# 85. The Carbon Zip Reaction: A Method for Expanding Carbocycles

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*Summary*

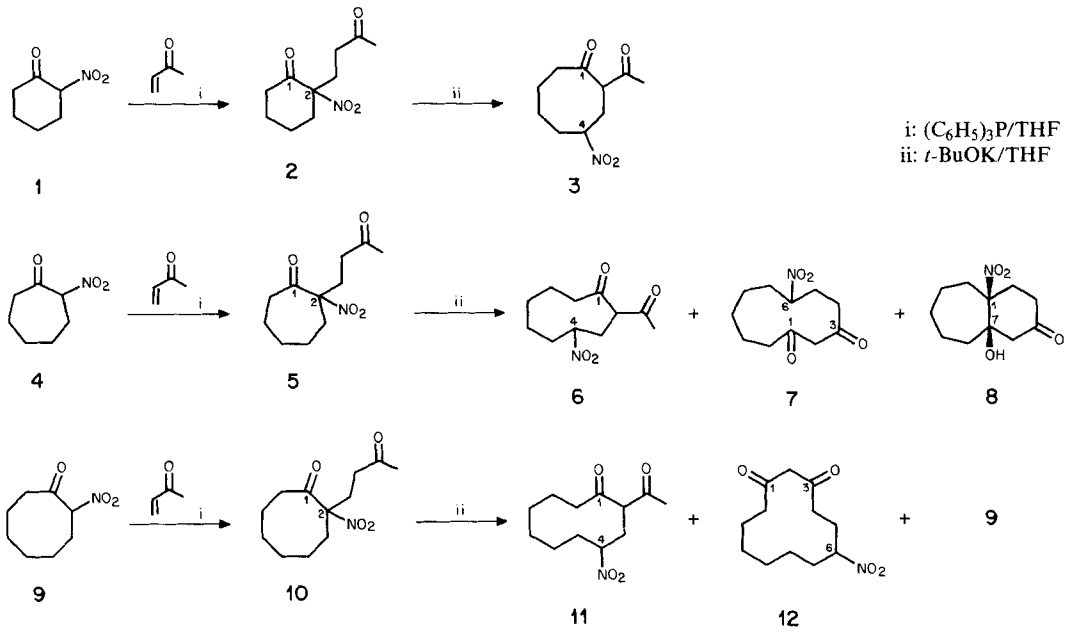
A general method for enlargement of carbocyclic rings by the so called zip reaction is given. The *Michael* adducts of 2-nitrocycloalkanones with 3-oxo-4-pentenoates in the presence of tetrabutylammonium fluoride give in high yield compounds with the ring enlarged by four C-atoms. By this method 7-, 8-, and 12-membered cycloalkanones were converted respectively to 11-, 12-, and 16-membered functionalized carbocycles (see *Scheme 2* and *3*).

In the last few years a large number of natural products with medium and large rings, mainly ketonic or lactonic, have been identified. The pharmacological importance of these compounds has resulted in much synthetic work (*cf.* [1]). In order to develop a general pathway for their synthesis we have tried to use the zip reaction [2] to enlarge normal and medium rings [3]. We now describe a method to produce medium and large ring ketonic of lactonic compounds by incorporation of four C-atoms in one step.

The cyclohexyl *Michael* adduct **2**, prepared from **1** and methyl vinyl ketone, added to *t*-BuOK (2 mol-equiv.) in THF at $-80°$ yielded cyclooctyl compound **3** (85%) (see *Scheme 1*) which produced a strong dark violet color with ferric chloride. The $^1$H-NMR. spectrum of this product contains a *m* at 4.68–4.27 (H–C(4)), a *d* at 3.01 (H–C(3), a *s* at 2.02 ($CH_3CO$) and a *s* at 16.93 ppm (enolic OH). A broad absorption at 1760–1590 $cm^{-1}$, characteristic of an enolic 1,3-diketone was observed in the IR. spectrum. In the $^{13}$C-NMR. spectra, the *s* at 96.3 ppm (C(2)) in the spectrum of **2** was lost in the spectrum of **3**, while new signals appeared at 104.7 ppm (C(2), *s*, enol form) and 86.7 (*d*, C(4)). These observations are consistent with cleavage of the C(1),C(2)-bond in **2**. The carbonyl resonances were also shifted from 205.8 and 200.3 ppm in **2** to 193.9 and 193.3 ppm in **3**. The physical data indicate that **3** exists in the enol form [4].

Several unrecognizable products were obtained when the cycloheptyl adduct **5**, prepared from **4**, or the cyclooctyl adduct **10**, prepared from **9**, were treated in a manner similar to **2**. However, addition of a THF solution of *t*-BuOK to **5** in THF (*i.e.*, the reverse of the preceding experiment) afforded two main products with positive ferric chloride tests on TLC. The cyclononyl compound **6** (44%) gave a violet color with ferric chloride, while the cycloundecyl compound **7** (35%) gave a

*Scheme 1*




reddish-orange color. Physical data for **6** were very similar to those of **3**. Surprisingly, physical data suggest that **7** exists primarily in the ketoform: the IR. spectrum exhibited clear carbonyl absorptions at 1730 and 1698 $cm^{-1}$ while broad absorption at 1600 $cm^{-1}$, characteristic of the enol form of a 1,3-diketone, was quite weak; Moreover, the methylene protons of C(2) were observed as an *AB*-system at 3.01 ppm in the $^1$H-NMR. spectrum and C(2) was observed at 61.8 ppm in the $^{13}$C-NMR. spectrum. The third compound **8** was an alcohol (IR.: 3350 $cm^{-1}$, $^1$H-NMR.: 3.92 ppm)[1]. Unfortunately the yield of **8** was variable. This compound is interesting because it is probably the intermediate of the rearrangement. When treated in the same manner as **5**, compound **8** yielded only **7** with no detectable trace of **6**. *Prelog et al.* [5] have reported that the tendency for the active methylene of the ring to attack the carbonyl of the side chain increases with increasing ring size under basic conditions. We believe that limiting the amount of base present in the reaction mixture by slow addition of base to substrate is an excellent method of circumventing this problem and producing the anion at the active methylene group of the side chain. Indeed, rearranged compounds were obtained in this manner[2].

Compound **10** also afforded two main products, the cyclodecyl product **11** (5%) and the cyclododecyl product **12** (40%), whose ferric chloride tests were dark violet and reddish orange, respectively. The $^1$H-NMR. spectrum of **11** suggests a mixture

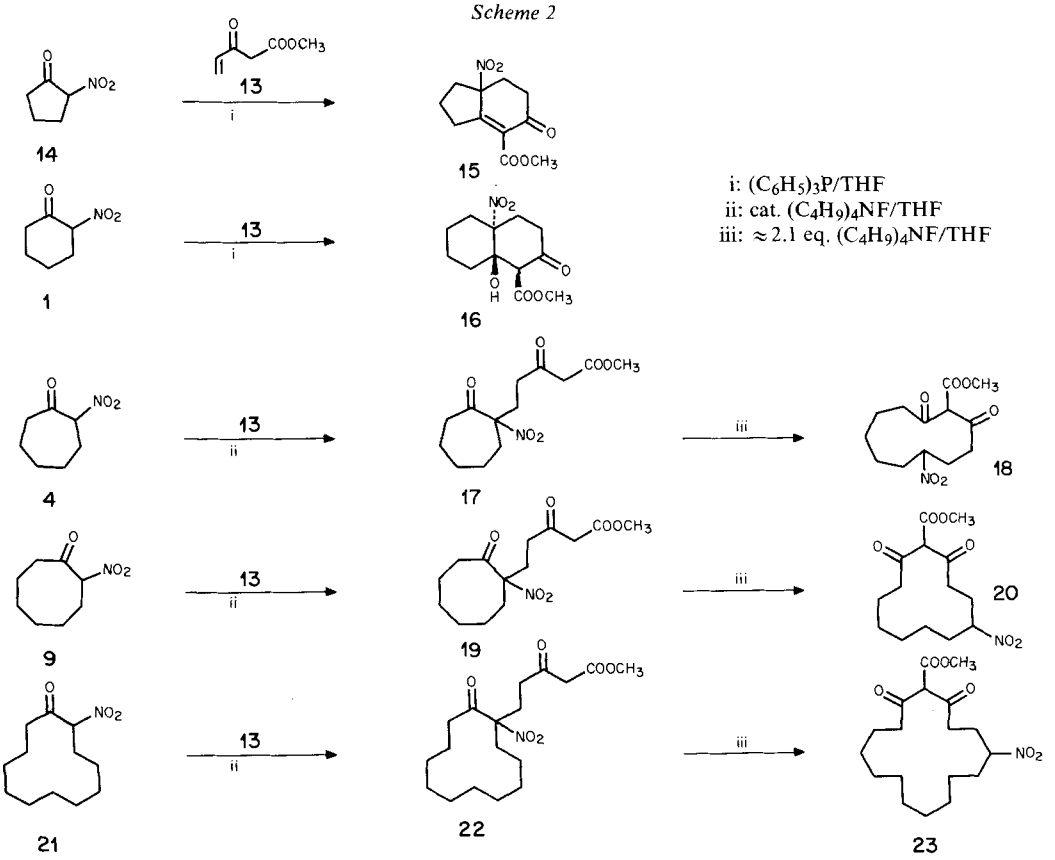
[1] Final proof of stereostructure **8** was obtained by X-ray crystallography [4].

[2] In case of cyclopentyl and cyclododecyl *Michael* adducts, many products with a negative ferric chloride test were obtained even when the reaction was performed in this manner.

of keto and enol forms, the signal between 3.13 and 2.70 ppm being very complex. The $^1$H- and $^{13}$C-NMR. spectra of **12** also showed a mixture (*ca.* 3:2) of keto and enol forms. On base treatment, only compound **10** underwent a retro-*Michael* reaction in addition (side-product **9**). The reason for this reverse reaction is that cyclooctanones exist in the «O-inside» conformation, rendering the ketone less active.

Rearrangements of compounds of type **5** or **10** gave compounds enlarged by 2 or 4 C-atoms. In order to have only one rearrangement, the use of a more specific reaction partner than methyl vinyl ketone was necessary. We have previously reported [2][3]) that the use of methyl 3-oxo-4-pentenoate (**13**, [6] and *Exper. Part*) in condensations with 2-nitroketones offered the best means of controlling the number of C-atoms inserted in the rearranged product. Attempts were therefore made to condense **13** with cyclic 2-nitroketones. Compound **14** afforded only the cyclized dehydration product **15**, relatively unstable even after recrystallization, while compound **1** yielded the cyclized alcohol **16**[4]) in 83% yield *(Scheme 2)*. How-

*Scheme 2*




[3]) In [2] a mechanism for this type of ring enlargement is proposed.

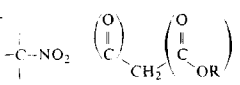
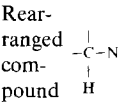
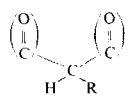
[4]) The proof of the configuration of **16** was also obtained by X-ray crystallography [4]. Its ring junction is *trans* in contrast to **8**.

ever, **16** did not rearrange under a variety of conditions (tetrabutylammonium fluoride, TBAF, at 25° or 50°; NaH in the presence or absence of 18-crown-6).

In the case of the cyclo-heptyl, -octyl, and -dodecyl nitroketones **4**, **9** and **21**, yields were low and reaction times very long with triphenylphosphine as a catalyst. It is well known that fluoride anion is a good base for the *Michael* reaction of nitro compounds [7]. Indeed, in the presence of catalytic amounts of TBAF, compounds **4**, **9**, and **21** rapidly yielded the adducts **17** (92% yield), **19** (90%), and **22** (93%).

The treatment of **17** with TBAF (2 mol-equiv.) in THF yielded the cycloundecyl product **18** (98% yield) whose ferric chloride test was bright orange. The IR. spectrum of **18** exhibited chracteristic strong absorptions at 1674, 1641, and 1580 $cm^{-1}$.

Table. *Comparison of the important signals in the $^{13}C$-NMR. spectra of unrearranged and rearranged compounds* ($CDCl_3$, RT.)

| Unrearranged compound |  | | C=O | Rearranged compound |  |  | C=O | |
|---|---|---|---|---|---|---|---|---|
| **2** | 96.3 | | 205.8<br>200.3 | **3** | 86.7<br>86.6 | 104.7 | 193.9<br>193.3 | |
| **5** | 99.0 | | 205.8<br>202.4 | **6** | 86.7 | 105.8 | 196.2<br>191.1 | |
| | | | | **7** | 84.4 | 61.8 | 202.8<br>201.1 | |
| **10** | 97.7 | | 205.7<br>204.6 | **11** | 84.6 | 105.5 | 196.8<br>190.4 | |
| | | | | **12** | 85.9<br>83.0 | 101.4<br>62.5 | 202.4<br>200.9 | 195.2<br>190.0 |
| **17** | 98.8 | 48.7 | 202.3<br>200.5 | **18** | 86.1<br>84.7 | 109.6<br>109.1 | 203.5<br>201.6 | 184.5<br>181.1 |
| **19** | 97.5 | 48.8 | 204.6<br>200.3 | **20** | 86.3 83.0<br>83.5 82.4 | 109.5 | 201.8<br>201.0 | 199.6<br>184.0 |
| **22** | 99.9 | 48.8 | 200.5<br>199.9 | **23** | 87.65<br>87.56<br>87.4<br>86.4<br>85.1 | 110.0<br>109.3<br>106.9 | 199.4<br>199.24<br>199.20<br>199.1<br>198.5<br>198.3 | 196.1<br>195.9<br>195.86<br>194.5<br>194.4<br>186.0 |
| **25** | 98.6 | 48.9 | 202.2<br>200.2 | **26** | 86.0<br>84.7 | 109.7<br>109.1 | 203.5<br>201.6 | 184.8<br>181.3 |
| **27** | 97.4 | 49.0 | 204.5<br>200.0 | **28** | 86.7 83.2<br>83.7 82.7 | 110.2<br>109.8 | 202.0<br>199.7 | 198.6<br>184.7 |
| | | | | **30** | 87.8<br>86.2<br>84.9 | 109.4 | 199.3<br>198.7<br>198.6 | 197.9<br>195.7<br>194.5 |
| **29** | 99.9 | 49.1 | 200.5<br>199.7 | **31** | 85.9 | 100.2<br>57.5 | 203.6<br>202.0 | 195.3<br>191.1 |

[a]) Compounds **12**, **18**, **20**, **23**, **26**, **28**, **30**, **31** in $CDCl_3$ exist in more than one conformation.

The $^1$H-NMR. spectrum showed that this compound has at least two significant conformations as the signal for the enolic proton was divided between two resonances at 13.60 and 13.52 ppm. Compound **19** also afforded a rearranged product, **20**, in 93% yield. The IR. spectrum of **20** is very similar to that of **18**, but its $^1$H-NMR. spectrum is more complex. The enolic proton signal is divided into four *s*, the H–C(5) signal into two *s*, and the ester methyl signal into five *s*. In the $^{13}$C-NMR. spectrum, the number of distinguishable C-resonances is 52, rather than the 14 expected[5]).

Conditions for the rearrangement of **22** were slightly different (50° for 5 h). The $^1$H-NMR. spectrum of the rearranged product **23** indicated at least two different conformations, the enolic proton signal being divided (17.87 and 13.73 ppm). The $^{13}$C-NMR. spectrum of **23** is much more complex than that of **18** or even **20**. The distinguishable C-resonance number is 62 rather than 18 (see *Exper. Part*).

In the case of acyclic 2-nitroketones, rearranged products were obtained directly when 2 mol-equiv. of TBAF were used in the *Michael* reaction with **13** [2]. Similarly, we treated the cyclic 2-nitroketones **1**, **9**, and **21** with **13**, in the presence of TBAF (2 mol-equiv.) in THF at 15°. Compound **1** afforded only the non-rearranged **16**. Compounds **9** and **21** afforded the rearranged products **20** and **23** directly, but in low yield. The main products from both reactions were the *Michael* adducts **19** and **22**. When the reaction mixture was warmed at 50° for 5 h, compounds **9** and **21** yielded **20** and **23** in 20 and 23% yield, respectively, accompanied by many unidentified products. Under the same conditions compound **1** gave only unidentified products.

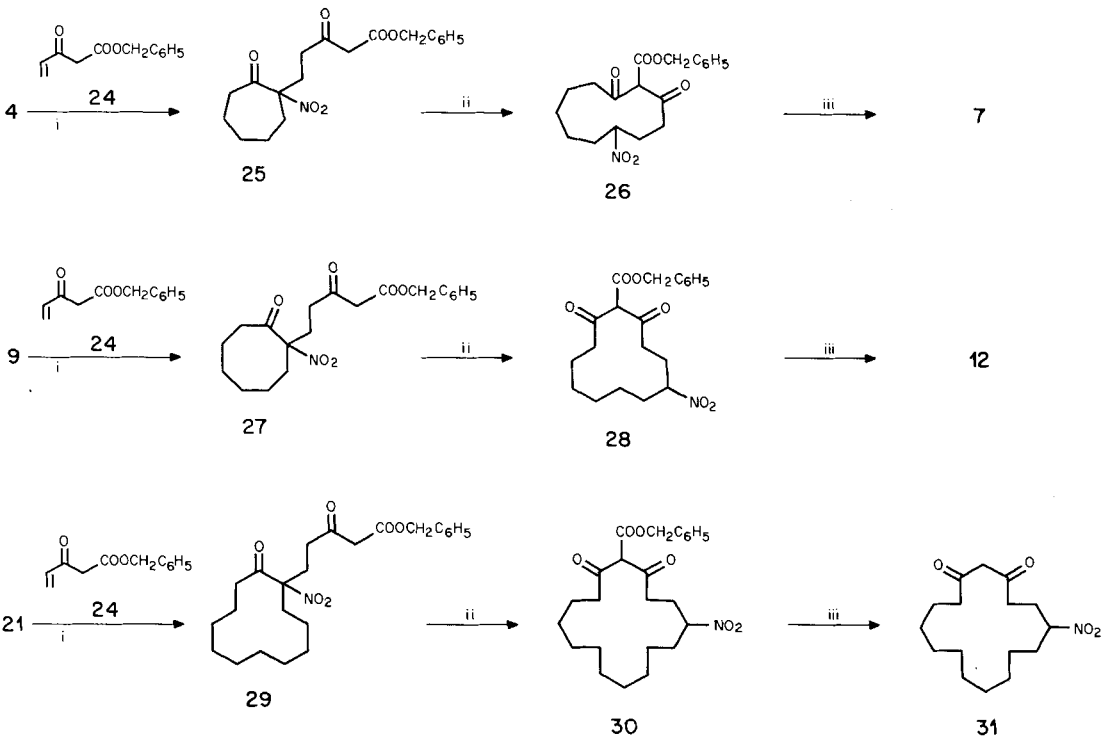
Thus, compound **13** provides a good reagent for ring expansions and for control of the number of C-atoms inserted. However, utility of this reagent for further reactions seems to be limited by the conditions required for cleavage of the methyl ester. Benzyl 3-oxo-4-pentenoate (**24**) provides a reasonable alternative synthon for extending the utility of this ring expansion procedure.

All syntheses of **13** seem complex [6]. *Yonemitsu et al.* have reported a convenient $\beta$-keto ester synthesis [8]. We modified and simplified this method for **13** and for the new synthesis of **24** (see *Exper. Part*). In the presence of TBAF, compound **24** condensed with **4**, **9**, and **21** to afford the adducts **25** (91%), **27** (83%), and **29** (91%) *(Scheme 3)*. By treatment with TBAF in THF, compounds **25**, **27**, and **29** were then converted into the rearranged products **26** (78%), **28** (86%), and **30** (80%), with physical data similar to these of the corresponding methyl esters. For the rearrangement, it was necessary to warm the mixture at 50°, in contrast with the lower temperature used in the rearrangement of the methyl esters (except **22**). Compounds **26**, **28**, and **30** were hydrogenolyzed with Pt in EtOH in the presence of glacial acetic acid and directly afforded the desired decarboxylated nitrodiketones **7** (56%), **12** (61%), and **31** (87%). The IR. spectrum of **31** showed broad absorptions at 1698 and 1598 cm$^{-1}$ and its $^1$H-NMR. spectrum indicated a mixture (*ca.* 3 : 7) of keto and enol forms.

**Discussion.** – The results of the experiments with methyl vinyl ketone *(Scheme 1)* are summarized in *Scheme 4*. Base treatment of **2** gave only the eight-membered type **A** product **3**, while **5** and **10** gave products of both types **A** and **B** in different

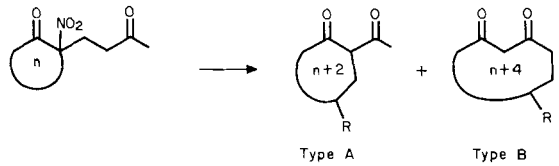
[5]) Final proof of the structure of **20** was obtained by X-ray crystallography [4].

*Scheme 3*




i: cat. $(C_4H_9)_4NF$/THF
ii: ≈2.1 eq. $(C_4H_9)_4NF$/THF
iii: $H_2$/Pt

*Scheme 4*




| R = $NO_2$ | | Ratio | |
|---|---|---|---|
| n = 6 **2** | **3** | 1:0 | |
| n = 7 **5** | **6** | 1.3:1 | **7** |
| n = 8 **10** | **11** | 1:8 | **12** |

ratios. The fact that base treatment of the cyclized alcohol **8** yielded only the type **B** product **7**, indicates that the intermediate in the formation of type **B** products must involve a six-membered ring of type **D**, while the intermediate in the formation of type **A** products must be different, such as type **C**. Recently, in a report of a three-C-atoms ring expansion using silyl-mediated fragmentation, *Trost & Vincent* [9] have discussed aspects of ring expansions. Calculations of ring strain energy were performed in the manner utilized in their study. Simple calculation [10] of the change in ring strain energy based on the intermediates of types **C** and **D** yielded the following values:

| Reaction | Difference of ring strain energy |
|---|---|
| **2**→**3** | − 16.8 kcal (exothermic) |
| **5** ⇄ **6** | − 20.1 kcal (exothermic) |
| **5** ⇄ **7** | + 4.7 kcal (endothermic) |
| **10** ⇄ **11** | −24 kcal (exothermic) |
| **10** ⇄ **12** | − 6 kcal (exothermic) |

With an increase in ring-strain energy, compound **7** is unexpected. Similarly, the ratio of **11** to **12** seems at variance with the expected result. Explanation of these differences requires consideration from an alternative perspective. X-ray crystallography of rearranged products **3**, **6** and **11** indicate that the conformation of the ring carbonyl groups in these compounds are 'O-outside'[6]) and that they are properly aligned to be in the enol form, conjugated with the acetyl carbonyl group [4]. Accordingly, it is certain that all the rearranged compounds must exist in the enol form under strongly basic conditions due to the newly formed 1,3-diketone system, the nitro function being in the aci-nitro form because of its lower $pK_a$-value [12]. A ring expansion involving formation of a 1,3-diketone system and secondary nitro substituent should be possible if at least one of the newly formed functions is able to release an adequate amount of energy resulting in a net decrease in total enthalpy of the product. For instance, the heat of neutralization of acetylacetone in 50% water/dioxane is about 9 kcal/mol exothermic [13], depending on the dielectric constant of the solvent. If energy is released from a newly formed 1,3-diketone in an analogous manner during the rearrangement, formation of **7** is not unreasonable, and the amount of this energy, 9 kcal/mol, seems adequate.

*Hünig & Hoch* [14] have reported physical properties of cycloalkanones (*Scheme 4*, types **A** and **B**, R = H), which indicate that in type **A** compounds the tendency toward enol formation decreases with increasing ring size while in type **B** compounds, the opposite is apparent. Our results are in substantial agreement with these trends, but slight differences exist which can be attributed to the influence of the nitro function on the preferred conformation. Obviously, if the extent of enol formation is decreased, then the amount of energy which can be released by the 1,3-diketone system must be similarly reduced. $^1$H-NMR. spectra (neutral condi-

[6]) In medium sized cycloalkanones, *Prelog* has commented that the so-called 'O-inside' conformation minimizes the number of methylene groups involved in gauche interactions and allows formation of an intramolecular H-bridge. This factor is also critical in reduction of ring strain [11].

tions: $CDCl_3$) indicate that **11** exists as a mixture of keto and enol forms in a ratio of 3:7, while in **12** this ratio is 3:2. However, the enolic proton of **12** could not be detected at low field in the $^1$H-NMR. spectrum, suggesting that it must be very acidic. Under basic conditions, **12** forms the enol form much more readily than **11**. These differences may account for the apparent discrepancy in yield ratio. On the other hand, the traditional 'normal' range of H-bond enthalpies is $\approx$2–10 kcal/mol. Fluoride anion generally forms very strong H-bonds, the enthalpy of which is beyond this range. For example, the fluoride-phenol H-bond enthalpy is $15 \pm 1$ kcal/mol [15]. It is plausible that the fluoride anion forms a much stronger H-bond with the newly formed 1,3-diketone and nitro substituent than other strong bases (*e.g. t*-BuOK), resulting in a greater release of energy from these functions, thus facilitating the reaction. This seems to be the primary reason for the higher yields of rearrangements when TBAF was used.

We believe this explanation to be fundamentally sound, although other factors may promote this kind of rearrangement. A 1,2-dipole interaction could be an important factor. Single crystal X-ray studies show a *cis* ring-junction for compound **8**, and a *trans*-junction for compound **16**. In **8**, a 1,2-dipole interaction under basic conditions could thus be a significant factor for the weakening of the C(1),C(7)-bond, facilitating the rearrangement. The *trans* ring-junction of **16** limits the possibility of such an interaction, thereby reducing its importance in the rearrangement. Further experiments are certainly necessary to establish the nature of the 'medium-size ring effect', which, as *Prelog* mentions, is not predicted by classical chemistry. This effect appears to be less important in acyclic and large ring compounds, as demonstrated in this and previous papers, however, if the products or starting materials are medium-size ring compounds, its contribution is significant. By using the principle of the so-called 'zip reaction' under mild conditions, expansion of acyclic and cyclic compounds (except 5- and 6-membered rings) was achieved in high yield, producing compounds with medium- and large-size rings.

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## Experimental Part

*General remarks.* Unless otherwise specified: IR. spectra in KBr in $cm^{-1}$. $^1$H-NMR. spectra in $CDCl_3$ at 90 MHz, $^{13}$C-NMR. spectra in $CDCl_3$ with *Varian XL 100;* $\delta$ in ppm, $J$ in Hz, standard tetramethylsilane = 0 ppm. Because of its complex nature the multiplicity of the signals of aliphatic C-atoms is not given. MS. in *m/z* (> 5% relative intensity). – Column chromatography was carried out using silicic acid (*Mallinckrodt*, 100 mesh); without solvent system given means: benzene/hexane 10:7. Color reactions with $FeCl_3$. Compounds **17**, **19**, **23**, **24**, **25**, **30** and **33** are oils. Because of their instability (even under reduced pressure) they could not be further purified by distillation. Abbreviations: *s* singlet, *d* doublet, *t* triplet, *qa* quadruplet, *m* multiplet; *S* shoulder, br. broad, TABF tetrabutylammonium fluoride, THF tetrahydrofuran.

**1. Reactions of 2-nitrocycloalkanones with methyl vinyl ketone.** – *1.1. 2-Nitro-2-(3-oxobutyl)cyclohexanone* (**2**). To a mixture of 2-nitrocyclohexanone (**1**, 2.86 g, 20 mmol) [16] and methyl vinyl ketone (1.44 ml, 24 mmol) in THF (50 ml) was added triphenylphosphine (10 mg, 0.05 mmol) at 20° under Ar.

The resulting mixture was stirred under the same conditions for 20 h. After addition of $CH_3I$, the organic solvent was removed under reduced pressure and the residue was purified by column chromatography (*Merck, Kieselgel 60* eluted with hexane/ether 10:3) to afford **2** as a colorless oil (4.13 g, 97%), b.p. (bath temp.) 140–145°/0.03 Torr. – IR. ($CHCl_3$): 1735 *S*, 1720, 1545. – $^1$H-NMR.: 3.0–1.52 (*m*, 12 H) with 2.01 (*s*, 3 H). – $^{13}$C-NMR.: 205.8, 200.3, 96.3, 39.6, 37.5, 37.0, 29.8, 28.8, 26.6, 21.4. – MS.: 213 (0, $M^+$), 137 (6), 99 (7), 95 (7), 81 (8), 79 (10), 67 (8), 55 (12), 53 (6), 43 (100), 41 (12).

$C_{10}H_{15}NO_4$ (213.23) Calc. C 56.32 H 7.09 N 6.57% Found C 56.52 H 6.85 N 6.30%

*1.2. 2-Acetyl-4-nitrocyclooctanone* (**3**). To *t*-BuOK (448 mg, 4.0 mmol) in THF (100 ml) was added **2** (426 mg, 2.0 mmol) in THF (100 ml) at −80° under Ar during 1 h. The colorless solution changed to bright yellow. Stirring was continued for 1 h under the same conditions, then glacial acetic acid (4 ml) in THF (5 ml) was added. After removal of *ca.* 170 ml of solvent under reduced pressure at 20° the residual mixture was neutralized with sat. aq. $NaHCO_3$-solution, and extracted with $CHCl_3$ (50 ml × 3). The combined extracts were washed with sat. aq. NaCl-solution, dried ($MgSO_4$) and evaporated under reduced pressure to a crude residue, which was purified by column chromatography to afford **3** as colorless crystals (362 mg, 85%); colorless needles, m.p. 69.4–70.2° (EtOAc/hexane/ether)[6]. – IR.: 1760–1590 br., 1548. – $^1$H-NMR.: 16.93 (*s*, 1 H); 4.68–4.27 (*m*, 1 H); 3.23–1.05 (*m*, 13 H) with 3.01 (*d*, $J$ = 7.5, 2 H) and 2.02 (*s*, 3 H). – $^{13}$C-NMR.: 193.9, 193.3, 104.7, 86.7, 86.6, 35.3, 35.2, 30.4, 30.3, 27.9, 23.6, 21.9. In ($D_6$)benzene: 193.8, 193.0, 104.8, 86.6, 35.0, 30.3, 30.2, 27.8, 23.1, 21.7. – MS.: 213 (4, $M^+$), 167 (11), 149 (5), 140 (5), 137 (5), 125 (9), 123 (8), 111 (6), 109 (6), 107 (8), 105 (8), 99 (6), 98 (5), 97 (12), 95 (13), 93 (6), 91 (6), 85 (8), 83 (9), 82 (5), 81 (13), 79 (12), 77 (8), 71 (12), 70 (8), 69 (21), 67 (14), 57 (20), 56 (6), 55 (32), 53 (6), 43 (100), 42 (6), 41 (35).

$C_{10}H_{15}NO_4$ (213.23) Calc. C 56.32 H 7.09 N 6.57% Found C 56.51 H 7.09 N 6.62%

*1.3. 2-Nitro-2-(3-oxobutyl)cycloheptanone* (**5**). After treatment of 2-nitrocycloheptanone (**4**, 3.14 g, 20 mmol) [17] with methyl vinyl ketone (1.44 ml, 24 mmol) as in 1.1, **5** was isolated as colorless plates, m.p. 61.0–61.5° (EtOAc/hexane), 4.22 g, 93%. – IR.: 1720, 1712, 1552, 1542. – $^1$H-NMR.: 2.93–1.30 (*m*, 17 H) with 2.01 (*s*, 3 H). – $^{13}$C-NMR.: 205.8, 202.4, 99.0, 41.2, 37.6, 35.0, 30.3, 29.8, 29.5, 25.7, 24.7. – MS.: 227 (0, $M^+$), 181 (15), 163 (6), 139 (7), 137 (8), 135 (8), 125 (8), 123 (8), 121 (17), 119 (13), 111 (6), 109 (16), 107 (7), 105 (6), 99 (10), 97 (20), 96 (8), 95 (34), 94 (11), 93 (20), 91 (13), 85 (8), 84 (7), 83 (25), 82 (5), 81 (31), 80 (8), 79 (25), 77 (7), 71 (20), 70 (5), 69 (25), 68 (8), 67 (45), 57 (12), 56 (6), 55 (69), 54 (13), 53 (18), 43 (100), 42 (14), 41 (79).

$C_{11}H_{17}NO_4$ (227.26) Calc. C 58.14 H 7.54 N 6.16% Found C 57.96 H 7.33 N 6.29%

*1.4. 2-Acetyl-4-nitrocyclononanone* (**6**), *6-nitrocycloundecane-1,3-dione* (**7**), *and 7-hydroxy-1-nitro-cis-bicyclo[5.4.0]undecane-9-one* (**8**). To 2-nitro-2-(3-oxobutyl)cycloheptanone (**5**, 454 mg, 2.0 mmol) in THF (100 ml) was added *t*-BuOK (448 mg, 4.0 mmol) in THF (100 ml) at −80° under Ar during 1 h. The resulting mixture was stirred for 3 h under the same conditions, then the temp. was raised to −20° within 1 h, during which a white precipitate formed. Glacial acetic acid (5 ml) in THF (5 ml) was added and stirring was continued until formation of a clear yellow solution (*ca.* 5 min). Approximately 180 ml of solvent was removed under reduced pressure then the residual mixture was neutralized with sat. aq. $NaHCO_3$-solution, and extracted with $CHCl_3$ (3 × 50 ml). The combined extracts were washed with sat. aq. NaCl-solution, dried ($MgSO_4$) and evaporated under reduced pressure. The brown residue was purified by column chromatography to afford **6** as the first eluate, colorless needles (200 mg, 44%); m.p. 73.8–74° (EtOAc/pentane/ether)[6]. A second eluate, **7**, was obtained as a colorless oil (160 mg, 35%), b.p. (bath temp.). Finally $CHCl_3$ eluted **8** (29.5 mg, 6.5%) as colorless needles; m.p. 116.3–116.7° (EtOAc/hexane/ether)[6].

*Data of* **6**. – IR.: 1900–1100 br., 1535. – $^1$H-NMR.: 17.07 (*s*, 1 enolic OH); 4.67–4.20 (*m*, 1 H); 3.3–1.1 (*m*, 15 H) with 3.01 (*d*, $J$ = 7.0, 2 H) and 2.20 (*s*, 3 H). – $^{13}$C-NMR.: 196.2, 191.1, 105.8, 86.7, 32.8, 31.5, 30.1, 24.6, 24.5, 24.4, 22.6. – MS.: 227 (1, $M^+$), 137 (6), 125 (5), 97 (6), 95 (7), 91 (6), 83 (5), 81 (6), 79 (5), 71 (6), 69 (5), 67 (8), 55 (17), 43 (100), 41 (19).

$C_{11}H_{17}NO_4$ (227.26) Calc. C 58.14 H 7.54 N 6.16% Found C 58.35 H 7.73 N 6.39%

*Data of* **7**. – IR. ($CHCl_3$): 1730, 1705 *S*, 1698, 1600 *S* br., 1550. – $^1$H-NMR.: 4.67–4.20 (*m*, 1 H); 3.72 (*AB*-system, $J$ = 9.0, 2 H); 3.13–0.73 (*m*, 14 H). – $^{13}$C-NMR.: 202.8, 201.1, 84.4, 61.8, 41.3, 37.2,

[6]) For X-ray [4] and elemental analysis.

30.1, 26.2, 25.3, 23.2, 21.5. – MS.: 227 (≪1, $M^+$), 181 (14), 163 (6), 139 (6), 137 (8), 135 (8), 125 (7), 123 (7), 121 (17), 119 (9), 111 (6), 109 (17), 107 (6), 105 (8), 99 (11), 98 (5), 97 (20), 96 (7), 95 (34), 94 (12), 93 (20), 91 (16), 86 (27), 85 (8), 84 (45), 83 (26), 82 (6), 81 (30), 80 (9), 79 (25), 77 (9), 71 (20), 70 (6), 69 (26), 68 (9), 67 (48), 57 (12), 56 (6), 55 (68), 54 (12), 53 (19), 51 (6), 49 (19), 47 (12), 43 (100), 42 (16), 41 (83).

$C_{11}H_{17}NO_4$ (227.26) Calc. C 58.14 H 7.54 N 6.16% Found C 58.27 H 7.32 N 5.97%

*Data of* **8**. – IR.: 3350, 1715, 1545. – $^1$H-NMR.: 3.92 (*s*, OH, exchangeable with $D_2O$); 3.1–1.15 (*m*, 16 H). – $^{13}$C-NMR.: 206.6, 97.5, 76.6, 52.3, 39.7, 36.3, 34.7, 31.1, 26.4, 22.0, 21.4. – MS.: 227 (1, $M^+$), 181 (6), 179 (8), 163 (9), 158 (6), 151 (5), 145 (5), 138 (5), 137 (12), 135 (7), 125 (23), 123 (8), 121 (28), 119 (11), 115 (8), 111 (6), 110 (7), 109 (35), 107 (11), 105 (11), 100 (5), 99 (21), 97 (17), 96 (11), 95 (37), 94 (27), 93 (26), 91 (19), 86 (5), 85 (12), 84 (5), 83 (22), 82 (9), 81 (40), 80 (7), 79 (36), 77 (17), 73 (5), 72 (5), 71 (56), 70 (13), 69 (23), 68 (11), 67 (64), 66 (5), 65 (9), 58 (7), 57 (14), 56 (7), 55 (68), 54 (12), 53 (28), 51 (7), 44 (10), 42 (100), 41 (12).

$C_{11}H_{17}NO_4$ (227.26) Calc. C 58.14 H 7.54% Found C 58.13 H 7.39%

*1.5. Conversion of* **8**→**7**. Compound **8** (50 mg, 0.22 mmol) was treated with *t*-BuOK (49.3 mg, 0.44 mmol) in THF as in 1.4. After chromatography, besides a variety of indeterminate materials the main product was obtained as a colorless oil (13 mg, 26%) identified as **7**.

*1.6. 2-Nitro-2-(3-oxobutyl)cyclooctanone* (**10**). Compound **10** was prepared as in 1.1 from 2-nitrocyclooctanone (**9**, 3.42 g, 20 mmol) [17], and methyl vinyl ketone (1.44 ml, 24 mmol) with triphenylphosphine (10 mg, 0.05 mmol). After purification by column chromatography *(Merck, Kieselgel 60)*, compound **10** was obtained as colorless crystals; m.p. 40.8–41.0° (ether/pentane at −20°), 4.58 g, 95%. – IR.: 1722, 1542. – $^1$H-NMR.: 3.0–1.0 (*m*, 19 H) with 2.01 (*s*, $CH_3$). – $^{13}$C-NMR.: 205.7, 204.6, 97.7, 38.2, 37.7, 32.0, 29.8, 28.6, 27.7, 25.5, 24.3, 22.5. – MS.: 241 (0, $M^+$), 195 (3), 110 (9), 109 (8), 107 (9), 99 (57), 97 (13), 95 (14), 93 (9), 91 (7), 83 (7), 81 (19), 79 (10), 71 (16), 69 (15), 68 (6), 67 (29), 55 (30), 54 (8), 53 (11), 44 (6), 43 (100), 42 (8), 41 (43).

$C_{12}H_{19}NO_4$ (241.29) Calc. C 59.73 H 7.94 N 5.81% Found C 60.02 H 7.87 N 5.70%

*1.7. 2-Acetyl-4-nitrocyclodecanone* (**11**) *and 6-nitrocyclododecane-1,3-dione* (**12**). To 2-nitro-2-(3-oxobutyl)cyclooctanone (**10**, 482 mg, 2.0 mmol) in THF (100 ml) was added *t*-BuOK (448 mg, 4.0 mmol) in THF (100 ml) at −80° under Ar during 1 h. The mixture was stirred for 3 h under the same conditions, then the temp., was gradually raised to −20° over 1 h, and worked up as in 1.2. The residue was purified by column chromatography to afford **11** as the first eluate, colorless needles; m.p. 97.4–98.2° (EtOAc/hexane)[6]), 25 mg, 5%. Compound **9**, the second eluate (125 mg, 25%), was identified by comparison with an authentic sample. Finally, compound **12** was eluted as a colorless oil which was further purified by distillation and recrystallization from ether/pentane at −20° (200 mg, 40%), b.p. (bath temp.) 180–190°/0.04 Torr, m.p. 43.0–43.9°.

*Data of* **11**. – IR.: 1800–1200 br., 1535. – $^1$H-NMR. (keto enol mixture): 17.37 (*s*, 0.7 H); 4.83–4.20 (*m*, 1 H); 3.13–1.0 (*m*, 14.3 H; contains *AB* portion of an *ABX* spin system at 3.30−2.98 ppm, $J(AX)=10.5$, $J(AB)=16.0$, $J(BX)=6.0$) and 2.23 (*s*, 3 H). – $^{13}$C-NMR.: 196.8, 190.4, 105.5, 84.6, 32.6, 28.2, 27.3, 26.0, 25.1, 24.6, 21.3, 20.5. – MS.: 241 (≪1, $M^+$), 172 (16), 134 (5), 133 (7), 125 (7), 119 (18), 111 (5), 109 (5), 105 (18), 101 (5), 99 (6), 98 (5), 97 (18), 95 (11), 93 (5), 91 (19), 85 (12), 84 (7), 83 (16), 82 (5), 81 (14), 79 (8), 77 (7), 71 (23), 70 (21), 69 (24), 68 (6), 67 (16), 59 (5), 57 (44), 56 (13), 55 (70), 54 (5), 53 (9), 43 (100), 42 (17), 41 (62).

$C_{12}H_{19}NO_4$ (241.29) Calc. C 59.73 H 7.94 N 5.81% Found C 59.44 H 8.08 N 6.08%

*Data of* **12**. – IR.: 1735 *S*, 1720 *S*, 1703 *S*, 1697 *S*, 1693, 1686 *S*, 1595 br., 1544. – $^1$H-NMR. (keto enol mixture): 5.70 (*s*, ≈0.4 H); 4.7–4.2 (*m*, 1 H); 3.63 (*s*, ≈1.2 H); 3.26–0.8 (*m*, 16 H); the enol OH could not be detected. – $^{13}$C-NMR. (keto enol mixture): 202.4, 200.9, 195.2, 190.0, 101.4, 85.9, 83.0, 62.5, 38.5, 38.0, 36.6, 35.4, 30.6, 29.2, 27.6, 26.2, 25.8, 24.8, 23.7, 23.5, 23.3, 22.6, 21.4. – MS.: 242 (≪1, $[M+1]^+$), 241 (0, $M^+$), 196 (6), 195 (39), 151 (5), 149 (5), 137 (7), 135 (12), 133 (9), 123 (5), 119 (8), 111 (8), 109 (16), 108 (7), 107 (9), 105 (7), 99 (5), 98 (7), 97 (23), 96 (5), 95 (24), 94 (16), 93 (21), 91 (14), 85 (10), 84 (18), 83 (26), 82 (6), 81 (32), 80 (5), 79 (20), 77 (6), 71 (16), 70 (6), 69 (29), 68 (7), 67 (48), 58 (5), 57 (12), 56 (6), 55 (72), 54 (15), 53 (16), 43 (100), 42 (12), 41 (86).

$C_{12}H_{19}NO_4$ (241.29) Calc. C 59.73 H 7.94 N 5.81% Found C 60.03 H 8.15 N 5.60%

**2. Reactions of 2-nitrocycloalkanones with methyl 3-oxo-4-pentenoate.** – *2.1. Methyl 3a-nitro-6-oxo-3a,4,5,6-tetrahydroindan-7-carboxylate* (**15**). To the mixture of 2-nitrocyclopentanone (**14**, 1 g, 7.8 mmol) [18] and methyl 3-oxo-4-pentenoate (**13**, 1.02 g, 8.0 mmol, see below) in THF (20 ml) was added triphenylphosphine (8 mg, 0.004 mmol) at 25° under Ar and the mixture was stirred for 20 h under the same conditions. After workup as in 1.1, the crude product was purified by column chromatography to give **15** as colorless needles; m.p. 87–88.2° (EtOAc/hexane), 500 mg, 27%. – IR.: 1729, 1683, 1646, 1542. – $^1$H-NMR.: 3.86 (*s*, 3 H); 3.1–1.0 (*m*, 10 H). – $^{13}$C-NMR.: 191.7, 164.3, 161.5, 130.9, 95.0, 52.0, 38.8, 32.7, 31.4, 30.4, 21.5. – MS.: 239 (1, $M^+$), 194 (7), 193 (49), 162 (38), 161 (100), 160 (8), 134 (5), 133 (16), 106 (7), 105 (33), 104 (6), 103 (8), 94 (10), 93 (41), 91 (19), 79 (19), 78 (11), 77 (23), 67 (6), 66 (5), 65 (10), 63 (6), 59 (23), 55 (27), 53 (15), 52 (13), 51 (24), 50 (8), 45 (5), 43 (9), 42 (12), 41 (22).

$C_{11}H_{13}NO_6$ (239.24) Calc. C 55.22 H 5.48 N 5.85% Found C 55.50 H 5.66 N 6.06%

*2.2. Methyl 1-hydroxy-6-nitro-3-oxo*-trans-*bicyclo[4.4.0]decane-2-carboxylate* (**16**). To a mixture of 2-nitrocyclohexanone (**1**, 2 g, 14.0 mmol) and **13** (1.8 g, 14.1 mmol) in THF (30 ml) was added triphenylphosphine (14 mg, 0.07 mmol) at 25° under Ar and stirring was continued for 20 h. After workup of the mixture as in 1.1, the crude product was purified by column chromatography (*Merck, Kieselgel 60*, hexane/$Et_2O$ 3:1) to yield **16** as colorless needles; m.p. 128–129° (EtOAc/hexane/$Et_2O$)[6]), 3.15 g, 83%. – IR.: 3500, 1736, 1714, 1705 *S*, 1700 *S*, 1681, 1548. – $^1$H-NMR.: 4.66 (*s*, 1 H, exchangeable with $D_2O$), 4.43 (*s*, 1 H); 3.83 (*s*, 3 H); 2.9–1.0 (*m*, 12 H). – $^{13}$C-NMR.: 202.1, 171.2, 93.2, 75.8, 62.1, 52.5, 37.2, 33.1, 32.5, 32.0, 20.9, 19.5. – MS.: 271 ($\ll$ 1, $M^+$), 223 (8), 209 (10), 207 (5), 195 (5), 193 (26), 192 (10), 191 (27), 181 (12), 179 (5), 175 (15), 167 (12), 165 (13), 164 (5), 163 (18), 152 (7), 151 (11), 149 (10), 147 (24), 139 (10), 137 (7), 135 (9), 133 (5), 129 (6), 125 (5), 124 (7), 123 (17), 122 (6), 121 (12), 119 (17), 117 (6), 111 (18), 109 (10), 108 (5), 107 (11), 105 (20), 101 (31), 98 (8), 97 (11), 96 (8), 95 (17), 93 (15), 91 (16), 85 (9), 84 (12), 83 (16), 82 (5), 81 (24), 80 (5), 79 (18), 77 (7), 71 (5), 69 (22), 68 (6), 67 (13), 59 (9), 57 (6), 55 (32), 53 (10), 43 (100), 42 (6), 41 (22).

$C_{12}H_{17}NO_6$ (271.29) Calc. C 53.15 H 6.32 N 5.16% Found C 53.08 H 6.08 N 5.04%

*2.3. Methyl 3-oxo-5-(1-nitro-2-oxocycloheptyl)pentanoate* (**17**). To a mixture of 2-nitrocycloheptanone (**4**, 1.3 g, 8.3 mmol) and **13** (1.1 g, 8.6 mmol) in THF (20 ml) was added anhydrous TBAF (30 mg, 0.11 mmol) under Ar at 25°. Stirring was continued for 5 h. Glacial acetic acid (0.5 ml) in THF (1 ml) was added and the solvent was removed under reduced pressure to give a residue, which was dissolved in $CHCl_3$ (50 ml). The solution was washed with water, then sat. aq. NaCl-solution, and dried ($MgSO_4$). Evaporation under reduced pressure afforded a pale brown residue, which was purified by column chromatography to yield **17** as a colorless oil (2.17 g, 92%). – IR. ($CHCl_3$): 1750, 1725, 1712 *S*, 1705 *S*, 1660, 1635, 1549. – $^1$H-NMR. (a small portion of **17** exists in an enolic form; integration was not possible): 3.73 (*s*, 3 H); 3.44 (*s*, 2 H); 3.0–1.2 (*m*, 14 H). – $^{13}$C-NMR.: 202.3, 200.5, 167.1, 98.8, 52.2, 48.7, 41.2, 37.2, 35.0, 30.1, 29.5, 25.7, 24.6. – MS.: 285 (0, $M^+$), 223 (6), 221 (12), 212 (9), 207 (11), 205 (8), 191 (13), 182 (6), 177 (13), 166 (18), 165 (22), 163 (9), 154 (7), 153 (13), 149 (5), 140 (5), 138 (17), 137 (26), 136 (8), 135 (20), 131 (6), 129 (23), 128 (6), 126 (5), 125 (22), 124 (5), 123 (11), 121 (5), 119 (13), 117 (16), 112 (5), 111 (16), 110 (6), 109 (20), 108 (5), 107 (14), 105 (5), 101 (51), 99 (12), 98 (8), 97 (14), 96 (8), 95 (32), 94 (14), 93 (30), 91 (16), 85 (7), 84 (8), 83 (10), 82 (8), 81 (35), 80 (7), 79 (24), 77 (9), 71 (9), 70 (5), 69 (28), 68 (13), 67 (58), 66 (5), 65 (7), 59 (71), 57 (27), 56 (10), 55 (100), 54 (21), 53 (33), 45 (5), 43 (39), 42 (22), 41 (72).

*2.4. Methyl 5-nitro-2,11-dioxo-cycloundecane-1-carboxylate* (**18**). To a stirred solution of **17** (500 mg, 1.75 mmol) in THF (30 ml) at 0° was added anhydrous TBAF (970 mg, 3.72 mmol) in THF (30 ml) under Ar over 30 min, then the reaction mixture was allowed to stand at 25° and stirring was continued for 7 h. The resulting bright brown solution was quenched by the addition of glacial acetic acid (3 ml) in THF (3 ml). Evaporation under reduced pressure gave a brown residue, which was dissolved in $CHCl_3$ (50 ml). The solution was washed with water, sat. aq. $NaHCO_3$-, and NaCl-solutions, dried ($MgSO_4$) and evaporated under reduced pressure. The pale brown residue was purified by column chromatography to afford **18** as colorless fine needles; m.p. 83.3–83.5° (EtOAc/hexane), 430 mg, 86% (98% based on reacted starting material). (Further elution allowed recovery of the starting material **17**, 60 mg, 12%). – IR.: 1780–1700 *S* br., 1688 *S*, 1674, 1655 *S*, 1650 *S*, 1641, 1580, 1550. – $^1$H-NMR.: 13.60 (*s*, 0.78 H); 13.52 (*s*, 0.22 H); 4.77–4.20 (*m*, 1 H); 3.90 (*s*, 3 H); 3.1–1.0 (*m*, 14 H). – $^{13}$C-NMR.: 203.5, 201.6, 184.5, 181.1, 171.4, 109.6, 109.1, 86.1, 84.7, 52.2, 43.8, 40.2, 31.2, 29.6, 29.0, 28.7, 28.4, 28.2, 28.1, 26.1, 24.8, 24.6, 23.5, 23.3, 21.0. – MS.: 285 ($\ll$ 1, $M^+$), 239 (5),

223 (8), 208 (7), 207 (53), 206 (5), 205 (14), 181 (5), 179 (8), 177 (8), 165 (8), 163 (9), 161 (5), 155 (8), 153 (5), 151 (5), 149 (5), 147 (5), 142 (11), 139 (6), 138 (5), 137 (20), 135 (10), 129 (8), 127 (5), 125 (8), 124 (9), 123 (15), 121 (9), 119 (16), 116 (7), 114 (7), 111 (10), 110 (7), 109 (22), 107 (10), 105 (5), 101 (27), 99 (6), 98 (5), 97 (13), 96 (6), 95 (31), 94 (6), 93 (16), 91 (9), 85 (9), 84 (13), 83 (13), 82 (8), 81 (31), 80 (8), 79 (18), 77 (5), 71 (11), 70 (9), 69 (51), 68 (9), 67 (38), 59 (18), 57 (9), 56 (9), 55 (100), 54 (14), 53 (18), 43 (34), 42 (20), 41 (76).

$C_{13}H_{19}NO_6$ (285.30) Calc. C 54.73 H 6.71 N 4.91% Found C 54.88 H 6.90 N 4.83%

*2.5. Methyl 3-oxo-5-(1-nitro-2-oxocyclooctyl)pentanoate* (**19**). Compound **19** was prepared as in 2.3 from 2-nitrocyclooctanone (**9**, 2 g, 11.7 mmol), **13** (1.6 g, 12.5 mmol) and anhydrous TBAF (50 mg, 0.19 mmol) for 5 h. The crude product was purified by column chromatography to yield **19** as a colorless oil (3.8 g, 90%). – IR. ($CHCl_3$): 1747, 1724, 1705 *S*, 1698 *S*, 1686 *S*, 1657, 1632, 1544. – $^1$H-NMR.: 12.03 (*s*, ≈0.1 enolic H); 4.99 (*s*, ≈0.1 olefinic H); 3.70 (*s*, 3 H); 3.42 (*s*, ≈1.8 H); 2.9–1.3 (*m*, 16 H). – $^{13}$C-NMR.: 204.6; 200.3, 167.1, 97.5, 52.3, 48.8, 38.3, 37.4, 32.0, 28.6, 27.5, 25.5, 24.2, 22.5. – MS.: 299 (0, $M^+$), 226 (5), 221 (6), 219 (7), 196 (5), 195 (5), 191 (6), 180 (7), 179 (10), 177 (5), 168 (5), 167 (13), 153 (7), 152 (9), 151 (9), 149 (10), 140 (9), 139 (13), 137 (5), 133 (8), 131 (5), 129 (19), 128 (5), 125 (9), 124 (6), 123 (9), 121 (6), 119 (6), 113 (6), 112 (5), 111 (18), 110 (5), 109 (20), 108 (9), 107 (18), 105 (15), 101 (38), 99 (10), 98 (12), 97 (16), 96 (8), 95 (24), 94 (7), 93 (13), 91 (25), 85 (10), 84 (16), 83 (18), 82 (10), 81 (39), 80 (7), 79 (21), 77 (8), 71 (8), 70 (9), 69 (39), 68 (38), 67 (61), 66 (5), 65 (7), 60 (5), 59 (58), 57 (27), 56 (21), 55 (96), 54 (20), 53 (31), 43 (38), 42 (29), 41 (100).

*2.6. Methyl 5-nitro-2,12-dioxo-cyclododecane-1-carboxylate* (**20**). Compound **20** was prepared according to 2.4 from **19** (300 mg, 1.0 mmol) in THF (25 ml) by treatment with anhydrous TBAF (520 mg, 2.01 mmol) in THF (25 ml) for 7 h. After column chromatography, compound **20**, the first eluate, was obtained as colorless needles, m.p. 81.1–81.8° (EtOAc/hexane/$Et_2O$)[6]), 260 mg, 87% (93% based on reacted material). Further elution yielded starting material **19** (20 mg, 6.7%). – IR.: 1800–1700 *S* br., 1688 *S*, 1678, 1658 *S*, 1652, 1638 *S*, 1580, 1548. – $^1$H-NMR.: 13.34+13.32 (*ca.* 0.2H) +13.28+13.26 (*ca.* 0.5 H, 4 *s*, enolic H); 4.97–4.50 (*ca.* 0.6 H) and 4.40–3.97 (*ca.* 0.4 H), (2 *m*); 3.9–3.7 (main signal at 3.83 with 4 small *s*); 3.6–1.0 (*m*, 16 H). – $^{13}$C-NMR.: 201.8, 201.0, 199.6, 184.0, 179.3, 171.1, 109.5, 86.3, 83.5, 83.0, 82.4, 75.9, 75.5, 52.4, 52.0, 51.5, 41.1, 39.5, 39.2, 39.1, 38.9, 36.5, 31.9, 31.1, 30.6, 29.1, 28.7, 28.5, 28.3, 28.1, 27.4, 27.1, 26.7, 26.3, 26.0, 25.7, 24.9, 24.2, 23.1, 22.7, 22.3, 22.2, 22.0, 21.8, 21.7, 21.6, 21.5, 21.48, 21.4, 21.3, 21.2, 20.8. – MS.: 299 (≪1, $M^+$), 253 (9), 237 (9), 222 (5), 221 (35), 219 (10), 193 (5), 184 (6), 179 (6), 177 (10), 155 (7), 151 (9), 149 (10), 142 (8), 141 (6), 139 (6), 137 (10), 136 (5), 135 (9), 133 (12), 131 (5), 129 (6), 125 (7), 124 (8), 123 (14), 121 (10), 119 (5), 116 (8), 114 (5), 111 (9), 110 (5), 109 (17), 108 (5), 107 (13), 105 (7), 101 (26), 98 (6), 97 (15), 96 (6), 95 (27), 94 (11), 93 (15), 91 (12), 85 (10), 84 (16), 83 (18), 82 (9), 81 (41), 80 (6), 79 (18), 77 (6), 71 (11), 70 (7), 69 (56), 68 (11), 67 (50), 65 (5), 59 (18), 57 (12), 56 (8), 55 (91), 54 (18), 53 (19), 43 (37), 42 (19), 41 (100).

$C_{14}H_{21}NO_6$ (299.34) Calc. C 56.17 H 7.08 N 4.68% Found C 56.47 H 6.89 N 4.92%

*2.7. Methyl 3-oxo-5-(1-nitro-2-oxocyclododecyl)pentanoate* (**22**). Compound **22** was prepared according to 2.3 from 2-nitrocyclododecanone (**21**, 1.2 g, 5.5 mmol) [17], **13** (0.9 g, 7.0 mmol) and anhydrous TBAF (25 mg, 0.096 mmol) in THF (20 ml) for 6 h. The crude product was purified by column chromatography to afford **22** as fine colorless needles, m.p. 77.0–77.2° (EtOAc/hexane), 1.83 g, 93%). – IR.: 1750, 1726, 1716, 1543. – $^1$H-NMR.: 3.70 (*s*, 3 H); 3.42 (*s*, 2 H); 3.15–1.75 (*m*, 8 H); 1.75–0.7 (*m*, 16 H). – $^{13}$C-NMR.: 200.5, 199.9, 167.0, 99.9, 52.3, 48.8, 36.8, 32.6, 30.5, 26.7, 26.4, 26.2, 23.3, 22.6, 22.0, 21.9, 21.4, 19.2. – MS.: 355 (0, $M^+$), 293 (6), 279 (8), 265 (5), 251 (11), 247 (5), 228 (20), 194 (6), 182 (5), 139 (5), 137 (6), 135 (7), 129 (9), 126 (5), 125 (11), 124 (7), 123 (23), 122 (5), 121 (8), 113 (7), 112 (7), 111 (19), 110 (10), 109 (19), 108 (5), 107 (10), 101 (20), 99 (9), 98 (23), 97 (28), 96 (14), 95 (41), 94 (7), 93 (13), 91 (7), 85 (12), 84 (16), 83 (38), 82 (18), 81 (48), 80 (7), 79 (15), 78 (6), 77 (12), 73 (7), 72 (5), 71 (32), 70 (44), 69 (61), 68 (15), 67 (46), 65 (6), 61 (7), 60 (9), 59 (25), 58 (14), 57 (25), 56 (16), 55 (100), 54 (12), 53 (13), 51 (5), 44 (5), 43 (58), 42 (21), 41 (82).

$C_{18}H_{29}NO_6$ (355.43) Calc. C 60.83 H 8.22 N 3.94% Found C 61.04 H 8.31 N 3.91%

*2.8. Methyl 5-nitro-2,15-dioxocyclohexadecane-1-carboxylate* (**23**). To a stirred solution of **22** (500 mg, 1.41 mmol) in THF (30 ml) at 0° was added anhydrous TBAF (757 mg, 2.9 mmol) in THF (30 ml) under Ar over 30 min. The mixture was stirred at 25° for 1 h, warmed at 50° for 5 h, then at 0°

glacial acetic acid (3 ml) in THF (3 ml) was added. After workup as in 2.4, the crude product was purified by column chromatography to give **23** as a colorless oil (436 mg, 87%). – IR. ($CHCl_3$): 1740 *S*, 1735 *S*, 1718 *S*, 1712, 1706 *S*, 1702 *S*, 1698 *S*, 1685 *S*, 1640, 1620–1560 *S* br., 1549. – $^1$H-NMR.: 17.78 (*s*, 0.75 H); 13.73 (*s*, 0.25 H); 4.80–4.23 (*m*, 1 H); 3.87 (*s*, 3 H); 3.4–0.6 (*m*, 24 H). – $^{13}$C-NMR.: 199.4, 199.24, 199.20, 199.1, 198.5, 198.3, 196.1, 195.9, 195.86, 194.5, 194.4, 186.0, 171.6, 167.3, 110.0, 109.3, 106.9, 87.65, 87.56, 87.4, 86.4, 85.1, 51.9, 39.2, 36.4, 33.5, 32.9, 32.8, 32.6, 32.3, 32.1, 31.7, 31.1, 30.5, 30.4, 30.2, 29.7, 29.3, 29.15, 29.1, 28.9, 28.6, 28.1, 28.0, 27.5, 27.3, 27.1, 26.9, 26.6, 26.3, 25.8, 25.5, 25.4, 25.1, 24.7, 24.5, 24.3, 23.8, 23.7, 23.6, 23.5, 23.0. – MS.: 355 (1, $M^+$), 307 (5), 293 (10), 277 (13), 276 (5), 275 (17), 229 (5), 228 (27), 155 (5), 151 (5), 141 (5), 139 (5), 137 (8), 135 (5), 125 (6), 123 (8), 121 (6), 111 (9), 109 (12), 107 (6), 101 (8), 98 (14), 97 (20), 96 (6), 95 (26), 93 (8), 85 (7), 84 (12), 83 (26), 82 (8), 81 (32), 79 (9), 71 (18), 70 (45), 69 (46), 68 (8), 67 (31), 61 (8), 60 (7), 59 (8), 57 (16), 56 (11), 55 (100), 54 (10), 53 (8), 43 (57), 42 (19), 41 (78).

**3. Reactions of 2-nitrocycloalkanones with benzyl 3-oxo-4-pentenoate.** – *3.1. Benzyl 3-oxo-5-(1-nitro-2-oxocycloheptyl)pentanoate* (**25**). Compound **25** was prepared according to 2.3 from **4** (1.57 g, 10.0 mmol), benzyl 3-oxo-4-pentenoate (**24**, 2.65 g, 13.0 mmol) and anhydrous TBAF (52 mg, 0.2 mmol) in THF (50 ml) for 6 h under Ar. After chromatography, compound **25** was obtained as a colorless oil (3.29 g, 91%). – IR. ($CHCl_3$): 1753 *S*, 1740, 1720, 1700 *S*, 1695 *S*, 1685 *S*, 1544, 1497, 695. – $^1$H-NMR.: 7.41 (*s*, 5 H); 5.18 (*s*, 2 H); 3.50 (*s*, 2 H); 3.0–1.0 (*m*, 14 H). – $^{13}$C-NMR.: 202.2, 200.2, 166.4, 135.1, 128.4, 128.2, 128.1, 127.9, 98.6, 67.0, 48.9, 41.1, 37.2, 34.9, 30.0, 29.4, 25.6, 24.6. – MS.: 361 (0, $M^+$), 208 (6), 207 (17), 166 (10), 165 (16), 158 (6), 156 (15), 142 (5), 138 (8), 137 (11), 125 (32), 123 (7), 119 (6), 112 (8), 111 (9), 110 (6), 109 (14), 108 (26), 107 (47), 105 (8), 99 (9), 98 (6), 97 (12), 96 (7), 95 (17), 94 (14), 93 (13), 92 (23), 91 (94), 90 (7), 89 (6), 87 (5), 85 (8), 84 (12), 83 (33), 82 (16), 81 (97), 80 (10), 79 (55), 78 (15), 77 (52), 75 (5), 74 (5), 73 (8), 71 (17), 70 (12), 69 (33), 68 (24), 67 (69), 66 (9), 65 (33), 63 (7), 62 (5), 59 (8), 58 (13), 57 (32), 56 (38), 55 (98), 54 (29), 53 (35), 52 (9), 51 (34), 50 (15), 45 (8), 44 (7), 43 (99.7), 42 (33), 41 (100).

*3.2. Benzyl 5-nitro-2,11-dioxocycloundecane-1-carboxylate* (**26**). Anhydrous TBAF (940 mg, 3.60 mmol) in THF (30 ml) was added dropwise over 30 min to a stirred solution of **25** (640 mg, 1.77 mmol) in THF (30 ml) under Ar at 25°. The resulting mixture was stirred at 50° for 7 h, then cooled and quenched with glacial acetic acid (3 ml) in THF (3 ml). Workup and purification as usual yielded **26** as colorless needles, m.p. 77.0–77.7° (EtOAc/hexane/$Et_2O$)[6]), 500 mg, 78%. – IR.: 1790–1700 *S* br., 1686 *S*, 1678, 1657 *S*, 1653, 1640 *S*, 1576, 1540, 1499, 742, 698. – $^1$H-NMR.: 13.63 (*s*, 0.67 H); 13.53 (*s*, 0.33 H); 7.43 (*s*, 5 H); 5.33 (*s*, 1.94 H); 5.23 (*s*, 0.06 H); 5.0–4.7 (*m*, 0.06 H); 4.7–4.2 (*m*, 0.94 H); 3.2–1.0 (*m*, 14 H). – $^{13}$C-NMR.: 203.5, 201.6, 184.8, 181.3, 170.7, 134.4, 129.2, 128.6, 128.2, 109.7, 109.1, 86.0, 84.7, 67.3, 44.0, 40.3, 31.2, 28.7, 28.2, 28.1, 26.2, 24.8, 24.5, 23.5, 23.3, 21.0. – MS.: 361 (0, $M^+$), 207 (7), 191 (10), 149 (7), 119 (10), 108 (6), 107 (10), 105 (10), 95 (6), 92 (25), 91 (100), 81 (7), 79 (9), 77 (8), 71 (8), 69 (8), 67 (7), 65 (15), 57 (14), 55 (18), 51 (5), 43 (13), 41 (22).

$C_{19}H_{23}NO_6$ (361.39) Calc. C 63.14 H 6.42 N 3.88% Found C 62.89 H 6.68 N 4.08%

*3.3. Benzyl 3-oxo-5-(1-nitro-2-oxocyclooctyl)pentanoate* (**27**). Compound **27** was prepared according to 2.3 from **9** (1.71 g, 10.0 mmol), **24** (2.65 g, 13 mmol) and anhydrous TBAF (52 mg, 0.2 mmol) in THF (50 ml). After chromatography, compound **27** was obtained as colorless needles, m.p. 37.5–38° ($Et_2O$/pentane at −20°), 3.11 g, 83%. – IR.: 1775 *S*, 1754 *S*, 1742, 1739, 1720, 1712, 1704 *S*, 1690 *S*, 1685, 1776 *S*, 1670 *S*, 1537, 1499, 742, 700. – $^1$H-NMR.: 7.41 (*s*, 5 H); 5.18 (*s*, 2 H); 3.50 (*s*, 2 H); 3.0–1.0 (*m*, 14 H). – $^{13}$C-NMR.: 204.5, 200.0, 166.4, 135.1,, 128.4, 128.1, 97.4, 67.0, 49.0, 38.2, 37.3, 31.9, 28.5, 27.5, 25.4, 24.2, 22.4. – MS.: 375 (0, $M^+$), 222 (7), 221 (23), 218 (9), 180 (8), 179 (18), 172 (7), 170 (8), 164 (10), 163 (5), 157 (6), 156 (46), 155 (7), 154 (5), 153 (5), 152 (8), 151 (8), 149 (9), 143 (5), 142 (12), 141 (10), 140 (6), 139 (12), 137 (9), 135 (5), 133 (8), 127 (7), 126 (14), 125 (73), 124 (6), 123 (11), 119 (9), 117 (5), 115 (11), 113 (9), 112 (7), 111 (15), 110 (11), 109 (32), 108 (99.7), 107 (99.8), 106 (7), 105 (17), 99 (15), 98 (40), 97 (35), 96 (10), 95 (26), 94 (10), 93 (14), 92 (34), 91 (100), 90 (20), 89 (15), 87 (7), 85 (15), 84 (28), 83 (36), 82 (23), 81 (32), 80 (19), 79 (99.8), 78 (38), 77 (99.8), 75 (5), 74 (7), 73 (6), 71 (32), 70 (35), 69 (45), 68 (27), 67 (44), 66 (8), 65 (47), 63 (12), 62 (5), 60 (5), 59 (11), 58 (26), 57 (36), 56 (29), 55 (99.6), 54 (18), 53 (30), 52 (14), 51 (72), 50 (26), 45 (8), 44 (7), 43 (99), 42 (39), 41 (92).

$C_{20}H_{25}NO_6$ (375.42) Calc. C 63.99 H 6.71 N 3.73% Found C 64.19 H 6.61 N 3.59%

*3.4. Benzyl 5-nitro-2,12-dioxocyclododecane-1-carboxylate* (**28**). Anhydrous TBAF (990 mg, 3.80 mmol) in THF (35 ml) was added dropwise over 30 min to a stirred solution of **27** (690 mg, 1.84 mmol) in THF (35 ml) under Ar at 25°. The mixture was stirred at 50° for 6 h, worked up and purified by the usual procedure. After chromatography, compound **28** was obtained as colorless crystals; m.p. 54.8–55.1° (EtOAc/hexane), 590 mg, 85.5%. – IR.: 1770–1712 *S* br., 1708, 1686, 1679, 1662, 1647, 1636 *S*, 1630 *S*, 1590 *S*, 1576 *S*, 1570 *S*, 1567 *S*, 1562, 1548, 1498, 698; ($CHCl_3$): 1785–1745 *S* br., 1725 *S*, 1705, 1693 *S*, 1688 *S*, 1682, 1655 *S*, 1650 *S*, 1640, 1615–1569 *S* br., 1550, 1499, 697. – $^1$H-NMR.[7]): 13.76, 13.73, 13.67 and 13.65 [4 *s* (like *d*×*d*), 1 H]; 7.36 (*s*, 5 H); 5.45, 5.31, 5.27 and 5.21 (4 *s*, 2 H); 5.01–4.53 and 4.50–4.0 (*m*, 1 H); 3.4–0.8 (*m*, 16 H). – $^{13}$C-NMR.: 202.0, 199.7, 198.6, 184.7, 179.9, 170.8, 134.4, 129.3, 129.24, 129.17, 128.8, 128.6, 128.4, 110.2, 109.8, 86.7, 83.7, 83.2, 82.7, 67.6, 67.3, 66.9, 41.5, 39.8, 39.4, 39.2, 36.8, 32.2, 31.4, 30.8, 29.4, 29.2, 28.8, 28.3, 27.7, 27.4, 27.0, 25.2, 25.1, 24.4, 23.3, 23.1, 22.9, 22.5, 22.4, 22.2. – MS.: 375 (0, $M^+$), 221 (6), 173 (6), 172 (60), 149 (10), 143 (7), 141 (5), 125 (15), 123 (11), 109 (6), 108 (16), 107 (21), 105 (6), 99 (13), 98 (9), 97 (73), 96 (5), 95 (20), 93 (8), 92 (46), 91 (85), 89 (5), 87 (6), 85 (16), 84 (11), 83 (38), 82 (7), 81 (36), 80 (6), 79 (31), 77 (16), 73 (6), 72 (8), 71 (90), 70 (90), 69 (81), 68 (10), 67 (30), 65 (26), 60 (9), 59 (6), 57 (26), 56 (26), 55 (94), 54 (12), 53 (14), 51 (9), 45 (13), 44 (11), 43 (99), 42 (60), 41 (100).

$C_{20}H_{25}NO_6$ (375.42) Calc. C 63.99 H 6.71 N 3.73% Found C 64.25 H 6.79 N 3.71%

*3.5. Benzyl 3-oxo-5-(1-nitro-2-oxocyclododecyl)pentanoate* (**29**). Compound **29** was prepared according to 2.3 from **21** (2.27 g, 10.0 mmol), **24** (2.65 g, 13 mmol) and anhydrous TBAF (52 mg, 0.2 mmol) in THF (50 ml) for 6 h. After chromatography compound **29** was afforded as colorless fine needles; m.p. 101.5–101.9° (EtOAc/hexane), 3.92 g, 91%. – IR.: 1745, 1737 *S*, 1720, 1713, 1700 *S*, 1537, 1499, 746, 701. – $^1$H-NMR.: 7.42 (*s*, 5 H); 5.17 (*s*, 2 H); 3.50 (*s*, 2 H); 3.0–0.9 (*m*, 24 H). – $^{13}$C-NMR.: 200.5, 199.7, 166.4, 135.1, 128.4, 128.3, 128.2, 99.9, 67.1, 49.1, 36.8, 32.7, 30.5, 26.7, 26.4, 26.2, 23.3, 22.6, 22.1, 21.9, 21.4, 19.2. – MS.: 431 (0, $M^+$), 383 (6), 355 (6), 295 (7), 293 (10), 279 (7), 278 (13), 277 (34), 259 (13), 252 (5), 251 (20), 249 (7), 236 (8), 235 (24), 228 (8), 224 (5), 221 (14), 218 (19), 213 (27), 210 (5), 207 (6), 199 (5), 197 (5), 196 (5), 195 (9), 194 (8), 193 (9), 192 (6), 182 (5), 181 (8), 180 (8), 179 (6), 171 (7), 169 (5), 168 (6), 167 (14), 166 (8), 165 (9), 164 (13), 163 (12), 161 (11), 157 (6), 155 (10), 154 (6), 153 (16), 152 (13), 151 (11), 150 (7), 149 (37), 147 (8), 145 (5), 143 (7), 141 (8), 140 (8), 139 (13), 138 (9), 137 (23), 136 (8), 135 (22), 134 (6), 133 (13), 132 (5), 131 (15), 129 (11), 128 (6), 127 (13), 126 (12), 125 (23), 124 (13), 123 (35), 122 (10), 121 (22), 120 (5), 119 (16), 117 (13), 115 (23), 114 (6), 113 (19), 112 (33), 111 (42), 110 (22), 109 (65), 108 (88), 107 (88), 106 (7), 105 (24), 104 (8), 103 (7), 102 (10), 101 (12), 100 (7), 99 (27), 98 (80), 97 (74), 96 (38), 95 (89), 94 (19), 93 (35), 92 (90), 91 (90), 90 (22), 89 (17), 87 (25), 86 (11), 85 (45), 84 (56), 83 (90), 82 (40), 81 (91), 80 (25), 79 (91), 78 (20), 77 (71), 76 (5), 74 (10), 73 (37), 72 (23), 71 (92), 70 (92), 69 (93), 68 (38), 67 (93), 66 (9), 65 (62), 63 (12), 62 (5), 61 (14), 60 (81), 59 (57), 58 (29), 57 (95), 56 (54), 55 (96), 54 (43), 53 (40), 52 (13), 51 (39), 50 (14), 46 (7), 45 (32), 44 (15), 43 (99), 42 (58), 41 (100).

$C_{24}H_{33}NO_6$ (431.53) Calc. C 66.80 H 7.71 N 3.25% Found C 66.97 H 7.50 N 3.06%

*3.6. Benzyl 5-nitro-2,16-dioxocyclohexadecane-1-carboxylate* (**30**). Anhydrous TBAF (653 mg, 2.50 mmol) in THF (20 ml) was added dropwise over 30 min to a stirred solution of **29** (500 mg, 1.16 mmol) in THF (20 ml) under Ar at 25°. The mixture was stirred at 50° for 5 h and then worked up and purified as usual. After chromatography compound **29** was yielded as a colorless viscous oil (400 mg, 80%). – IR. ($CHCl_3$): 1735 *S*, 1720 *S*, 1710, 1700 *S*, 1698 *S*, 1685 *S*, 1675 *S*, 1650–1560 *S* br., 1550, 1495, 695. – $^1$H-NMR.: 17.82 (*s*, 0.85 H); 13.70 and 13.67 (2 *s*, 0.15 H); 7.47 (*s*, 5 H); 5.30 (*s*, 2 H); 4.83–4.17 (*m*, 1 H); 3.4–0.8 (*m*, 24 H). – $^{13}$C-NMR.: 199.3, 198.7, 198.6, 197.9, 195.7, 194.5, 166.6, 134.9, 129.0, 128.6, 127.8, 109.4, 87.8, 86.2, 84.9, 67.3, 65.7, 39.2, 36.3, 36.0, 33.4, 32.9, 32.7, 32.4, 31.9, 30.9, 30.5, 30.4, 30.0, 29.8, 29.6, 29.59, 29.3, 29.0, 28.8, 28.5, 28.2, 28.1, 27.9, 27.5, 27.3, 26.8, 26.2, 25.8, 25.7, 25.5, 25.3, 25.1, 24.6, 24.3, 23.6, 22.4, 15.2. – MS.: 431 (2, $M^+$), 385 (6), 383 (6), 367 (7), 365 (8), 340 (6), 324 (10), 322 (8), 295 (8), 294 (8), 293 (28), 279 (6), 278 (20), 277 (91), 276 (11), 275 (22), 259 (8), 249 (10), 235 (8), 233 (8), 229 (7), 228 (28), 215 (5), 213 (5), 207 (5), 205 (6), 199 (6), 197 (6), 193 (7), 191 (7), 189 (7), 187 (6), 183 (5), 182 (14), 181 (10), 180 (5), 179 (12), 177 (9), 175 (7), 174 (10), 173 (7), 171 (5), 169 (6), 167 (18), 166 (10), 165 (18), 164 (7), 163 (15), 161 (12), 159 (7),

[7]) The number of signals in the regions around ≈13.7 and 5.3 ppm as well as their intensities and general appearance were concentration dependent.

157 (6), 155 (7), 154 (14), 153 (9), 152 (10), 151 (36), 150 (8), 149 (39), 148 (8), 147 (12), 145 (12), 143 (8), 141 (14), 140 (11), 139 (17), 138 (10), 137 (25), 136 (10), 135 (23), 134 (25), 133 (26), 132 (14), 131 (25), 129 (10), 128 (10), 127 (6), 126 (9), 125 (26), 124 (12), 123 (34), 122 (10), 121 (28), 120 (15), 119 (79), 118 (5), 117 (25), 115 (12), 113 (18), 112 (27), 111 (42), 110 (14), 109 (44), 108 (67), 107 (73), 106 (11), 105 (49), 104 (9), 103 (7), 101 (5), 100 (8), 99 (17), 98 (62), 97 (72), 96 (24), 95 (97), 94 (16), 93 (45), 92 (97), 91 (97), 90 (14), 89 (17), 88 (9), 87 (9), 86 (10), 85 (63), 84 (58), 83 (96), 82 (35), 81 (98), 80 (28), 79 (98), 78 (19), 77 (67), 76 (5), 75 (5), 74 (6), 73 (10), 72 (17), 71 (98), 70 (99), 69 (98), 68 (37), 67 (99), 66 (12), 65 (71), 64 (6), 63 (16), 62 (8), 61 (7), 60 (11), 59 (19), 58 (22), 57 (99), 56 (56), 55 (99), 53 (40), 52 (14), 51 (36), 50 (16), 49 (9), 48 (12), 47 (22), 46 (5), 45 (16), 44 (15), 43 (100), 42 (58), 41 (100).

**4. Transformation reactions.** – *4.1. 6-Nitro-cyclohexadecane-1,3-dione* (**31**). A mixture of **30** (200 mg, 0.464 mmol) in EtOH (10 ml) and $PtO_2$ (20 mg, *Fluka*, reagent grade) was stirred in the presence of glacial acetic acid (0.1 ml) under $H_2$ (1 at.) at 25° for 48 h (reaction monitored by TLC.). Filtration of the mixture and concentration of the filtrate under reduced pressure afforded a crude product. Chromatography gave **31** as a colorless oil; m.p. 37.2–37.5° ($Et_2O$/pentane at −20°), colorless crystals, 100 mg, 87%. – IR.: 1735 *S*, 1720, 1698, 1675–1618 *S* br., 1598, 1542. – $^1$H-NMR. (keto-enol mixture): 16.0–15.4 (br., *ca.* ≈0.7 H); 5.62 (*s*, 0.8 H); 4.75–4.35 (*m*, 1 H); 3.65 (*s*, 0.2 H); 2.8–0.8 (*m*, 24 H). – $^{13}$C-NMR.: 203.6, 202.0, 195.3, 191.1, 100.2, 85.9, 57.5, 42.4, 38.5, 37.4, 33.7, 30.8, 29.6, 29.1, 27.3, 27.1, 26.8, 26.6, 26.3, 26.1, 25.8, 24.9, 23.9, 23.3, 22.2. – MS.: 297 (1, $M^+$), 251 (10), 249 (6), 149 (7), 147 (5), 137 (7), 135 (9), 133 (6), 125 (8), 123 (10), 121 (11), 113 (6), 112 (6), 111 (16), 110 (7), 109 (21), 108 (6), 107 (14), 105 (5), 100 (7), 99 (7), 98 (15), 97 (30), 96 (10), 95 (41), 94 (6), 93 (16), 91 (8), 85 (23), 84 (24), 83 (33), 82 (13), 81 (47), 80 (6), 79 (14), 71 (20), 70 (15), 69 (49), 68 (12), 67 (45), 58 (7), 57 (21), 56 (12), 55 (100), 54 (11), 53 (11), 43 (73), 42 (14), 41 (88).

$C_{16}H_{27}NO_4$ (297.41) Calc. C 64.62 H 9.08 N 4.71% Found C 64.40 H 9.11 N 4.59%

*4.2. Transformation* **26**→7. A mixture of **26** (150 mg, 0.416 mmol) in EtOH (10 ml) and $PtO_2$ (20 mg, *Fluka*, reagent grade) was stirred in the presence of glacial acetic acid (0.1 ml) under $H_2$ (1 at.) at 25° for 7 h (reaction monitored by TLC.). Filtration of the mixture and concentration of the filtrate under reduced pressure afforded a crude product, which was purified as usual to yield 7 (53 mg, 56%).

*4.3. Transformation* **28**→**12**. A mixture of **28** (100 mg, 0.267 mmol) and $PtO_2$ (10 mg, *Fluka*, reagent grade) in EtOH (5 ml) was stirred in the presence of glacial acetic acid (0.05 ml) under $H_2$ (1 at.) at 25° for 7 h (monitored by TLC.). After workup and chromatography as usual compound **12** was afforded as a colorless oil (39 mg, 61%).

**5. Synthesis of reagents.** – *5.1. Synthesis of methyl 3-oxo-4-pentenoate* (**13**). We simplified the synthesis of methyl 3-oxo-5-phenylthiopentanoate (**32**) which is part of the synthesis of **13** [6]. 3-Phenylthiopropionyl chloride (43.8 g, 219 mmol), prepared from the corresponding acid by treatment with $SOCl_2$, in anhydrous $CH_2Cl_2$ (100 ml) [6] was added dropwise over 1 h to a stirred solution of *Meldrum's* acid (31.5 g, 219 mmol) [19] in anhydrous $CH_2Cl_2$ (200 ml) in the presence of anhydrous pyridine (35 g, 443 mmol) at 0° under Ar. Stirring was continued under the same conditions for 1 h more then at 25° for 1 h. The organic system was washed with cold water, cold 5% hydrochloric acid, and cold water, then dried ($MgSO_4$). Removal of the solvent at r.t. under reduced pressure afforded the crude acyl *Meldrum's* acid, which was used for the next step without further purification. The crude acyl *Meldrum's* acid was dissolved in anhydrous MeOH (300 ml) and refluxed for 2 h with the concurrent evolution of $CO_2$. The solvent was removed under reduced pressure and the crude residue was purified by column chromatography (*Merck*, Kieselgel 60, hexane) to yield **32** (45 g, 87%), identical with an authentic sample.

*5.2. Benzyl 3-oxo-5-phenylthiopentanoate* (**33**). Compound **33** was prepared according to experiment 5.1 from 3-phenylthiopropionyl chloride (43.8 g, 219 mmol) and *Meldrum's* acid (31.5 g, 219 mmol) in the presence of anhydrous pyridine (35 g, 443 mmol). The crude acyl *Meldrum's* acid was dissolved in a mixture of benzyl alcohol (47.8 g, 443 mmol) and benzene (200 ml) and refluxed for 2 h, then the solvent was removed *in vacuo*. The crude product was purified by column chromatography (*Merck, Kieselgel 60*, hexane) to afford **33** as a colorless oil. – IR. ($CHCl_3$): 1745, 1720, 1650, 1587. – $^1$H-NMR.: 7.5–7.0 (*m*, 10 H); 5.13 (*s*, 2 H); 3.43 (*s*, 2 H); 3.25–2.65 ($A_2B_2$-like *m*, 4 H). – MS.: 314 (2, $M^+$), 181 (6), 180 (23), 164 (6), 163 (7), 137 (17), 136 (7), 135 (9), 123 (19), 111 (5), 110 (45), 109 (27), 108 (22), 107 (53), 106 (5), 105 (9), 92 (9), 91 (100), 90 (7), 89 (7), 88 (5), 87 (5), 85 (6), 84 (6), 79 (29), 78 (8),

77 (29), 71 (16), 70 (7), 69 (9), 66 (13), 65 (35), 63 (8), 59 (7), 58 (13), 57 (17), 56 (5), 55 (21), 52 (5), 51 (24), 50 (11), 45 (23), 44 (9), 43 (93), 42 (7), 41 (14).

*5.3. Benzyl 3-oxo-4-pentenoate* (**24**). Compound **33** (40 g, 127.4 mmol) in MeOH (660 ml) was oxidized with sat. aq. sodium metaperiodate (45 g, 195.3 mmol) in water (300 ml) for 12 h following [6]. The crude residue was dissolved in $CHCl_3$ (300 ml) and refluxed for 12 h in the presence of hydroquinone. After removal of $CHCl_3$ at atmospheric pressure and of volatile compounds under reduced pressure (*ca.* 15 Torr, under 5°) the residual material was distilled, 110–120°, $2 \times 10^{-2}$ Torr, to a vessel containing hydroquinone at −80°. The distilled product was stored below −20° prior to use (Note: repetition of the distillation under reduced pressure leads to complete decomposition of the product). – IR. ($CHCl_3$): 1740, 1688, 1662, 1590. – $^1$H-NMR. (crude product; keto enol mixture): 11.78 (*s*); 7.37 (*s*); 6.4–5.4 (*m*); 5.20+5.17 (2 *s*); 5.12 (*s*); 3.63 (*s*). – MS.: 204 (5, $M^+$), 107 (6), 92 (8), 91 (100), 70 (9), 65 (11), 55 (8).

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