_{28}H_{37}NNaO_{14}$ [M + Na]$^+$ 634.2112; found 634.2081. $C_{28}H_{37}NO_{14}$ (611.59): calcd. C 54.99, H 6.10, N, 2.29; found C 55.08, H 6.17, N 2.32.

Di-*tert*-butyl {4-[2-*tert*-Butoxy-1-(*tert*-butoxycarbonyl)-2-oxoethyl]-3-nitrobenzylidene}malonate (3b): Yield: 102 mg, 18%; yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ = 8.20 (d, J = 1.9 Hz, 1 H, 2-H), 7.71 (dd, J = 8.4, 1.9 Hz, 1 H, 6-H), 7.57 (d, J = 8.4 Hz, 1 H, 5-H), 7.50 (s, 1 H, CH=), 5.10 (s, 1 H, CH), 1.48 (s, 18 H, 6 CH_3), 1.38 (s, 18 H, 6 CH_3) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 167.1 (2 C), 163.0 (2 C), 149.3 (C), 138.0 (C), 136.3 (CH), 134.5 (C), 134.0 (CH), 132.1 (C), 131.6 (CH), 125.2 (CH), 83.6 (2 C), 83.3 (2 C), 56.5 (CH), 28.3 (6 CH_3), 28.0 (6 CH_3) ppm. HRMS (ESI): calcd. for $C_{29}H_{41}NNaO_{10}$ [M + Na]$^+$ 586.2628; found 586.2657. $C_{29}H_{41}NO_{10}$ (563.63): calcd. C 61.80, H 7.33, N 2.49; found C 61.76, H 7.39, N 2.56.

Tetra-*tert*-butyl 2-{4-[2-*tert*-Butoxy-1-(*tert*-butoxycarbonyl)-2-oxoethyl]-3-nitrophenyl}prop-1-ene-1,1,3,3-tetracarboxylate (4b): Yield: 375 mg, 48%; yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.10 (d, J = 1.9 Hz, 1 H, 2-H), 7.65 (dd, J = 8.2, 2.0 Hz, 1 H, 6-H), 7.43 (d, J = 8.2 Hz, 1 H, 5-H), 5.01 (s, 1 H, CH), 4.18–3.80 (m, 3 H, 3 CH), 1.46 (s, 18 H, 6 CH_3), 1.40 (s, 18 H, 6 CH_3), 1.26 (s, 18 H, 6 CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 167.2 (2 C), 167.0 (2 C), 166.4 (2 C), 148.6 (C), 139.6 (C), 135.5 (CH), 130.6 (CH), 128.0 (C), 127.0 (C), 82.7 (2 C), 82.5 (2 C), 82.3 (2 C), 56.4 (CH), 56.3 (2 CH), 43.3 (CH), 28.1 (6 CH_3), 28.0 (6 CH_3), 27.8 (6 CH_3) ppm. HRMS (ESI): calcd. for $C_{40}H_{61}NNaO_{14}$ [M + Na]$^+$ 802.3990; found 802.4100. $C_{40}H_{61}NO_{14}$ (779.91): calcd. C 61.60, H 7.88, N 1.80; found C 61.56, H 7.76, N 1.74.

Di-*tert*-Butyl (4-Formyl-2-nitrophenyl)malonate (5): Yield: 95 mg, 26%; yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ = 10.09 (s, 1 H, CHO), 8.51 (d, J = 1.6 Hz, 1 H, 3-H), 8.14 (dd, J = 8.0, 1.6 Hz, 1 H, 5-H), 7.78 (d, J = 8.0 Hz, 1 H, 6-H), 5.17 (s, 1 H, CH), 1.50 (s, 18 H, 6 CH_3) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 189.6 (CH), 166.0 (2 C), 149.8 (C), 136.7 (C), 134.9 (C), 133.1 (CH), 132.5 (CH), 126.1 (CH), 83.7 (2 C), 56.7 (CH), 28.1 (6 CH_3) ppm. HRMS (ESI): calcd. for $C_{18}H_{23}NNaO_7$ [M + Na]$^+$ 388.1372; found 388.1384. $C_{18}H_{12}NO_7$ (365.38): calcd. C 59.17, H 6.34, N 3.83; found C 59.11, H 6.29, N 3.71.

Diethyl [4-(Dichloromethyl)-2-nitrophenyl](methyl)malonate (9): Yield: 35 mg, 9%; yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ = 8.23 (d, J = 2.1 Hz, 1 H, 3-H), 7.83 (dd, J = 8.4, 2.1 Hz, 1 H, 5-H), 7.44 (d, J = 8.4 Hz, 1 H, 6-H), 6.77 (s, 1 H, CH), 4.64–4.22 (m, 4 H, 2 CH_2), 2.03 (s, 3 H, CH_3), 1.35–1.20 (m, 6 H, 2 CH_3) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 169.5, 141.1, 136.3, 134.5, 130.8, 130.4, 124.1, 69.5, 61.9, 61.7, 59.7, 23.8, 14.2, 14.1 ppm. HRMS (ESI): calcd. for $C_{15}H_{17}Cl_2NNaO_6$ [M + Na]$^+$ 400.0331; found 400.0347. $C_{15}H_{17}Cl_2NO_6$ (378.20): calcd. C 47.64, H 4.53, N 3.70; found C 47.57, H 4.48, N 3.57.

(±)-Diethyl (Chloro{4-[2-ethoxy-1-(ethoxycarbonyl)-1-methyl-2-oxoethyl]-3-nitrophenyl}-methyl)(methyl)malonate (10): Yield: 289 mg, 56%; yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ = 8.12 (d, J = 2.1 Hz, 1 H, 2-H), 7.74 (dd, J = 8.2, 2.1 Hz, 1 H, 6-H), 7.30 (d, J = 8.2 Hz, 1 H, 5-H), 5.85 (s, 1 H, CH), 4.34–4.05 (m, 8 H, 4 CH_2), 1.99 (s, 3 H, CH_3), 1.58 (s, 3 H, CH_3), 1.38–1.14 (m, 12 H, 4 CH_3) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 169.7 (2 C), 168.6 (2 C), 148.4, 138.4, 134.9, 134.2, 129.2, 127.1, 62.6, 62.5, 62.4, 62.2, 60.9, 59.6, 23.7, 15.1, 14.2 (2 C), 14.0 (2 C) ppm. MS (EI): *m*/*z* (%) = 517 (1), 515 (3), 505 (2), 503 (5), 473 (14), 472 (41), 470 (42), 469 (100), 443 (5), 442 (19), 426 (2), 424 (6). HRMS (ESI): calcd. for $C_{23}H_{30}ClNNaO_{10}$ [M + Na]$^+$ 538.1456; found 538.1474. $C_{23}H_{30}ClNO_{10}$ (515.94): calcd. C 53.54, H 5.86, N 2.71; found C 53.66, H 5.99, N 2.59.

(±)-Tetraethyl 2,2′-[6-(Dichloromethylene)-2-nitrocyclohex-4-ene-1,3-diyl]dimalonate (11a): Yield: 74 mg, 14%; orange oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.41 (d, J = 10.4, Hz, 1 H, 5-H), 5.94 (dd, J = 10.4, 2.4 Hz, 1 H, 4-H), 4.96 (dd, J = 10.8, 3.6 Hz, 1 H, 2-H), 4.64 (dd, J = 8.8, 3.6 Hz, 1 H, 1-H), 4.27–3.94 (m, 8 H, 4 CH_2), 3.74 (d, J = 8.8 Hz, 1 H, CH), 3.33 (d, J = 2.8 Hz, 1 H, CH), 1.28–1.10 (m, 12 H, 4 CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$) δ = 167.6 (C), 167.1 (C), 166.8 (C), 166.7 (C), 130.0 (C), 128.2 (CH), 125.0 (CH), 123.2 (C), 85.0 (CH), 62.9 (CH_2), 62.7 (CH_2), 62.6 (CH_2), 62.5 (CH_2), 51.3 (CH), 50.9 (CH), 40.5 (CH), 36.8 (CH), 14.5 (CH_3), 14.4 (CH_3), 14.3 (CH_3), 14.2 (CH_3) ppm. HRMS (ESI): calcd. for $C_{21}H_{27}{}^{35}Cl_2NNaO_{10}$ [M + Na]$^+$ 546.0910; found 546.0895. $C_{21}H_{27}Cl_2NO_{10}$ (524.34): calcd. C 48.10, H 5.19, N 2.67; found C 48.01, H 5.23, N 2.71.

(±)-Tetraethyl 2,2′-[5-Chloro-6-(dichloromethylene)-2-nitrocyclohex-4-ene-1,3-diyl]dimalonate (11b): Yield: 302 mg, 54%; orange oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ = 6.25 (d, J = 3.9 Hz, 1 H, 4-H), 5.17 (dd, J = 10.2, 3.9 Hz, 1 H, 2-H), 4.88 (dd, J = 9.8, 3.9 Hz, 1 H, 1-H), 4.28–4.10 (m, 8 H, 4 CH_2), 3.95 (ddd, J = 10.2, 3.9, 3.2 Hz, 1 H, 3-H), 3.83 (d, J = 9.8 Hz, 1 H, CH), 3.45 (d, J = 3.2 Hz, 1 H, CH), 1.34–1.22 (m, 12 H, 4 CH_3) ppm. ^{13}C NMR (100 MHz, $CDCl_3$) δ = 167.2 (C), 166.6 (C), 166.3 (C), 166.2 (C), 129.4 (CH), 127.8 (2 C), 127.2 (C), 83.7 (CH), 62.8 (CH_2), 62.7 (CH_2), 62.6 (CH_2), 62.5 (CH_2), 51.8 (CH), 50.4 (CH), 44.3 (CH), 38.5 (CH), 14.3 (CH_3), 14.2 (CH_3), 14.1 (CH_3), 14.0 (CH_3) ppm. HRMS (ESI): calcd. for $C_{21}H_{26}{}^{35}Cl_3NNaO_{10}$ [M + Na]$^+$ 580.0520; found 580.0545. $C_{21}H_{26}Cl_3NO_{10}$ (558.79): calcd. C 45.14, H 4.69, N 2.51; found C 45.03, H 4.79, N 2.46.

(±)-(2*E*)-3-{4-[Cyano(phenyl)methyl]-3-nitrophenyl}-2-phenylacrylonitrile (14a): Yield: 169 mg, 46%; colorless microcrystals; m.p. 125–126 °C (EtOH). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.45 (d, J = 2.0 Hz, 1 H, 2-H), 8.27 (dd, J = 8.2, 2.0 Hz, 1 H, 6-H), 7.83 (d, J = 8.2 Hz, 1 H, 5-H), 7.73–7.67 (m, 2 H, Ph), 7.54 (s, 1 H, CH=), 7.52–7.45 (m, 3 H, Ph), 7.43–7.33 (m, 5 H, Ph), 6.18 (s, 1 H, CH) ppm. ^{13}C NMR (100 MHz, $CDCl_3$): δ = 147.8 (C), 137.4 (CH), 135.5 (C), 133.5 (C), 133.4 (CH), 133.1 (C), 131.7 (C), 131.6 (CH), 130.3 (CH), 129.5 (CH), 129.3 (CH), 128.9 (2 CH), 127.9 (2 CH), 126.4 (2 CH), 126.2 (2 CH), 118.2 (C), 116.8 (C), 116.1 (C), 38.3 (CH) ppm. HRMS (ESI): calcd. for $C_{23}H_{15}N_3NaO_2$ [M + Na]$^+$ 388.1062; found 388.1076.. $C_{23}H_{15}N_3O_2$ (365.38): calcd. C 75.60, H 4.14, N 11.50; found C 75.51, H 4.16, N 11.42.

(±)-(2*E*)-3-{2-Chloro-4-[cyano(phenyl)methyl]-5-nitrophenyl}-2-phenylacrylonitrile (14b): Yield: 149 mg, 37%; yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ = 8.85 (s, 1 H, 6-H), 7.86 (s, 1 H, 5-H), 7.79

(s, 1 H, CH=), 7.79–7.72 (m, 2 H, Ph), 7.56–7.50 (m, 3 H, Ph), 7.44–7.34 (m, 5 H, Ph), 6.26 (s, 1 H, CH) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 146.1 (C), 140.6 (C), 134.6 (C), 134.3 (CH), 133.3 (C), 133.2 (CH), 132.9 (C), 132.3 (C), 131.0 (CH), 129.9 (CH), 129.7 (CH), 129.5 (2 CH), 128.2 (2 CH), 126.9 (2 CH), 126.8 (2 CH), 118.9 (C), 118.1 (C), 116.4 (C), 38.4 (CH) ppm. $C_{23}H_{14}ClN_3O_2$ (399.83): calcd. C 69.09, H 3.53, N 10.51; found C 69.06, H 3.46, N 10.50.

(±)-Isopropyl (2*E*)-3-[2-Chloro-4-(2-isopropoxy-2-oxo-1-phenylethyl)-5-nitrophenyl]-2-phenylacrylate (14c): Yield: 215 mg, 44%; yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ = 7.73 (s, 1 H, CH=), 7.72 (d, J = 1.9 Hz, 1 H, 2-H), 7.43–7.30 (m, 7 H, Ph), 7.25–7.18 (m, 3 H, Ph), 7.11 (dd, J = 8.3, 1.9 Hz, 1 H, 6-H), 6.87 (d, J = 8.3 Hz, 1 H, 5-H), 5.53 (s, 1 H, CH), 5.24–5.00 (m, 2 H, CH), 1.31 (d, J = 6.4 Hz, 12 H, 4 CH_3) ppm. ^{13}C NMR (50 MHz, $CDCl_3$): δ = 170.8 (2 C), 148.9 (C), 136.6 (C), 136.4 (CH), 136.3 (C), 135.4 (C), 135.1 (2 C), 134.4 (CH), 131.6 (CH), 129.6 (CH), 129.4 (CH), 129.3 (CH), 129.1 (2 CH), 128.6 (2 CH), 128.1 (2 CH), 126.8 (2 CH), 69.5 (CH), 69.3 (CH), 53.6 (CH), 22.0 (CH_3), 21.9 (CH_3), 21.6 (2 CH_3) ppm. $C_{29}H_{28}ClNO_6$ (521.99): calcd. C 66.73, H 5.41, N, 2.68; found C 66.65, H 5.34, N 2.59.

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