The Synthesis of Unsubstituted Cyclic Imides Using Hydroxylamine under Microwave Irradiation†

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Abstract: Unsubstituted cyclic imides were synthesized from a series of cyclic anhydrides, hydroxylamine hydrochloride (NH2OH·HCl), and 4-N,N-dimethylamino-pyridine (DMAP, base catalyst) under microwave irradiation in monomode and multimode microwaves. This novel microwave synthesis produced high yields of the unsubstituted cyclic imides for both the monomode (61 - 81%) and multimode (84 - 97%) microwaves.

Keywords: Hydroxylamine·HCl; unsubstituted cyclic imides; DMAP; microwaves.

Introduction

The unsubstituted cyclic imide is an important functionality which has been found to maintain significant biological activity [1-3]. The synthesis of unsubstituted cyclic imides either by conventional methods or microwave irradiation is often carried out under harsh conditions thereby increasing byproduct formation [4]. Currently, there are several conventional and microwave techniques to produce unsubstituted cyclic imides. Many conventional syntheses of unsubstituted
cyclic imides use the reaction of cyclic anhydrides with reactants including ammonia, urea, formamide, and lithium nitride [5-7]. Other conventional reactions catalyze the cyclization of acid-amide functionalities forming unsubstituted cyclic imides. These catalysts include carbonyldiimidazole (CDI), DMAP, and AlCl₃ [8, 9]. Additional microwave syntheses use the reaction of cyclic anhydrides with urea or thiourea, formamide, benzonitrile, cyanate, thiocyanate, DMAP/ammonium chloride, and ammonium acetate [10-15].

The application of microwave technology in many conventional syntheses offers many advantages including increased product yields and decreased reaction times [16-19]. We wish to report the synthesis of a series of unsubstituted cyclic imides using cyclic anhydrides, NH₂OH·HCl, and DMAP via a novel microwave technique. This novel microwave synthesis produced unsubstituted cyclic imides in good yields within minutes.

Results and Discussion

Microwave Synthesis

The novel syntheses were conducted under microwave irradiation using hydroxylamine hydrochloride, DMAP, and an array of cyclic anhydrides yielding the corresponding unsubstituted cyclic imide. (Scheme 1) [20]. Although modifications of several experimental parameters gave moderate yields of the N-hydroxy cyclic imides (~30 percent), repeated studies found that the unsubstituted cyclic imides were the major products. Increased N-hydroxy cyclic imides yields were identified at lower temperatures and shorter reaction times. These results contradict Sugamoto et al., who reported that N-hydroxy cyclic imides were synthesized in high yield under similar conditions [20]. The current data supports research done by Consonni et al., which found that cyclic N-hydroximides are converted to unsubstituted cyclic imides under basic conditions [21]. Application of this novel microwave technique can be used to synthesize many biologically important molecules including that of streptimidone, a glutarimide antibiotic [22].

**Scheme 1. The Synthesis of Unsubstituted Cyclic Imides**

Whereas this novel microwave synthesis produced high yields of the unsubstituted cyclic imides, no definite mechanism has been identified. One possible mechanism for unsubstituted cyclic imide formation is the breakdown of hydroxylamine·HCl into ammonia and water (Scheme 2). Ammonia production then promotes unsubstituted cyclic imide formation. A second possibility is the conversion of cyclic N-hydroximide to the unsubstituted cyclic imide. Unsubstituted cyclic imides formation appears to be enhanced by the addition of a base catalyst and additional heating.
Scheme 2. Possible Mechanisms for the Hydroxylamine and Cyclic Anhydride Synthesis

Monomode Microwave Synthesis

The monomode microwave synthesis furnished unsubstituted cyclic imides using hydroxylamine as a source for nitrogen, DMAP, and cyclic anhydrides for the cyclic carbon backbone. The microwave synthesis was done at 150 °C over 5 minutes with a maximum energy output of 300W, producing between 61 and 81 isolated percent yields.

| Entry | Imides | Time (min) | Temp (°C) | Yield (%) |
|-------|--------|------------|-----------|-----------|
| 1     | ![Imide 1](image1.png) | 5          | 150       | 70        |
| 2     | ![Imide 2](image2.png) | 5          | 150       | 71        |
| 3     | ![Imide 3](image3.png) | 5          | 150       | 61        |
| 4     | ![Imide 4](image4.png) | 5          | 150       | 61        |
| 5     | ![Imide 5](image5.png) | 5          | 150       | 61        |
| 6     | ![Imide 6](image6.png) | 5          | 150       | 81        |
Multimode Microwave Synthesis

A series of multimode microwave reactions were used to identify a cost effective alternative to the more expensive monomode synthesis. This technique used similar reaction conditions and anhydrides to that of the monomode microwave syntheses. The reaction times ranged from 1 to 3 minutes at full power until the material melted and started to vigorously bubble. Isolated percent yields were between 84 and 97 percent.

Table 2. Multimode Synthesis of Unsubstituted Imides Using NH₂OH and DMAP.

| Entry | Imides | Time (min) | Yield (%) |
|-------|--------|------------|-----------|
| 1     | ![Imide 1](image1.png) | 2.68       | 97        |
| 2     | ![Imide 2](image2.png) | 1.82       | 96        |
| 3     | ![Imide 3](image3.png) | 1.20       | 96        |
| 4     | ![Imide 4](image4.png) | 1.57       | 84        |

Unsubstituted cyclic imides were produced in good yields in both the multimode and monomode microwaves. Slightly higher isolated yields were found in the multimode reactions compared to the monomode result. This variation may stem from energy output differences for the multimode (1100 W) and the monomode (300 W) microwaves.

Crystals isolated from this and previous unsubstituted cyclic imide syntheses were analyzed by single crystal X-ray diffraction generating good structural data for the desired cyclic imide products [23]. Specifically, the unsubstituted cyclic imide 3a,4,5,6,7,7a-hexahydro-1H-isoidole-1,3(2H)-dione (4, Figure 1) was characterized by X-ray diffraction studies [24]. The crystal structure of this compound has previously been reported by Wang and co-workers [25]. Our unpublished crystal data found an unsubstituted cyclic imide bound in the cis position of a well defined cyclohexane ring (R factor = 0.0393).
**Experimental**

**General**

The monomode microwave reactions were carried out in a CEM Discover Microwave. Multimode microwave reactions were done in a Kennmore Microwave Oven (Household) Output: 1100 Watts (Frequency: 2450 MHz). All Gas Chromatograph Mass Spectrometry (GC-MS) was performed using a Shimadzu GC-17A and GCMS-QP5050A Labsolutions system. All reagents were purchased from Aldrich Chemical Company and were used without further purification. Since two different methods are described in this article, Method 1 will refer to synthesis carried out under monomode conditions, while, Method 2 will refer to synthesis under multimode conditions. Only the GCMS data is given, however unsubstituted cyclic imides data matched that reported earlier [15].

Phthalimide (1): Method 1. Phthalic anhydride (0.20 g, 1.35 mmol), NH₂OH·HCl (0.09 g, 1.30 mmol), and DMAP (0.04 g, 0.33 mmol) were thoroughly mixed in a CEM vial with a stirrer. This was capped and heated in a CEM Discover microwave for 5 minutes at 150 °C. This was rapidly cooled to room temperature yielding a dark brown solid. The reaction mixture was dissolved in AcOEt (4 mL) and washed with distilled water (2 x 2 mL). The organic layer was concentrated to obtain a white solid (0.14 g, 70%); MS m/z 147 (M⁺) 104, 76, 50.

Phthalimide (1): Method 2. Phthalic anhydride (1.0 g, 6.75 mmol), NH₂OH·HCl (0.54 g, 7.7 mmol), and DMAP (0.08 g, 0.65 mmol) were mixed in an 8 mL Teflon capped vial. The mixture was allowed to heat for 4 minutes and 11 seconds at 30 percent power in the multimode microwave and then cooled to room temperature. The sample was dissolved in acetone and flash chromatographed using silica (~30 g) with pure acetone as the mobile phase to obtain a yellow solid. Yield: 0.96 g (97%); MS m/z 147 (M⁺) 104, 76, 50.

Succinimide (2): Method 1. Succinic anhydride (0.20 g, 2.00 mmol), NH₂OH·HCl (0.14 g, 2.0 mmol), and DMAP (0.04 g, 0.33 mmol) were thoroughly mixed in a CEM vial with a stirrer. This was capped
and heated in a CEM Discover microwave for 5 minutes at 150 °C. This was rapidly cooled to room temperature yielding a dark brown solid. The reaction mixture was dissolved in AcOEt (4 mL) and was washed with distilled water (2 x 2 mL). The organic layer was concentrated to obtain a white solid (0.14 g, 71%); MS m/z 99 (M+) 56.

**Succinimide (2): Method 2.** Succinic anhydride (1.0 g, 10 mmol), NH\(_2\)OH·HCl (0.80 g, 11 mmol), and DMAP (0.12 g, 0.98 mmol) were mixed in an 8 mL Teflon capped vial. The mixture was allowed to heat for 1 minute 49 seconds at full power in the multimode microwave and then cooled to room temperature. The sample was dissolved in acetone and flash chromatographed using silica (~30 g) with pure acetone as the mobile phase to obtain a yellow solid (0.95 g, 96%); MS m/z 99 (M+) 56.

cis-1,2-Cyclobutanedicarboximide (3): Method 1. cis-1,2-Cyclobutanedicarboxylic acid anhydride (0.20 g, 1.59 mmol), NH\(_2\)OH·HCl (0.11 g, 1.58 mmol), and DMAP (0.04 g, 0.33 mmol) were thoroughly mixed in a CEM vial with a stirrer. This was capped and heated in a CEM Discover microwave for 5 minutes at 150 °C. This was rapidly cooled to room temperature yielding a white solid. The reaction mixture was dissolved in AcOEt (4 mL) and was washed with distilled water (2 x 2 mL). The organic layer was concentrated to obtain a white solid (0.12 g, 61%); MS m/z 125 (M+) 82, 54.

cis-1,2-Cyclobutanedicarboximide (3): Method 2. cis-1,2-Cyclobutanedicarboxylic acid anhydride (1.0 g, 7.9 mmol), NH\(_2\)OH·HCl (0.63 g, 9.1 mmol), and DMAP (0.10 g, 0.82 mmol) were mixed in an 8 mL Teflon capped vial. The mixture was allowed to heat for 1 minute 12 seconds at full power in the multimode microwave and then cooled to room temperature. The sample was dissolved in acetone and flash chromatographed using silica (~30 g) with pure acetone as the mobile phase to obtain a light brown solid, (0.95 g, 96%); MS m/z 125 (M+) 82, 54.

3a,4,5,6,7,7a-Hexahydro-1H-isoinole-1,3(2H)-dione (4): Method 1. cis-1,2-Cyclohexanedicarboxylic acid anhydride (0.20 g, 1.30 mmol), NH\(_2\)OH·HCl (0.09 g, 1.29 mmol), and DMAP (0.04 g, 0.33 mmol) were thoroughly mixed in a CEM vial with a stirrer. This was capped and heated in a CEM Discover microwave for 5 minutes at 150 °C. This was rapidly cooled to room temperature yielding a white solid. The reaction mixture was dissolved in AcOEt (4 mL) and was washed with distilled water (2 x 2 mL). The organic layer was concentrated to obtain a white solid (0.12 g, 61%); MS m/z 153 (M+) 125, 99, 82, 67, 54, 41.

3a,4,5,6,7,7a-Hexahydro-1H-isoinole-1,3(2H)-dione (4): Method 2. cis-1,2-Cyclohexanedicarboxylic acid anhydride (1.0 g, 6.5 mmol), NH\(_2\)OH·HCl (0.51 g, 7.3 mmol), and DMAP (0.08 g, 0.65 mmol) were mixed in an 8 mL Teflon capped vial. The mixture was allowed to heat for 1 minute 49 seconds at full power in the multimode microwave and then cooled to room temperature. The sample was dissolved in acetone and flash chromatographed using silica (~30 g) with pure acetone as the mobile phase to obtain a white solid (0.83 g, 84%); MS m/z 153 (M+) 125, 99, 82, 67, 54, 41.
Glutarimide (5): Method 1. Glutaric anhydride (0.20 g, 1.75 mmol), NH₂OH·HCl (0.12 g, 1.73 mmol), and DMAP (0.04 g, 0.33 mmol) were thoroughly mixed in a CEM vial with a stirrer. This was capped and heated in a CEM Discover microwave for 5 minutes at 150 °C. This was rapidly cooled to room temperature yielding a dark brown solid. The reaction mixture was dissolved in AcOEt (4 mL) and was washed with distilled water (2 x 2 mL). The organic layer was concentrated to obtain a light brown solid (0.12 g, 61%); MS m/z 113 (M⁺) 70, 42.

3a,4,7,7a-Tetrahydro-4,7-ethano-1H-isooindole-1,3(2H)-dione (6): Method 1. cis-Bicyclo[2.2.2]oct-5-ene-2,3-dicarboxylic acid anhydride (0.10 g, 0.56 mmol), NH₂OH·HCl (0.05 g, 0.72 mmol) and DMAP (0.02 g, 0.16 mmol) were mixed thoroughly in a CEM-sealed vial with a magnetic stirrer. The mixture was heated for 5 min at 150 °C in a CEM Discover microwave powered at 150 W. The sample was then cooled rapidly to 40 °C. The reaction mixture was dissolved in AcOEt (4 mL) and was washed with distilled water (2 x 2 mL). The organic layer was concentrated to obtain a light brown solid (0.08 g, 81%); MS m/z 177 (M⁺) 149, 99, 78, 51.

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*Sample Availability*: Samples of the compounds are commercially available.

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Supporting Data

Table 1. Crystal Data for 3a,4,5,6,7,7a-Hexahydro-1H-isoindole-1,3(2H)-dione.

| Characteristic                        | Value                                      |
|---------------------------------------|--------------------------------------------|
| Identification code                   | 3a,4,5,6,7,7a-Hexahydro-1H-isoindole-1,3(2H)-dione |
| Empirical formula                     | C₈H₁₁NO₂                                    |
| Formula weight                        | 153.18                                     |
| Temperature                           | 203(2) K                                   |
| Wavelength                            | 0.71073 Å                                  |
| Crystal system                        | Orthorhombic                               |
| Space group                           | P₂₁/2₁/2₁                                  |
| Unit cell dimensions                  | a = 6.7185(4) Å, b = 7.8339(4) Å, c = 14.2861(10) Å |
| Volume                                | 751.91(8) Å                                |
| Z                                      | 4                                          |
| Density (calculated)                  | 1.353 Mg/m³                                 |
| Absorption coefficient                | 0.098 mm⁻¹                                  |
| F(000)                                | 328                                        |
| Crystal size                          | 0.65 x 0.55 x 0.35 mm³                      |
| Theta range for data collection       | 4.91 to 32.46°                             |
| Index ranges                          | -4=<h=<9, -9=<k=<11, -20=<l=<18            |
| Reflections collected                 | 5210                                       |
| Independent reflections               | 2427 [R(int) = 0.0317]                      |
| Completeness to theta = 25.00°        | 99.1 %                                     |
| Absorption correction                 | Semi-empirical from equivalents            |
| Max. and min. transmission            | 1.00000 and 0.90324                        |
| Refinement method                     | Full-matrix least-squares on F₂            |
| Data / restraints / parameters         | 2427 / 0 / 100                             |
| Goodness-of-fit on F2                 | 0.873                                       |
| Final R indices [I>2sigma(I)]         | R₁ = 0.0393, wR₂ = 0.0772                  |
| R indices (all data)                  | R₁ = 0.0674, wR₂ = 0.0821                  |
| Absolute structure parameter          | -1.2(9)                                    |
| Largest diff. peak and hole           | 0.248 and -0.202 e.Å⁻³                    |
Table 2. Atomic coordinates (x 10^4) and equivalent isotropic displacement parameters (Å^2 x 10^3) for 3a,4,5,6,7,7a-Hexahydro-1H-isoindole-1,3(2H)-dione. U(eq) is defined as one third of the trace of the orthogonalized U^ij tensor.

| Atoms | x        | y        | z        | U(eq)     |
|-------|----------|----------|----------|-----------|
| O(1)  | 14804(1) | 4204(1)  | 1252(1)  | 36(1)     |
| O(2)  | 9681(1)  | 1315(1)  | 2592(1)  | 36(1)     |
| N     | 12075(1) | 3090(1)  | 2005(1)  | 28(1)     |
| C(1)  | 13916(1) | 2996(1)  | 1573(1)  | 27(1)     |
| C(2)  | 14594(1) | 1165(1)  | 1644(1)  | 27(1)     |
| C(3)  | 15963(1) | 537(1)   | 866(1)   | 34(1)     |
| C(4)  | 14865(1) | 35(1)    | -21(1)   | 34(1)     |
| C(5)  | 13199(1) | -1214(1) | 201(1)   | 33(1)     |
| C(6)  | 11673(1) | -391(1)  | 850(1)   | 28(1)     |
| C(7)  | 12617(1) | 196(1)   | 1778(1)  | 27(1)     |
| C(8)  | 11271(1) | 1519(1)  | 2197(1)  | 27(1)     |

Table 3. Bond lengths [Å] for 3a,4,5,6,7,7a-Hexahydro-1H-isoindole-1,3(2H)-dione.

| Bonds          | Lengths |
|----------------|---------|
| O(1)-C(1)      | 1.2089(7)|
| O(2)-C(8)      | 1.2185(9)|
| N-C(8)         | 1.3718(8)|
| N-C(1)         | 1.3840(9)|
| N-H(0A)        | 0.8700   |
| C(1)-C(2)      | 1.5091(8)|
| C(2)-C(3)      | 1.5241(10)|
| C(2)-C(7)      | 1.5419(9)|
| C(2)-H(2A)     | 0.9900   |
| C(3)-C(4)      | 1.5179(10)|
| C(3)-H(3A)     | 0.9800   |
| C(3)-H(3B)     | 0.9800   |
| C(4)-C(5)      | 1.5208(10)|
| C(4)-H(4A)     | 0.9800   |
| C(4)-H(4B)     | 0.9800   |
| C(5)-C(6)      | 1.5246(10)|
| C(5)-H(5A)     | 0.9800   |
| C(5)-H(5B)     | 0.9800   |
| C(6)-C(7)      | 1.5401(10)|
| C(6)-H(6A)     | 0.9800   |
| C(6)-H(6B)     | 0.9800   |
| C(7)-C(8)      | 1.5000(10)|
| C(7)-H(7A)     | 0.9900   |
Table 4. Bond Angles [°] for 3a,4,5,6,7,7a-Hexahydro-1H isoindole-1,3(2H)-dione.

| Atoms                      | Angles     |
|----------------------------|------------|
| C(8)-N-C(1)                | 113.19(5)  |
| C(8)-N-H(0A)               | 123.4      |
| C(1)-N-H(0A)               | 123.4      |
| O(1)-C(1)-N                | 124.68(6)  |
| O(1)-C(1)-C(2)             | 128.35(6)  |
| N-C(1)-C(2)                | 106.88(5)  |
| C(1)-C(2)-C(3)             | 116.13(5)  |
| C(1)-C(2)-C(7)             | 102.49(5)  |
| C(3)-C(2)-C(7)             | 116.87(5)  |
| C(1)-C(2)-H(2A)            | 106.9      |
| C(3)-C(2)-H(2A)            | 106.9      |
| C(7)-C(2)-H(2A)            | 106.9      |
| C(4)-C(3)-C(2)             | 113.50(6)  |
| C(4)-C(3)-H(3A)            | 108.9      |
| C(2)-C(3)-H(3A)            | 108.9      |
| C(4)-C(3)-H(3B)            | 108.9      |
| C(2)-C(3)-H(3B)            | 108.9      |
| H(3A)-C(3)-H(3B)           | 107.7      |
| C(3)-C(4)-C(5)             | 110.48(6)  |
| C(3)-C(4)-H(4A)            | 109.6      |
| C(5)-C(4)-H(4A)            | 109.6      |
| C(3)-C(4)-H(4B)            | 109.6      |
| C(5)-C(4)-H(4B)            | 109.6      |
| H(4A)-C(4)-H(4B)           | 108.1      |
| C(4)-C(5)-C(6)             | 110.47(6)  |
| C(4)-C(5)-H(5A)            | 109.6      |
| C(6)-C(5)-H(5A)            | 109.6      |
| C(4)-C(5)-H(5B)            | 109.6      |
| C(6)-C(5)-H(5B)            | 109.6      |
| H(5A)-C(5)-H(5B)           | 108.1      |
| C(5)-C(6)-C(7)             | 111.88(6)  |
| C(5)-C(6)-H(6A)            | 109.2      |
| C(7)-C(6)-H(6A)            | 109.2      |
| C(5)-C(6)-H(6B)            | 109.2      |
| C(7)-C(6)-H(6B)            | 109.2      |
| H(6A)-C(6)-H(6B)           | 107.9      |
| C(8)-C(7)-C(6)             | 107.52(6)  |
| C(8)-C(7)-C(2)             | 103.25(5)  |
| C(6)-C(7)-C(2)             | 113.23(6)  |
| C(8)-C(7)-H(7A)            | 110.8      |
| C(6)-C(7)-H(7A)            | 110.8      |
| C(2)-C(7)-H(7A)            | 110.8      |
| O(2)-C(8)-N                | 123.75(6)  |
| O(2)-C(8)-C(7)             | 128.51(6)  |
| N-C(8)-C(7)                | 107.61(6)  |
Symmetry transformations used to generate equivalent atoms:

Table 5. Anisotropic displacement parameters (Å² x 10³) for eb1a. The anisotropic displacement factor exponent takes the form: 

\[-2\pi^2 \left( h^2 a^{*2} U^{11} + \ldots + 2hk a^* b^* U^{12} \right)\]

| Atom | U₁₁  | U₂₂  | U₃₃  | U₁₂  | U₁₃  | U₂₃  |
|------|------|------|------|------|------|------|
| O(1) | 42(1)| 28(1)| 39(1)| 1(1) | 7(1) | -8(1)|
| O(2) | 38(1)| 28(1)| 42(1)|-1(1) |14(1)| -4(1)|
| N    | 32(1)| 20(1)| 33(1)|-1(1) | 4(1) | -1(1)|
| C(1) | 31(1)| 26(1)| 23(1)| 0(1) |-4(1)| -5(1)|
| C(2) | 25(1)| 24(1)| 31(1)| 2(1) |-5(1)| -3(1)|
| C(3) | 25(1)| 29(1)| 47(1)| 0(1) | 5(1)|  4(1)|
| C(4) | 37(1)| 30(1)| 34(1)|-2(1)|  9(1)|  1(1)|
| C(5) | 36(1)| 29(1)| 34(1)|-6(1)|  2(1)|  2(1)|
| C(6) | 27(1)| 23(1)| 35(1)|-6(1)|-4(1)|  1(1)|
| C(7) | 29(1)| 23(1)| 28(1)| 4(1)|  1(1)|  0(1)|
| C(8) | 31(1)| 27(1)| 23(1)| 1(1)|-1(1)| -2(1)|

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Table 6. Hydrogen coordinates ( x10⁴) and isotropic displacement parameters (Å² x 10³) for 3a,4,5,6,7,7a-Hexahydro-1H-isoindole-1,3(2H)-dione.

| Atom | x     | y     | z     | U(eq) |
|------|-------|-------|-------|-------|
| H(0A)| 11488 | 4048  | 2141  | 34    |
| H(2A)| 15344 | 1059  | 2237  | 32    |
| H(3A)| 16922 | 1439  | 716   | 40    |
| H(3B)| 16715 | 452   | 1094  | 40    |
| H(4A)| 15798 | 491   | -462  | 40    |
| H(4B)| 14308 | 1057  | -317  | 40    |
| H(5A)| 13755 | 2233  | 502   | 40    |
| H(5B)| 12546 | 1569  | -380  | 40    |
| H(6A)| 10610 | 1213  | 983   | 34    |
| H(6B)| 11075 | 595   | 535   | 34    |
| H(7A)| 12791 | 780   | 2211  | 32    |
Table 7. Torsion angles [°] for 3a,4,5,6,7,7a-Hexahydro-1H-isoindole-1,3(2H)-dione.

| Torsional Atoms                  | Atoms       |
|----------------------------------|-------------|
| C(8)-N-C(1)-O(1)                 | 171.80(6)   |
| C(8)-N-C(1)-C(2)                 | -11.56(7)   |
| O(1)-C(1)-C(2)-C(3)              | -32.24(10)  |
| N-C(1)-C(2)-C(3)                 | 151.28(6)   |
| O(1)-C(1)-C(2)-C(7)              | -160.86(7)  |
| N-C(1)-C(2)-C(7)                 | 22.66(7)    |
| C(1)-C(2)-C(3)-C(4)              | -80.77(7)   |
| C(7)-C(2)-C(3)-C(4)              | 40.46(8)    |
| C(2)-C(3)-C(4)-C(5)              | -52.03(7)   |
| C(3)-C(4)-C(5)-C(6)              | 61.99(7)    |
| C(4)-C(5)-C(6)-C(7)              | -59.17(7)   |
| C(5)-C(6)-C(7)-C(8)              | 159.28(5)   |
| C(5)-C(6)-C(7)-C(2)              | 45.88(7)    |
| C(1)-C(2)-C(7)-C(8)              | -24.88(6)   |
| C(3)-C(2)-C(7)-C(8)              | -153.05(6)  |
| C(1)-C(2)-C(7)-C(6)              | 91.07(6)    |
| C(3)-C(2)-C(7)-C(6)              | -37.09(8)   |
| C(1)-N-C(8)-O(2)                 | 178.41(6)   |
| C(1)-N-C(8)-C(7)                 | -5.39(7)    |
| C(6)-C(7)-C(8)-O(2)              | 75.38(9)    |
| C(2)-C(7)-C(8)-O(2)              | -164.68(7)  |
| C(6)-C(7)-C(8)-N                 | -100.59(6)  |
| C(2)-C(7)-C(8)-N                 | 19.36(7)    |

Symmetry transformations used to generate equivalent atoms:

Table 8. Hydrogen bonds for 3a,4,5,6,7,7a-Hexahydro-1H-isoindole-1,3(2H)-dione [Å and °].

| D-H...A       | d(D-H) | d(H...A) | d(D...A) | <(DHA) |
|---------------|--------|---------|---------|--------|
| N-H(0A)...O(2)#1 | 0.87   | 1.98    | 2.8472(7)| 175.8  |

Symmetry transformations used to generate equivalent atoms:

#1 -x+2,y+1/2,-z+1/2