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Reaction of α,β-unsaturated ketones with tetracyanoethylene

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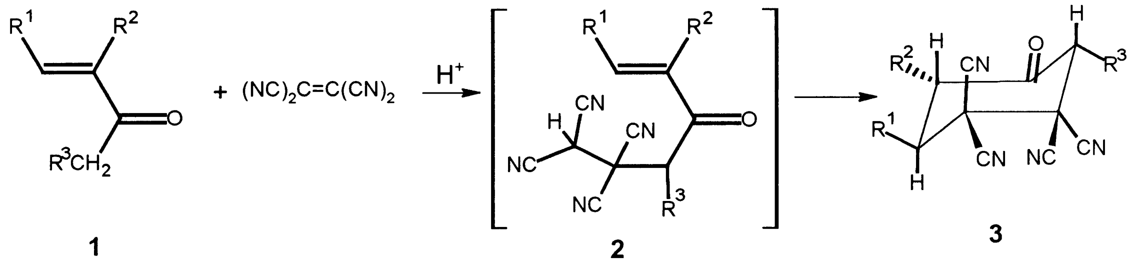
Abstract—Reaction of tetracyanoethylene with α,β-unsaturated ketones was investigated. 3-R^1-4-R^2-6-R^3-5-oxo-1,1,2,2-cyclohexanetetracarbonitriles, unsaturated tetracyanoalkanones, 3-R-5,5-dihydroxy-1,1,2,2-cyclohexanetetracarbonitriles, 1,2,2-tricyano-3-R-5-oxo-1-cyclohexanecarboxamides, 3-R^1-4-R^2-8-R^3-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitriles were synthesized. © 2001 Elsevier Science Ltd. All rights reserved.

The synthesis of six-membered carbocyclic derivatives with three or four cyano groups was of interest in 1966 to the American Cyanamid Company, who were able to obtain a new class of photochromic compounds, the (1:1) adducts of tetracyanoethylene (TCNE) and 3-benzoyl-2-benzylchromone.[1] In order to synthesize new biologically active compounds, several substituted tetracyanocyclohexanes were prepared by interaction of TCNE with some derivatives of arylidenepyrazolones[2] and oxoindolin-3-ylidenes.[3] In the majority of cases, tetracyano-substituted

Table 1.

Compound	R^1	R^2	R^3	Time (h)	Yield (%)	Mp (°C)
3a	CH_3	C_3H_7	H	8	57	103–104
3b	C_3H_7	C_3H_7	H	8	64	107–108
3c	Ph	C_3H_7	H	6	82	130–131
3d	4-$CH_3OC_6H_4$	C_3H_7	H	6	79	118–119
3e	4-$CH_3OC_6H_4$	CH_3	CH_3	6	73	155–156
3f	4-$CH_3OC_6H_4$	H	*i*-C_3H_7	6	89	117–118
3g	2-Furyl	H	H	3	68	144–145
3h	*i*-C_3H_7	H	H	12	68	141–142
3i	C_4H_9	H	H	12	63	160–161
3j	Ph	H	H	6	48	158–159
3k	Ph	H	CH_3	6	77	165–166
3l	4-$CH_3OC_6H_4$	H	CH_3	3	61	168–169



Scheme 1.

Keywords: addition reactions; bicyclic heterocyclic compounds; cyano compounds; cyclohexanones; ketones.

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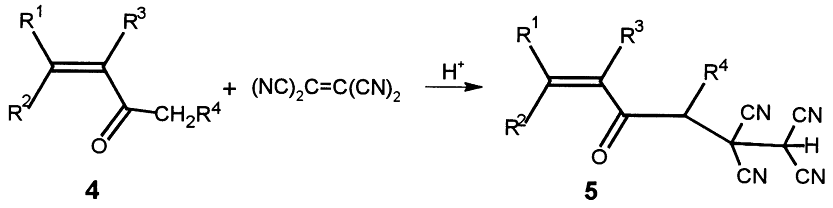
Table 2.

Compound	R^1	R^2	R^3	R^4	Time (min)	Yield (%)	Mp (°C)
5a	CH_3	CH_3	H	H	10	81	105–106
5b	2-Furyl	H	$(CH_2)_3$		5	89	120–121
5c	2-Furyl	H	$(CH_2)_2$		5	97	111–112
5d	Ph	H	$(CH_2)_3$		10	94	142–143
5e	$4\text{-}CH_3OC_6H_4$	H	$(CH_2)_3$		10	84	145–146



Scheme 2.

six-membered carbocycles were obtained by [4+2] cycloaddition reactions.[4,5]

In our laboratory, tetracyanocyclohexanes were first synthesized by reaction of 1,1,3,3-tetracyanopropanes with dialkylhydrazones of α,β-unsaturated aldehydes.[6]

As we observed before, the adducts of TCNE to alkanones—β,β,γ,γ-tetracyanoalkanones—exhibit high reactivity, have unusual properties and give complex heterocyclic products in a one pot-synthetic process[7–11] with reagents such as HCl, HBr, $CH_3COCOOH$, H_2O_2, $NaBH_4$, and NH_3. This is one reason why we consider investigations in the area of adducts of TCNE and α,β-unsaturated ketones to be of interest.

Scheme 1 shows how 3-R^1-4-R^2-6-R^3-5-oxo-1,1,2,2-cyclohexanetetracarbonitriles (**3a–l**) were synthesized from ketones (**1a–l**) and TCNE. The reaction was performed in dioxane with yields of 48–89% (Table 1, Scheme 1).

As in the case of reaction of TCNE with alkanones,[12] the reaction starts with the formation of the tetracyanoethylated ketones **2**, resulting from addition of the α-carbon atom bearing the R^3 group to TCNE. The next stage of the reaction is intermolecular Michael-type addition of the $CH(CN)_2$ fragment to the α,β-unsaturated double bond, which leads to cyclization and formation of cyclohexanones **3**.

The preparation conditions for cyclohexanones **3a–f** and **3g–l** are different. Compounds **3a–f** are synthesized by the mixing of the initial reagents in dioxane in the presence of 7–8 drops of concentrated HCl. Cyclohexanones **3g–l** were obtained only in anhydrous solvents in the presence of 1–2 drops of concentrated HCl. In anhydrous acetonitrile or dioxane, the reaction proceeds in 6–12 h with 48–89% yields. In the case of aqueous solvents, the products were 3-R^1-4-R^2-8-R^3-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitriles (**8g–l**). This can be explained by the higher reactivity of compounds **3g–l** as their carbonyl group is not sterically hindered.

The sequence of reactions shown in Scheme 1 is verified by the reaction of TCNE with ketones **4**. If the ketones double bond is sterically hindered for cyclization, the reaction with TCNE, as in the case of saturated ketones[12], results in the formation of unsaturated tetracyanoalkanones (**5**) (Table 2, Scheme 2).

The reaction goes rapidly (5–10 min) after mixing of the

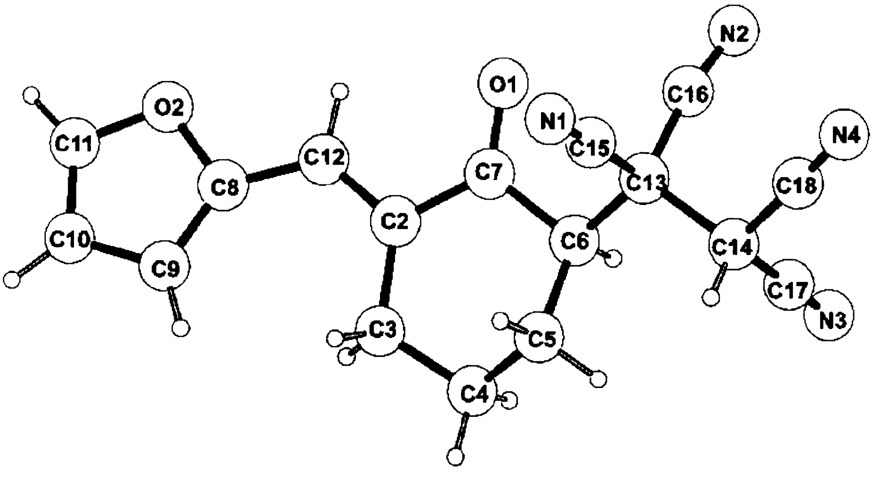
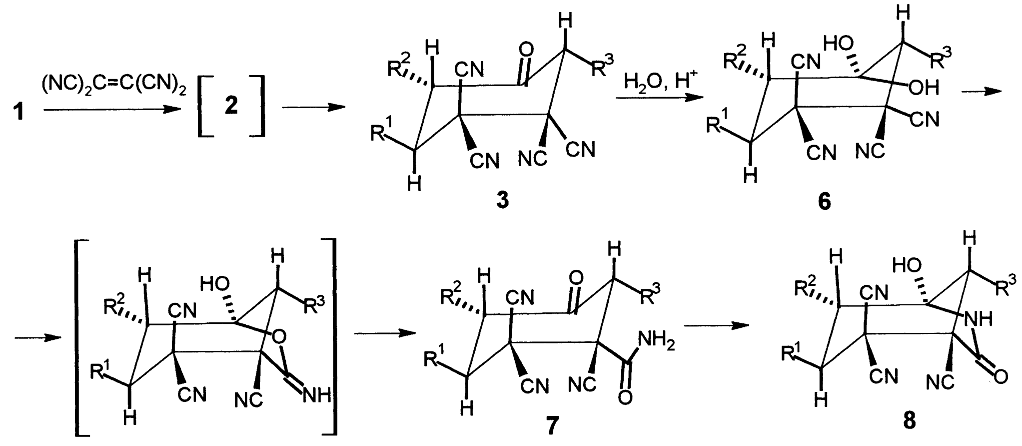


Figure 1. Molecular structure of **5b**.

Table 3.

Compound	R^1	R^2	R^3	Time	Yield (%)	Mp (°C)
6g	2-Furyl	H	H	2 h	67	165–166
6h	i-C_3H_7	H	H	12 h	41	133–134
7g	2-Furyl	H	H	5 min	95	170–171(decomp.)
7h	i-C_3H_7	H	H	10 min	92	180–181(decomp.)
8a	CH_3	C_3H_7	H	5 min[a]	90[a]	114–115
8b	C_3H_7	C_3H_7	H	7 min[a]	89[a]	110–111
8c	Ph	C_3H_7	H	10 min[a]	98[a]	211–212(decomp.)
8d	4-$CH_3OC_6H_4$	C_3H_7	H	5 min[a]	97[a]	185–186(decomp.)
8e	4-$CH_3OC_6H_4$	CH_3	CH_3	5 min[a]	98[a]	176–178(decomp.)
8f	4-$CH_3OC_6H_4$	H	i-C_3H_7	5 min[a]	80[a]	187–188(decomp.)
8g	2-Furyl	H	H	3 h; 5 min[a]	94[a]	206–207(decomp.)
8h	i-C_3H_7	H	H	12 h; 5 min[a]	69, 81[a]	175–176
8i	C_4H_9	H	H	12 h; 10 min[a]	72, 79[a]	173–174
8j	Ph	H	H	8 h; 5 min[a]	82, 92[a]	210–211(decomp.)
8k	Ph	H	CH_3	3 h; 10 min[a]	74, 95[a]	224–225(decomp.)
8l	4-$CH_3OC_6H_4$	H	CH_3	10 min; 5 min[a]	69, 96[a]	226–227(decomp.)
8m	CH_3	H	H	12 h	73	181–182
8n	C_2H_5	H	H	12 h	81	185–186
8o	C_3H_7	H	H	12 h	78	184–185
8p	C_5H_{11}	H	H	12 h	78	185–186
8q	4-$CH_3OC_6H_4$	H	H	6 h	64	207–208(decomp.)
8r	$(CH_2)_4$		H	12 h	52	215–216(decomp.)
8s	Ph	CH_3	H	4 h	83	223–224(decomp.)
8t	Ph	Br	H	3–4 days	75	246–247
8u	4-$CH_3OC_6H_4$	CH_3	H	1 h	79	228–229(decomp.)

[a] When prepared from **3**.



Scheme 3.

initial compounds in dioxane with 7–8 drops of concentrated HCl. The yields are high (81–97%). The structures of **5a–e** were established by IR, ^{1}H NMR and mass-spectroscopy and were confirmed by X-ray diffraction analysis of compound **5b** (Fig. 1). Michael-type cyclization of compounds **5b–e** is impossible due to the rigid fixation of the α-carbon atoms to the carbonyl group. Compound **5a** does not give a cyclohexanone because of high steric hindrance at the β-carbon atom of the double bond. This carbon atom is surrounded by two methyl groups in ketones **4a** and **5a**, while in ketones **1** and **2**, which give cyclohexanones **3**, the β-carbon atom is surrounded by only one (aryl or alkyl) group.

The reaction of TCNE with ketones **1g–u** in aqueous dioxane with several drops of concentrated HCl gives 3-R^1-4-R^2-8-R^3-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitriles (**8g–u**) with 42–83% yields (Table 3, Scheme 3).

This multistage process is rather complex. We assume ketone **1** adds one molecule of TCNE and immediately transforms into cyclic structure **3**. Attack by water on the carbonyl group converts it into hydrate **6**, which undergoes intramolecular cyclization to a 3-R^1-4-R^2-8-R^3-5-hydroxy-7-imino-6-oxabicyclo[3.2.1]octane-1,2,2-tricarbonitrile. The latter is recyclized into **8** through carboxamide **7**.

The structures of **8a–u** were established by IR, ^{1}H NMR and mass-spectroscopy and were confirmed by X-ray diffraction analysis (compounds **8h** and **8s**, Figs. 3 and 4).

Cyclohexanones **3g–u** are very reactive and we suppose them to be only intermediates as the reaction does not

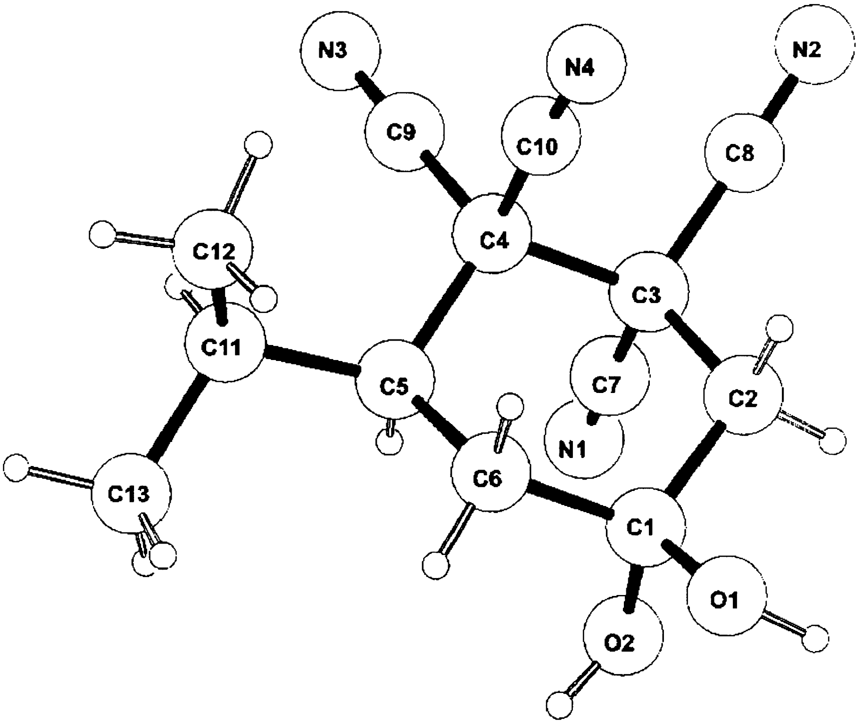


Figure 2. Molecular structure of **6h**.

stop at this stage. This can be explained by the comparatively small steric constraints of the carbonyl group. Thus if we analyse steric hindrance groups R^2 and R^3 of cyclohexanones **3**, we would see that higher reactivity is exhibited mostly when R^2 and R^3 are H and in four cases when R^2 or R^3 is CH_3 (compounds **3k**,**l**,**s**,**u**) and in one case when R^2 is Br (compound **3t**). For the most stable cyclohexanones **3a–f** (Scheme 1), the sum of R^2+R^3 reaches two or three carbon atoms.

The sequence of steps **1→8** is supported by the fact that some intermediates were separated as individual products. For example compounds **6g**,**h** were isolated in 41 and 67% yields, respectively, when cyclohexanones **3g**,**h** were

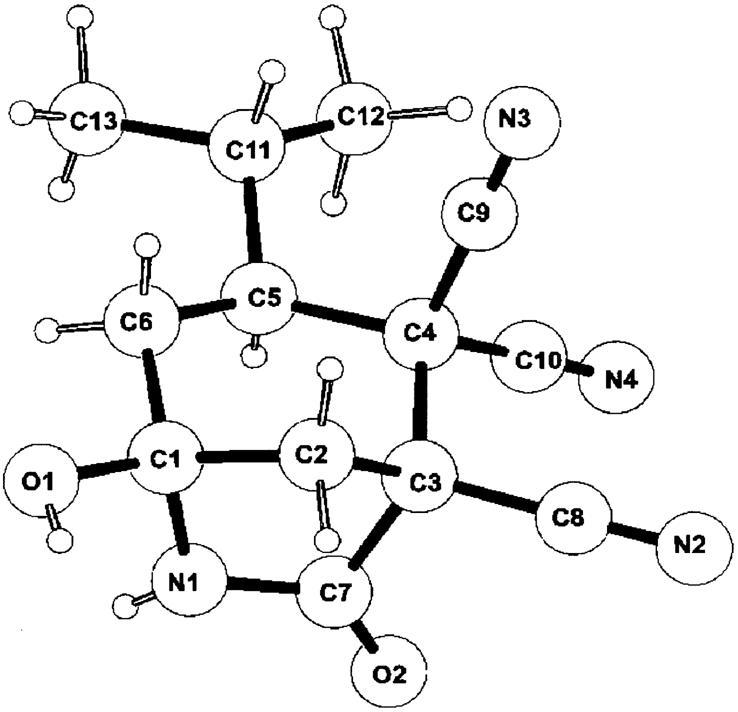


Figure 3. Molecular structure of **8h**.

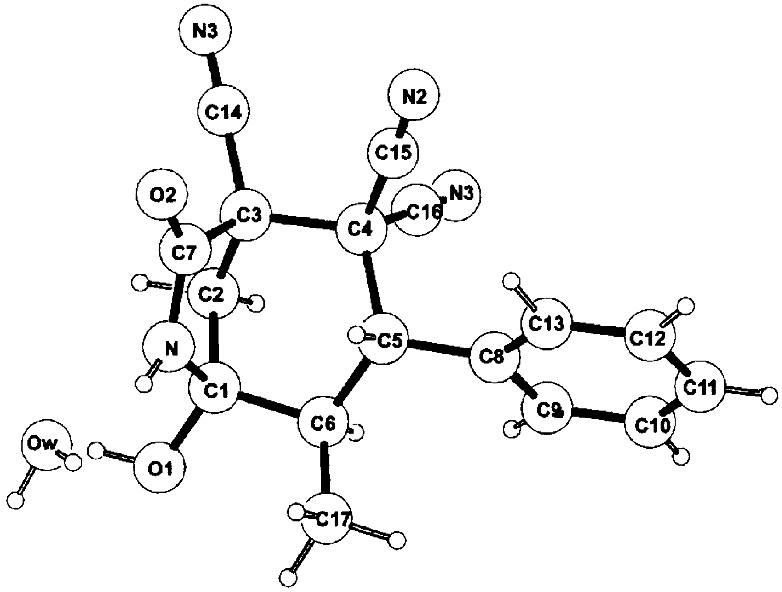


Figure 4. Molecular structure of **8s**.

allowed to stand in aqueous dioxane solution with several drops of concentrated HCl. The structures of **6g**,**h** were established by IR, ^{1}H NMR and mass-spectroscopy and by X-ray diffraction analysis (compound **6h**, Fig. 2).

Amides **7g**,**h** were obtained in harsher conditions by boiling of hydrate **6g**,**h** in isopropanol. The step **7g**,**h**→**8g**,**h** is confirmed by the transformation of compounds **7g**,**h** into **8g**,**h**, which was performed in boiling dioxane in the presence of 5–6 drops of concentrated HCl. The last four stages **3a**–**l**→**8a**–**l** can also be carried out in a one-pot synthetic operation. Boiling compounds **3a**–**l** in dioxane with concentrated HCl (1:1) gives compounds **8a**–**l**.

Hereby on the basis of the reaction of TCNE with α,β-unsaturated ketones, we were able to obtain several novel structures: tetracyanoethylated unsaturated ketones, tetracyanocyclohexanones and tetracyanocyclohexanediols, carboxamidotricyanocyclo-hexanones 3-R^1-4-R^2-8-R^3-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitriles. These compounds with a large number of functional groups are very interesting for further synthetic investigations. Moreover, intermediate products, that were individually isolated, enhance the value of our investigation, as they give the possibility of studying the mechanism of the tetracyanoethylation of α,β-unsaturated ketones.

1. Experimental

The ^{1}H NMR spectra were recorded in DMSO-d_6 solution at 300 MHz on a Bruker AM-300 spectrometer. Mass spectra were determined at an ionizing voltage of 70 eV using a Finnigan mat.incos50 spectrometer. The whole calculations were carried out according to the programme SHELXL-97. Atomic co-ordinates, bond lengths, bond angles and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre (CCDC). All solvents were distilled prior to use, unless otherwise noted. Melting points were recorded on a capillary melting point apparatus. TLC was performed on Sylufol UV254 silica gel plates in ethyl acetate. Spots were visualized with iodine or by heating.

The hydroquinone test was carried out on a sheet of paper covered with a thin layer of hydroquinone. The reaction with TCNE was considered to be completed when the spot was not colored blue.

1.1. Synthesis of 3-R^1-4-R^2-6-R^3-5-oxo-1,1,2,2-cyclohexanetetra-carbonitriles (3a–f), unsaturated tetracyanoalkanones (5a–e) and 3-R^1-4-R^2-8-R^3-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitriles (8g–u)

Ketone **1** (15 mmol) was dissolved at 40–50°C in a solution of TCNE (1.28 g, 10 mmol) in 20 mL of dioxane. Then 3–4 drops of concentrated HCl were added. When the reaction was over (hydroquinone test), the reaction was diluted with 80 mL of water. The separated oil crystallized into the solid product (the time of crystallization varied with individual ketones). The precipitate was collected by filtration, washed with water, isopropanol and with ether. Recrystallization was effected from isopropanol analytical samples.

1.2. Synthesis of 3-R^1-4-R^2-6-R^3-5-oxo-1,1,2,2-cyclohexanetetracarbonitriles (3g–l) from α,β-unsaturated ketones in absolute dioxane

TCNE (1.28 g, 10 mmol) was dissolved in 25 mL of absolute dioxane. Then 15 mmol of ketone **1** and 1–2 drops of concentrated HCl were added. When the reaction was over (hydroquinone test), the reaction mixture was diluted with 80 mL of water. The separated oil crystallized into the solid product (the time of crystallization varied with individual ketones). The precipitate was collected by filtration, washed with water, isopropanol and at last with ether. Recrystallization from isopropanol finally gave analytical samples of **3a**–**l**.

1.3. Synthesis of 3-R-5,5-dihydroxy-1,1,2,2-cyclohexanetetracarbonitriles (6g,h) from 3-R^1-4-R^2-6-R^3-5-oxo-1,1,2,2-cyclohexanetetracarbonitriles (3g,h)

Cyclohexanone **3** (1 mmol) was dissolved in 10 mL of dioxane with 2–3 drops of concentrated HCl. The solvent was allowed to evaporate from the open vessel at room temperature. Crystallization usually occurred in 1–2 days. The precipitate was collected by filtration, washed with water and ether. Recrystallization was effected from isopropanol.

1.4. Synthesis of 1,2,2-tricyano-3-R-5-oxo-1-cyclohexanecarboxamides (7g,h) from 3-R-5,5-dihydroxy-1,1,2,2-cyclohexanetetracarbonitriles (6g,h)

Cyclohexanediol **6** (1 mmol) was boiled in 5 mL of isopropanol and 1 mL of water for 5–10 min (examination by TLC). Cooling of the reaction mass resulted in the formation of a precipitate which was collected by filtration and washed with isopropanol.

1.5. Synthesis of 3-R^1-4-R^2-8-R^3-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitriles (8g,h) from 1,2,2-tricyano-3-R-5-oxo-1-cyclohexanecarboxamides (7g,h)

3-Carboxamido-3,4,4-tricyanocyclohexanone **8** (1 mmol) was boiled in 5 mL of dioxane with 5–6 drops of concentrated HCl for 1 min (examination by TLC). Addition of 30 mL of water resulted in the formation of a precipitate which was collected by filtration and washed with isopropanol. Where necessary, recrystallization was effected from isopropanol.

1.6. Synthesis of 3-R^1-4-R^2-8-R^3-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitriles (8a–l) from 3-R^1-4-R^2-6-R^3-5-oxo-1,1,2,2-cyclohexanetetracarbonitriles (3a–l)

Cyclohexanone **3** (0.001 mol) was boiled in 10 mL of dioxane and conc. HCl (1:1) for 5–10 min (examination by TLC). Addition of 20 mL of water resulted in the formation of a precipitate which was collected by filtration and washed with isopropanol. Where necessary, recrystallization was effected from isopropanol.

1.6.1. 3-Methyl-5-oxo-4-propyl-1,1,2,2-cyclohexanetetracarbonitrile (3a). (1.45 g, 57%) as a colorless solid, mp 103–104°C; [Found: C, 66.5; H, 5.5; N, 22.2. $C_{14}H_{14}N_4O$ requires C, 66.13; H, 5.55; N, 22.03%]; ν_{max}(Nujol) 2275, 1715 cm^{-1}; δ_H (300 MHz, DMSO) 3.7 (1H, d, J=15 Hz, COCH$_2$), 3.63 (1H, d, J=15 Hz, COCH$_2$), 2.8 (1H, dq, J=12.5, 6.5 Hz, CH$_3$C*H*C(CN)$_2$), 2.63 (1H, dt, J=12.5, 4.5 Hz, COCHPr), 1.62 (2H, m, CH$_2$C*H*$_2$CH$_3$), 1.55 (3H, d, J=6.5 Hz, CHC*H*$_3$), 1.37 (2H, m, C*H*$_2$CH$_2$CH$_3$), 1.2 (m, 1H, C*H*$_2$CH$_2$CH$_3$), 0.93 (3H, t, J=6.0 Hz, CH$_2$CH$_2$C*H*$_3$).

1.6.2. 5-Oxo-3,4-dipropyl-1,1,2,2-cyclohexanetetracarbonitrile (3b). (1.8 g, 64%) as a colorless solid, mp 107–108°C; [Found: C, 67.9; H, 6.5; N, 19.9. $C_{16}H_{18}N_4O$ requires C, 68.08; H, 6.43; N, 19.84%]; ν_{max}(Nujol) 2265, 1720 cm^{-1}; δ_H (300 MHz, DMSO) 3.63 (1H, d, J=14.0 Hz, COCH$_2$), 3.6 (1H, d, J=14.0 Hz, COCH$_2$), 2.71 (1H, m, COCHPr), 2.62 (1H, m, C(CN)$_2$CHPr), 1.9–1.2 (8H, m, C(CN)$_2$CHC*H*$_2$C*H*$_2$CH$_3$, COCHC*H*$_2$C*H*$_2$CH$_3$), 1.06 (3H, t, J=6.0 Hz, CH$_3$), 0.83 (3H, t, J=5.5 Hz, CH$_3$).

1.6.3. 5-Oxo-3-phenyl-4-propyl-1,1,2,2-cyclohexanetetracarbonitrile (3c). (2.59 g, 82%) as a colorless solid, mp 130–131°C; [Found: C, 72.3; H, 5.2; N, 17.5. $C_{19}H_{16}N_4O$ requires C, 72.14; H, 5.10; N, 17.71%]; ν_{max}(Nujol) 2270, 1715 cm^{-1}; δ_H (300 MHz, DMSO) 7.5–7.65 (5H, m, Ph), 3.83 (2H, s, COCH$_2$), 3.86 (1H, d, J=13.5 Hz, CHPh), 3.48 (1H, dd, J=13.5, 5.5 Hz, COCHPr), 1.1–1.5 (4H, m, C*H*$_2$C*H*$_2$CH$_3$), 0.75 (3H, t, J=6.5 Hz, CH$_2$C*H*$_3$).

1.6.4. 3-(4-Methoxyphenyl)-5-oxo-4-propyl-1,1,2,2-cyclohexanetetracarbonitrile (3d). (2.73 g, 79%) as a colorless solid, mp 118–119°C; [Found: C, 69.4; H, 5.4; N, 16.3. $C_{20}H_{18}N_4O_2$ requires C, 69.35; H, 5.24; N, 16.17%]; ν_{max}(Nujol) 2275, 1715 cm^{-1}; δ_H (300 MHz, DMSO) 7.58 (2H, d, J=8.5 Hz, *o*-Ph), 7.1 (2H, d, J=8.5 Hz, *m*-Ph), 3.87 (2H, s, COCH$_2$), 3.85 (1H, d, J=14.0 Hz, CHAr), 3.83 (3H, s, OCH$_3$), 3.47 (1H, dd, J=14.0, 6.5 Hz, CHPr), 1.4–1.0 (4H, m, C*H*$_2$C*H*$_2$CH$_3$), 0.82 (3H, t, J=6.5 Hz, CH$_2$CH$_2$C*H*$_3$).

1.6.5. 3-(4-Methoxyphenyl)-4,6-dimethyl-5-oxo-1,1,2,2-cyclohexanetetracarbonitrile (3e). (2.31 g, 73%) as a colorless solid, mp 155–156°C; [Found: C, 68.8; H, 4.7; N, 16.9. $C_{19}H_{16}N_4O_2$ requires C, 68.66; H, 4.85; N, 16.86%]; ν_{max}(Nujol) 2265, 1715 cm^{-1}; δ_H (300 MHz, DMSO) 7.53 (2H, d, J=8.5 Hz, *o*-Ph), 7.08 (2H, d, J=8.5 Hz, *m*-Ph), 4.21 (1H, d, J=13.5 Hz, CHAr), 3.88 (1H, q, J=6.5 Hz, COC*H*CH$_3$), 3.84 (3H, s, OCH$_3$), 3.06 (1H, m, ArCHC*H*CH$_3$), 0.97 (3H, d, J=6.5 Hz, CHC*H*$_3$), 0.88 (3H, d, J=6.5 Hz, CHC*H*$_3$).

1.6.6. 3-Isopropyl-6-(4-methoxyphenyl)-4-oxo-1,1,2,2-cyclohexanetetracarbonitrile (3f). (3.1 g, 89%) as a colorless solid, mp 117–118°C; [Found: C, 69.5; H, 5.3; N, 16.0. $C_{20}H_{18}N_4O_2$ requires C, 69.35; H, 5.24; N, 16.17%]; ν_{max}(Nujol) 2260, 1720 cm^{-1}; δ_H (300 MHz, DMSO) 7.48 (2H, d, J=8.5 Hz, *o*-Ph), 7.04 (2H, d, J=8.5 Hz, *m*-Ph), 4.12 (1H, dd, J=14.0, 4.0 Hz, CHAr), 3.84 (3H, s, OCH$_3$), 3.68 (1H, d, J=5.0 Hz, CHCO), 3.62 (1H, t, J=14.0 Hz, CH$_2$), 2.72 (1H, dd, J=14.0, 4.0 Hz, CH$_2$), 2.47 (1H, m, CHMe$_2$), 1.28 (6H, d, J=7.0 Hz, CH*Me*$_2$).

1.6.7. 3-(2-Furyl)-5-oxo-1,1,2,2-cyclohexanetetracarbonitrile (3g). (1.8 g, 68%) as a colorless solid, mp 144–145°C; [Found: C, 63.8; H, 3.2; N, 21.4. $C_{14}H_8N_4O_2$ requires C, 63.64; H, 3.05; N, 21.20%]; ν_{max}(Nujol) 2260, 1720 cm^{-1}; δ_H (300 MHz, DMSO) 7.97 (1H, d, J=1.5 Hz, Fu), 6.82 (1H, d, J=3.0 Hz, Fu), 6.67 (1H, dd, J=1.5, 3.0 Hz, Fu), 3.78 (1H, dd, J=13.5, 4.5 Hz, CHFu), 2.97 (1H, d, J=14.5 Hz, CH$_2$C(CN)$_2$), 2.66 (1H, d, J=14.5 Hz, CH$_2$C(CN)$_2$), 2.4 (1H, dd, J=14.5, 13.5 Hz, C*H*$_2$CH), 2.35 (1H, dd, J=14.5, 4.5 Hz, C*H*$_2$CH).

1.6.8. 3-Isopropyl-5-oxo-1,1,2,2-cyclohexanetetracarbonitrile (3h). (1.63 g, 68%) as a colorless solid, mp 141–142°C; [Found: C, 64.8; H, 5.1; N, 23.4. $C_{16}H_{18}N_4O$ requires C, 64.99; H, 5.03; N, 23.32%]; ν_{max}(Nujol) 2270, 1710 cm^{-1}; δ_H (300 MHz, DMSO) 2.95 (1H, d, J=14.0 Hz, CH$_2$C(CN)$_2$), 2.54 (1H, m, C*H*CH(Me)$_2$), 2.47 (1H, d, *J*=14.0 Hz, CH$_2$C(CN)$_2$), 2.28 (1H, m, C*H*Me$_2$), 2.1 (1H, dd, *J*=14.5, 12.5 Hz, CHC*H*$_2$CO), 1.68 (1H, dd, *J*=14.5, 4.0 Hz, CHC*H*$_2$CO), 1.16 (3H, d, *J*=6.5 Hz, CHC*H*$_3$), 1.1 (3H, d, *J*=6.5 Hz, CHC*H*$_3$).

1.6.9. 3-Butyl-5-oxo-1,1,2,2-cyclohexanetetracarbonitrile (3i). (1.6 g, 63%) as a colorless solid, mp 160–161°C; [Found: C, 66.3; H, 5.5; N, 21.9. C$_{14}$H$_{14}$N$_4$O requires C, 66.13; H, 5.55; N, 22.03%]; $\nu_{\max}$(Nujol) 2270, 1695 cm^{-1}; δ_{H} (300 MHz, DMSO) 2.83 (1H, d, *J*=13.0 Hz, CH$_2$C(CN)$_2$), 2.49 (1H, d, *J*=13.0 Hz, CH$_2$C(CN)$_2$), 2.28 (1H, m, C*H*Bu), 2.1 (1H, dd, *J*=13.5, 12.5 Hz, CHC*H*$_2$CO), 1.68 (1H, dd, *J*=13.5, 4.0 Hz, CHC*H*$_2$CO), 1.58–1.18 (6H, m, CHC*H*$_2$C*H*$_2$C*H*$_2$CH$_3$), 0.89 (3H, d, *J*=6.0 Hz, CHC*H*$_3$).

1.6.10. 5-Oxo-3-phenyl-1,1,2,2-cyclohexanetetracarbonitrile (3j). (1.32 g, 48%) as a colorless solid, mp 158–159°C; [Found: C, 70.2; H, 3.5; N, 20.6. C$_{16}$H$_{10}$N$_4$O requires C, 70.07; H, 3.67; N, 20.43%]; $\nu_{\max}$(Nujol) 2265, 1700 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.48–7.67 (5H, m, Ph), 4.36 (1H, dd, *J*=11.0, 3.5 Hz, CHPh), 3.57 (1H, dd, *J*=14.5, 11.0 Hz, PhCHC*H*$_2$), 3.32–3.44 (3H, m, COCH$_2$, PhCHC*H*$_2$).

1.6.11. 3-Methyl-4-oxo-6-phenyl-1,1,2,2-cyclohexanetetracarbonitrile (3k). (2.22 g, 77%) as a colorless solid, mp 165–166°C; [Found: C, 70.9; H, 4.0; N, 19.6. C$_{17}$H$_{12}$N$_4$O requires C, 70.82; H, 4.20; N, 19.43%]; $\nu_{\max}$(Nujol) 2270, 1715 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.5–7.7 (5H, m, Ph), 4.32 (1H, dd, *J*=12.0, 4.5 Hz, CHPh), 4.07 (1H, q, *J*=6.5 Hz, COCHMe), 3.7 (1H, dd, *J*=14.5, 12.0 Hz, COCH$_2$), 2.87 (1H, dd, *J*=14.5, 4.5 Hz, COCH$_2$), 1.46 (3H, d, *J*=6.5 Hz, CHC*H*$_3$).

1.6.12. 6-(4-Methoxyphenyl)-3-methyl-4-oxo-1,1,2,2-cyclohexanetetracarbonitrile (3l). (1.94 g, 61%) as a colorless solid, mp 168–169°C; [Found: C, 67.9; H, 4.5; N, 17.4. C$_{18}$H$_{14}$N$_4$O$_2$ requires C, 67.92; H, 4.43; N, 17.60%]; $\nu_{\max}$(Nujol) 2275, 1710 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.55 (2H, d, *J*=8.0 Hz, *o*-Ph), 7.11 (2H, d, *J*=8.0 Hz, *m*-Ph), 4.25 (1H, dd, *J*=12.0, 3.5 Hz, CHAr), 4.03 (1H, q, *J*=7.0 Hz, C*H*CH$_3$), 3.84 (3H, s, OCH$_3$), 3.55 (1H, dd, *J*=13.5, 11.0 Hz, CH$_2$CO), 2.71 (1H, dd, *J*=13.5, 4.0 Hz, CH$_2$CO), 1.45 (3H, d, *J*=7.0 Hz, CHC*H*$_3$).

1.6.13. 6-Methyl-4-oxo-5-heptene-1,1,2,2-tetracarbonitrile (5a). (1.83 g, 81%) as a colorless solid, mp 105–106°C; [Found: C, 63.9; H, 4.5; N, 24.6. C$_{12}$H$_{10}$N$_4$O requires C, 63.71; H, 4.46; N, 24.76%]; $\nu_{\max}$(Nujol) 2275, 1670, 1605 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.16 (s, 1H, Me$_2$C=C*H*CO); 4.02 (s, 2H, CH$_2$CO); 1.8 (s, 6H, =CMe$_2$).

1.6.14. 1-3-[(*Z*)-1-(2-Furyl)methylidene]-2-oxocyclohexyl-1,1,2,2-ethanetetracarbonitrile (5b). (2.7 g, 89%) as a colorless solid, mp 120–121°C; [Found: C, 66.9; H, 4.1; N, 18.6. C$_{17}$H$_{12}$N$_4$O$_2$ requires C, 67.10; H, 3.97; N, 18.41%]; $\nu_{\max}$(Nujol) 2265, 1640, 1550 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.85 (1H, s, CH=), 7.35 (1H, d, *J*=2.0 Hz, Fu), 6.95 (1H, d, *J*=3.0 Hz, Fu), 6.15 (1H, dd, *J*=2.0, 3.0 Hz, Fu), 3.27 (1H, m, COC*H*C(CN)$_2$), 3.15 (1H, d, *J*=12.0 Hz, =CC*H*$_2$), 2.83 (1H, d, *J*=12.0 Hz, =CC*H*$_2$), 2.35 (1H, m, CH$_2$), 2.1 (1H, m, CH$_2$), 2.0 (1H, m, CH$_2$), 1.85 (1H, m, CH$_2$). Crystal data for **5b**: C$_{18}$H$_{11}$N$_4$O$_2$, *M*=315.31, crystals are monoclinic, at 293(2) K *a*=17.279(4) Å, *b*=6.2805(9) Å, *c*=14.732(5) Å, α=90°, β=101.46(2)°, γ=90°, *V*=1566.9(7) Å^3, d_{calcd}=1.337 g cm^{-3}, *Z*=4. The space group is *P*21/*c*. Summary of Data CCDC 153643.

1.6.15. 1-3-[(*Z*)-1-(2-Furyl)methylidene]-2-oxocyclopentyl-1,1,2,2-ethanetetracarbonitrile (5c). (2.8 g, 97%) as a colorless solid, mp 111–112°C; [Found: C, 66.1; H, 3.5; N, 19.2. C$_{16}$H$_{10}$N$_4$O$_2$ requires C, 66.20; H, 3.47; N, 19.30%]; $\nu_{\max}$(Nujol) 2265, 1665, 1580 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.79 (1H, s, CH=), 7.38 (1H, d, *J*=2.0 Hz, Fu), 6.97 (1H, d, *J*=3.0 Hz, Fu), 6.15 (1H, dd, *J*=2.0, 3.0 Hz, Fu), 3.29 (1H, m, COC*H*C(CN)$_2$), 3.24 (1H, d, *J*=12.5 Hz, =CC*H*$_2$), 2.86 (1H, d, =CC*H*$_2$), 2.46 (1H, m, CH$_2$), 2.13 (1H, m, CH$_2$), 1.93 (1H, m, CH$_2$).

1.6.16. 1-2-Oxo-3-[(*Z*)-1-phenylmethylidene]cyclohexyl-1,1,2,2-ethanetetracarbonitrile (5d). (2.95 g, 94%) as a colorless solid, mp 142–143°C; [Found: C, 72.5; H, 4.5; N, 17.6. C$_{19}$H$_{14}$N$_4$O requires C, 72.60; H, 4.49; N, 17.82%]; $\nu_{\max}$(Nujol) 2265, 1665, 1590 cm^{-1}.; δ_{H} (300 MHz, DMSO) 7.85(1H, s, CH=), 7.65–7.51 (5H, m, C$_6$H$_5$), 3.35 (1H, m, COC*H*C(CN)$_2$), 3.19 (1H, d, *J*=13.0 Hz, =CC*H*$_2$), 2.81 (1H, d, *J*=13.0 Hz, =CC*H*$_2$), 2.34 (1H, m, CH$_2$), 2.12 (1H, m, CH$_2$), 1.97 (1H, m, CH$_2$), 1.85 (1H, m, CH$_2$).

1.6.17. 1-3-[(*Z*)-1-(4-Methoxyphenyl)methylidene]-2-oxocyclohexyl-1,1,2,2-ethanetetracarbonitrile (5e). (2.9 g, 84%) as a colorless solid, mp 145–146°C; [Found: C, 69.9; H, 4.6; N, 24.6. C$_{20}$H$_{16}$N$_4$O$_2$ requires C, 69.76; H, 4.68; N, 16.27%]; $\nu_{\max}$(Nujol) 2270, 1675, 1580 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.85 (1H, s, CH=), 7.45 (2H, d, *J*=8.5 Hz, *o*-Ph), 7.05 (2H, d, *J*=8.5 Hz, *m*-Ph), 3.22 (1H, m, COC*H*C(CN)$_2$), 3.19 (1H, d, *J*=12.0 Hz, =CC*H*$_2$), 2.88 (1H, d, *J*=12.0 Hz, =CC*H*$_2$), 2.36 (1H, m, CH$_2$), 2.2 (1H, m, CH$_2$), 2.03 (1H, m, CH$_2$), 1.93 (1H, m, CH$_2$).

1.6.18. 3-(2-Furyl)-5,5-dihydroxy-1,1,2,2-cyclohexanetetracarbonitrile (6g). (0.2 g, 67%) as a colorless solid, mp 165–166°C; [Found: C, 59.5; H, 3.5; N, 19.6. C$_{14}$H$_{10}$N$_4$O$_3$ requires C, 59.57; H, 3.57; N, 19.85%]; $\nu_{\max}$(Nujol) 3225, 3370, 2265 cm^{-1}; δ_{H} (300 MHz, DMSO) 7.83 (1H, d, *J*=1.5 Hz, Fu), 6.79 (1H, d, *J*=2.5 Hz, Fu), 6.6 (1H, dd, *J*=1.5, 2.5 Hz, Fu), 3.96 (1H, dd, *J*=12.0, 4.0 Hz, CHFu), 3.08 (1H, d, *J*=14.5 Hz, C*H*$_2$C(CN)$_2$), 2.28 (1H, d, *J*=14.5 Hz, C*H*$_2$C(CN)$_2$), 2.05 (1H, m, CH$_2$CHFu), 2.09 (1H, dd, 13.5, 4.0 CH$_2$CHFu).

1.6.19. 5,5-Dihydroxy-3-isopropyl-1,1,2,2-cyclohexanetetracarbonitrile (6h). (0.11 g, 42%) as a colorless solid, mp 165–166°C; [Found: C, 60.4; H, 5.5; N, 21.6. C$_{13}$H$_{14}$N$_4$O$_2$ requires C, 60.46; H, 5.46; N, 21.69%]; $\nu_{\max}$(Nujol) 3360, 3390, 2280 cm^{-1}; δ_{H} (300 MHz, DMSO) 2.98 (1H, d, *J*=14.5 Hz, CH$_2$C(CN)$_2$), 2.46 (1H, m, C*H*CH(Me)$_2$), 2.42 (1H, d, *J*=14.5 Hz, CH$_2$C(CN)$_2$), 2.3 (1H, m, C*H*Me$_2$), 2.2 (1H, dd, *J*=14.5, 12.5 Hz, CHC*H*$_2$CO), 1.77 (1H, dd, *J*=14.5, 4.5 Hz, CHC*H*$_2$CO), 1.2 (3H, d, *J*=6.0 Hz, CHC*H*$_3$), 1.14 (3H, d, *J*=6.5 Hz, CHC*H*$_3$). Crystal data for **6h**: C$_{13}$H$_{13}$N$_4$O$_2$, *M*=257.27, crystals are monoclinic, at 293(2) K *a*=6.446(2) Å,

b=7.654(2) Å, c=14.725(2) Å, α=97.63(2)°, β=93.24(2)°, γ=109.90(2)°, V=637.0(3) Å^3, d_{calcd}=1.270 g cm^{-3}, Z=2. The space group is $P21/c$. Summary of Data CCDC 153640.

1.6.20. 1,2,2-Tricyano-3-(2-furyl)-5-oxo-1-cyclohexanecarboxamide (7g). (0.27 g, 95%) as a colorless solid, mp 170–171(decomp.)°C; [Found: C, 59.7; H, 3.4; N, 19.8. $C_{14}H_{10}N_4O_3$ requires C, 59.57; H, 3.57; N, 19.85%]; ν_{max}(Nujol) 3275, 3380, 2275, 1705, 1740 cm^{-1}; δ_H (300 MHz, DMSO) 7.94 (1H, d, J=1.5 Hz, Fu), 6.79 (1H, d, J=3.0 Hz, Fu), 6.68 (1H, dd, J=3.0, 1.5 Hz, Fu), 6.56 (1H, s, $CONH_2$), 6.51 (1H, s, $CONH_2$), 3.83 (1H, dd, J=12.0, 4.5 Hz, CHFu), 2.98 (1H, d, J=14.5 Hz, $C\mathit{H}_2C(CN)CONH_2$), 2.56 (1H, d, J=14.5 Hz, $C\mathit{H}_2C(CN)CONH_2$), 2.28 (1H, dd, J=14.5, 12.0 Hz, $C\mathit{H}_2$CHFu), 2.20 (1H, dd, J=14.5, 4.5 Hz, CH_2CHFu).

1.6.21. 1,2,2-Tricyano-3-isopropyl-5-oxo-1-cyclohexanecarboxamide (7h). (0.24 g, 92%) as a colorless solid, mp 180–181(decomp.)°C; [Found: C, 60.5; H, 5.3; N, 21.7. $C_{13}H_{14}N_4O_2$ requires C, 60.46; H, 5.46; N, 21.69%]; ν_{max}(Nujol) 3260, 3380, 2260, 1710, 1730 cm^{-1}; δ_H (300 MHz, DMSO) 6.58 (1H, s, $CONH_2$), 6.52 (1H, s, $CONH_2$), 2.86 (1H, d, J=14.0 Hz, $COCH_2$), 2.43 (1H, d, J=14.0 Hz, $COCH_2$), 2.25 (1H, m, $CHMe_2$), 2.2 (d, 1H, $COCH_2$), 2.04 (1H, d, J=14.5, 11.0 Hz, $CHC\mathit{H}_2$), 1.58 (1H, dd, J=14.5, 3.5 Hz, $CHC\mathit{H}_2$), 1.15 (3H, d, J=6.5 Hz, $CH\mathit{Me}_2$), 1.09 (3H, d, J=6.5 Hz, $CH\mathit{Me}_2$).

1.6.22. 5-Hydroxy-3-methyl-7-oxo-4-propyl-6-azabicyclo-[3.2.1]octane-1,2,2-tricarbonitrile (8a). (2.48 g, 90%) as a colorless solid, mp 114–115°C; [Found: C, 61.6; H, 5.8; N, 20.7. $C_{14}H_{16}N_4O_2$ requires C, 61.75; H, 5.92; N, 20.58%]; ν_{max}(Nujol) 3470, 3325, 2275, 1710, 1655 cm^{-1}; δ_H (300 MHz, DMSO) 9.51 (1H, s, NH), 7.82 (1H, s, OH), 2.67 (1H, d, J=13.0 Hz, CH_2), 2.42 (1H, d, J=13.0 Hz, CH_2), 2.61 (1H, dt, J=12.5, 5.5 Hz, CHPr), 2.55 (1H, m, $CH_3C\mathit{H}$), 1.62 (2H, m, $CH_2C\mathit{H}_2CH_3$), 1.55 (3H, d, J=6.5 Hz, $CHC\mathit{H}_3$), 1.32 (2H, m, $C\mathit{H}_2CH_2CH_3$), 1.21 (m, 1H, $C\mathit{H}_2CH_2CH_3$), 0.91 (3H, t, J=6.0 Hz, $CH_2CH_2C\mathit{H}_3$).

1.6.23. 5-Hydroxy-7-oxo-3,4-dipropyl-6-azabicyclo[3.2.1]-octane-1,2,2-tricarbonitrile (8b). (2.67 g, 89%) as a colorless solid, mp 110–111°C; [Found: C, 64.1; H, 6.8; N, 18.5. $C_{16}H_{20}N_4O_2$ requires C, 63.98; H, 6.71; N, 18.65%]; ν_{max}(Nujol) 3475, 3340, 2275, 1720, 1655 cm^{-1}; δ_H (300 MHz, DMSO) 9.57 (1H, s, NH), 7.85 (1H, s, OH), 2.73 (1H, d, J=12.5 Hz, CH_2), 2.38 (1H, d, J=12.5 Hz, CH_2), 1.1–1.9 (10H, m, CHPr, $C\mathit{H}_2C\mathit{H}_2CH_3$), 1.03 (3H, t, J=7.0 Hz, $CH_2C\mathit{H}_3$), 0.9 (3H, t, J=7.0 Hz, $CH_2C\mathit{H}_3$).

1.6.24. 5-Hydroxy-7-oxo-3-phenyl-4-propyl-6-azabicyclo-[3.2.1]octane-1,2,2-tricarbonitrile (8c). (3.27 g, 98%) as a colorless solid, mp 211–212(decomp.)°C; [Found: C, 68.5; H, 5.6; N, 16.5. $C_{19}H_{18}N_4O_2$ requires C, 68.25; H, 5.43; N, 16.76%]; ν_{max}(Nujol) 3535, 3335, 2270, 1710, 1645 cm^{-1}; δ_H (300 MHz, DMSO) 9.65 (1H, s, NH), 7.4–7.6 (5H, m, Ph), 6.97 (1H, s, OH), 3.05 (1H, d, J=11.5 Hz, $C\mathit{H}$Ph), 2.85 (1H, d, J=12.0 Hz, CH_2), 2.72 (1H, d, J=12.0 Hz, CH_2), 2.43 (1H, dt, J=11.5, 6.5 Hz, CHPr), 1.5 (1H, m, $C\mathit{H}_2$Et), 1.3 (1H, m, $C\mathit{H}_2$Et), 1.08 (1H, m, $CH_2C\mathit{H}_2CH_3$), 0.87 (1H, m, $CH_2C\mathit{H}_2CH_3$), 0.65 (3H, t, J=7.5 Hz, $CH_2C\mathit{H}_3$).

1.6.25. 5-Hydroxy-3-(4-methoxyphenyl)-7-oxo-4-propyl-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8d). (3.53 g, 97%) as a colorless solid, mp 185–186(decomp.)°C; [Found: C, 65.8; H, 5.5; N, 15.2. $C_{20}H_{20}N_4O_3$ requires C, 65.92; H, 5.53; N, 15.38%]; ν_{max}(Nujol) 3510, 3350, 2275, 1710, 1645 cm^{-1}; δ_H (300 MHz, DMSO) 9.54 (1H, s, NH), 7.51 (2H, d, J=8.5 Hz, o-Ph), 7.12 (2H, d, J=8.5 Hz, m-Ph), 7.09 (1H, s, OH), 3.84 (3H, s, OCH_3), 3.79 (1H, d, 12.5, CHAr), 3.74 (1H, d, J=14.5 Hz, CH_2), 3.37 (1H, d, J=12.5 Hz, CHPr), 3.26 (1H, d, J=14.5 Hz, CH_2), 1.5–1.1 (4H, m, $C\mathit{H}_2C\mathit{H}_2CH_3$), 0.82 (3H, t, J=6.5 Hz, $CH_2CH_2C\mathit{H}_3$).

1.6.26. 5-Hydroxy-3-(4-methoxyphenyl)-4,8-dimethyl-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8e). (3.27 g, 98%) as a colorless solid, mp 1176–1177(decomp.)°C; [Found: C, 65.1 H, 5.1; N, 16.0. $C_{19}H_{18}N_4O_3$ requires C, 65.13; H, 5.53; N, 15.99%]; ν_{max}(-Nujol) 3485, 3350, 2265, 1720, 1640 cm^{-1}; δ_H (300 MHz, DMSO) 9.48 (1H, s, NH), 7.45 (2H, d, J=8.5 Hz, o-Ph), 7.05 (2H, d, J=8.5 Hz, m-Ph), 7.02 (1H, s, OH), 3.84 (3H, s, OCH_3), 3.76 (1H, d, J=12.0 Hz, CHAr), 3.08 (1H, q, J=7.0 Hz, $C\mathit{H}CH_3$), 2.84 (1H, m, $ArCHC\mathit{H}CH_3$), 1.34 (3H, d, J=7.0 Hz, $CHC\mathit{H}_3$), 0.96 (3H, d, J=6.5 Hz, $CHC\mathit{H}_3$).

1.6.27. 5-Hydroxy-8-isopropyl-3-(4-methoxyphenyl)-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8f). (3.5 g, 96%) as a colorless solid, mp 187–188(decomp.)°C; [Found: C, 65.9; H, 5.5; N, 15.3. $C_{20}H_{20}N_4O_3$ requires C, 65.92; H, 5.53; N, 15.38%]; ν_{max}(Nujol) 3505, 3350, 2270, 1710, 1640 cm^{-1}; δ_H (300 MHz, DMSO) 9.50 (1H, s, NH), 7.4 (2H, d, J=8.5 Hz, o-Ph), 7.02 (2H, d, J=8.5 Hz, m-Ph), 7.06 (1H, s, OH), 3.9 (1H, dd, J=12.0, 4.0 Hz, CHAr), 3.84 (3H, s, OCH_3), 3.55 (1H, d, J=6.0 Hz, $C\mathit{H}$COH), 3.52 (1H, dd, J=14.0, 12.0 Hz, CH_2), 2.66 (1H, dd, J=14.0, 4.0 Hz, CH_2), 2.52 (1H, m, $C\mathit{H}Me_2$), 1.54 (3H, d, J=7.0 Hz, CH_3), 1.02 (3H, d, J=6.5 Hz, CH_3).

1.6.28. 3-(2-Furyl)-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]-octane-1,2,2-tricarbonitrile (8g). (2.65 g, 94%) as a colorless solid, mp 206–207(decomp.)°C; [Found: C, 59.7; H, 3.5; N, 19.8. $C_{14}H_{10}N_4O_3$ requires C, 59.57; H, 3.57; N, 19.85%]; ν_{max}(Nujol) 3510, 3370, 2265, 1725, 1605 cm^{-1}; δ_H (300 MHz, DMSO) 9.45 (1H, s, NH), 7.92 (1H, d, J=2.0 Hz, Fu), 7.25 (1H, s, OH), 6.72 (1H, d, J=3.0 Hz, Fu), 6.58 (1H, dd, J=2.0, 3.0 Hz, Fu), 3.73 (1H, dd, J=12.0, 5.0 Hz, CHFu), 2.89 (1H, d, J=12.5 Hz, CH_2CCN), 2.55 (1H, d, J=12.5 Hz, CH_2CCN), 2.28 (1H, t, J=12.0 Hz, $C\mathit{H}_2CH$), 2.25 (1H, dd, J=12.0, 5.0 Hz, $C\mathit{H}_2CH$).

1.6.29. 5-Hydroxy-3-isopropyl-7-oxo-6-azabicyclo[3.2.1]-octane-1,2,2-tricarbonitrile (8h). (1.78 g, 69%) as a colorless solid, mp 175–176°C; [Found: C, 60.3; H, 5.5; N, 19.2. $C_{13}H_{14}N_4O_2$ requires C, 60.46; H, 5.46; N, 21.69%]; ν_{max}(Nujol) 3490, 3295, 2270, 1700, 1610 cm^{-1}; δ_H (300 MHz, DMSO) 9.22 (1H, s, NH), 7.0 (1H, s, OH), 2.7 (1H, d, J=12.5 Hz, CH_2CCN), 2.35 (1H, d, J=12.5 Hz, CH_2CCN), 1.9–2.17 (3H, m, $C\mathit{H}CH_2$, $CHC\mathit{H}_2$, $Me_2C\mathit{H}$), 1.65 (1H, m, $CHC\mathit{H}_2$), 1.13 (3H, d, J=6.5 Hz, $CHC\mathit{H}_3$), 1.1 (3H, d, J=6.5 Hz, $CHC\mathit{H}_3$). Crystal data for **8h**: $C_{13}H_{14}N_4O_2$, M=258.35, crystals are triclinic, at 293(2) K a=7.1370(10) Å, b=8.9260(10) Å, c=12.3780(10) Å,

α=94.095(10)°, β=90.830(10)°, γ=100.830(10)°, V=772.20(15) Å^3, d_{calcd}=1.240 g cm^{-3}, Z=2. The space group is *P*-1. Summary of Data CCDC 153642.

1.6.30. 3-Butyl-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8i). (2.15 g, 72%) as a colorless solid, mp 173–174°C; [Found: C, 61.8; H, 6.0; N, 20.5. $C_{14}H_{16}N_4O_2$ requires C, 61.75; H, 5.92; N, 20.58%]; ν_{max}(Nujol) 3440, 3370, 2270, 1705, 1610 cm^{-1}; δ_H (300 MHz, DMSO) 9.36 (1H, s, NH), 6.94 (1H, s, OH), 2.84 (1H, d, *J*=13.0 Hz, CH$_2$CCN), 2.42 (1H, d, *J*=13.0 Hz, CH$_2$CCN), 2.15 (1H, m, C*H*Bu), 2.04 (1H, dd, *J*=12.0, 4.0 Hz, C*H*$_2$CHBu), 1.86 (2H, m, CHC*H*$_2$Pr), 1.64 (1H, t, *J*=12.0 Hz, C*H*$_2$CHBu), 1.47(2H, m, C*H*$_2$Et), 1.28 (2H, m, CH$_2$C*H*$_2$CH$_3$), 0.91 (3H, t, *J*=6.5 Hz, C*H*$_3$).

1.6.31. 5-Hydroxy-7-oxo-3-phenyl-6-azabicyclo[3.2.1]-octane-1,2,2-tricarbonitrile (8j). (2.39 g, 82%) as a colorless solid, mp 210–211(decomp.)°C; [Found: C, 65.8; H, 4.2; N, 19.1. $C_{16}H_{12}N_4O_2$ requires C, 65.75; H, 4.14; N, 19.17%]; ν_{max}(Nujol) 3490, 3300, 2270, 1700, 1610 cm^{-1}; δ_H (300 MHz, DMSO) 9.34 (1H, s, NH), 7.4–7.6 (5H, m, Ph), 7.13 (1H, s, OH), 3.5 (1H, dd, *J*=12.5, 5.5 Hz, C*H*Ph), 2.83 (1H, d, *J*=13.0 Hz, CH$_2$CCN), 2.52 (1H, t, *J*=12.5 Hz, CHC*H*$_2$), 2.51 (1H, d, *J*=13.0 Hz, CH$_2$CCN), 2.09 (1H, d, *J*=12.5 Hz, CHC*H*$_2$).

1.6.32. 5-Hydroxy-8-methyl-7-oxo-3-phenyl-6-azabicyclo-[3.2.1]octane-1,2,2-tricarbonitrile (8k). (2.26 g, 74%) as a colorless solid, mp 224–225(decomp.)°C; [Found: C, 66.6; H, 4.8; N, 18.1. $C_{17}H_{14}N_4O_2$ requires C, 66.66; H, 4.61; N, 18.29%]; ν_{max}(Nujol) 3445, 3300, 2265, 1710, 1645 cm^{-1}; δ_H (300 MHz, DMSO) 9.28 (1H, s, NH), 7.7 (5H, m, Ph), 3.81 (1H, dd, *J*=12.0, 3.5 Hz, CHPh), 6.96 (1H, s, OH), 3.63 (1H, q, *J*=6.5 Hz, C*H*Me), 3.2 (1H, dd, *J*=12.0, 3.5 Hz, CH$_2$), 2.57 (1H, dd, *J*=12.0, 2.5 Hz, CH$_2$), 1.25 (3H, d, *J*=6.5 Hz, C*H*$_3$).

1.6.33. 5-Hydroxy-3-(4-methoxyphenyl)-8-methyl-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8l). (2.32 g, 69%) as a colorless solid, mp 226–227(decomp.)°C; [Found: C, 64.4; H, 4.8; N, 16.6. $C_{18}H_{16}N_4O_3$ requires C, 64.28; H, 4.79; N, 16.66%]; ν_{max}(Nujol) 3460, 3285, 2275, 1710, 1590 cm^{-1}; δ_H (300 MHz, DMSO) 9.17 (1H, s, NH), 7.45 (2H, d, *J*=8.5 Hz, *o*-Ph), 7.0 (2H, d, *J*=8.5 Hz, *m*-Ph), 6.88 (1H, s, OH), 3.48 (1H, dd, *J*=12.5, 5.0 Hz, CHAr), 2.7 (1H, q, *J*=6.5 Hz, C*H*CH$_3$), 2.46 (1H, t, *J*=12.5 Hz, CH$_2$), 2.17 (1H, dd, *J*=12.5, 5.0 Hz, CH$_2$), 1.3 (3H, d, *J*=6.5 Hz, CHC*H*$_3$).

1.6.34. 5-Hydroxy-3-methyl-7-oxo-6-azabicyclo[3.2.1]-octane-1,2,2-tricarbonitrile (8m). (1.68 g, 73%) as a colorless solid, mp 181–182°C; [Found: C, 57.4; H, 4.3; N, 24.5. $C_{11}H_{10}N_4O_2$ requires C, 57.39; H, 4.38; N, 24.34%]; ν_{max}(Nujol) 3500, 3335, 2260, 1710, 1595 cm^{-1}; δ_H (300 MHz, DMSO) 9.28 (1H, s, NH), 7.0 (1H, s, OH), 2.73 (1H, d, *J*=12.0 Hz, CH$_2$CCN), 2.42 (1H, m, CH$_3$C*H*), 2.33 (1H, d, *J*=13.5 Hz, CH$_2$CCN), 2.07 (1H, dd, *J*=12.0, 5.0 Hz, CHC*H*$_2$), 1.62 (1H, t, *J*=12.0 Hz, CHC*H*$_2$), 1.38 (3H, d, *J*=6.5 Hz, CHC*H*$_3$).

1.6.35. 3-Ethyl-5-hydroxy-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8n). (1.98 g, 81%) as a colorless solid, mp 185–186°C; [Found: C, 59.1; H, 4.9; N, 22.8. $C_{12}H_{12}N_4O_2$ requires C, 59.01; H, 4.95; N, 22.94%]; ν_{max}(Nujol) 3490, 3340, 2270, 1710, 1590 cm^{-1}; δ_H (300 MHz, DMSO) 9.2 (1H, s, NH), 7.0 (1H, s, OH), 2.72 (1H, d, *J*=12.0 Hz, CH$_2$CCN), 2.34 (1H, d, *J*=12.0 Hz, CH$_2$CCN), 2.1–2.25 (2H, m, C*H*$_2$CHEt, EtC*H*CH$_2$), 1.88 (1H, m, C*H*$_2$CH$_3$), 1.68 (1H, m, C*H*$_2$CH$_3$), 1.53 (1H, t, *J*=13.0 Hz, C*H*$_2$CHEt), 1.1 (3H, t, *J*=7.0 Hz, CH$_2$C*H*$_3$).

1.6.36. 5-Hydroxy-7-oxo-3-propyl-6-azabicyclo[3.2.1]-octane-1,2,2-tricarbonitrile (8o). (2.01 g, 78%) as a colorless solid, mp 184–185°C; [Found: C, 60.4; H, 5.4; N, 21.8. $C_{13}H_{14}N_4O_2$ requires C, 60.46; H, 5.46; N, 21.69%]; ν_{max}(Nujol) 3480, 3340, 2260, 1705, 1595 cm^{-1}; δ_H (300 MHz, DMSO) 9.2 (1H, s, NH), 7.0 (1H, s, OH), 2.73 (1H, d, *J*=13.0 Hz, CH$_2$CCN), 2.35 (1H, d, *J*=13.0 Hz, CH$_2$CCN), 2.25 (1H, m, C*H*Pr), 2.13 (1H, dd, *J*=12.0, 3.5 Hz, C*H*$_2$CH), 1.33–1.83 (5H, m, CHC*H*$_2$C*H*$_2$CH$_3$, C*H*$_2$CH), 1.0 (1H, t, *J*=6.5 Hz, CH$_2$C*H*$_3$).

1.6.37. 5-Hydroxy-7-oxo-3-pentyl-6-azabicyclo[3.2.1]-octane-1,2,2-tricarbonitrile (8p). (2.23 g, 78%) as a colorless solid, mp 185–186°C; [Found: C, 62.8; H, 6.4; N, 19.7. $C_{15}H_{18}N_4O_2$ requires C, 62.92; H, 6.34; N, 19.57%]; ν_{max}(Nujol) 3480, 3340, 2270, 1705, 1610 cm^{-1}; δ_H (300 MHz, DMSO) 9.3 (1H, s, NH), 7.08 (1H, s, OH), 2.79 (1H, d, *J*=12.0 Hz, CH$_2$CCN), 2.37 (1H, d, *J*=12.0 Hz, CH$_2$CCN), 2.22 (1H, m, C*H*Pn), 2.11 (1H, dd, *J*=13.0, 5.0 Hz, C*H*$_2$CHPn), 1.75 (2H, m, CHC*H*$_2$Bu), 1.65 (1H, dd, *J*=13.0, 12.0 Hz, C*H*$_2$CHPn), 1.55–1.25 (6H, m, CH$_2$C*H*$_2$C*H*$_2$C*H*$_2$CH$_3$), 0.99 (3H, t, *J*=6.5 Hz, CH$_2$C*H*$_3$).

1.6.38. 5-Hydroxy-3-(4-methoxyphenyl)-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8q). (2.06 g, 64%) as a colorless solid, mp 207–208(decomp.)°C; [Found: C, 63.1; H, 4.3; N, 17.3. $C_{17}H_{14}N_4O_3$ requires C, 63.35; H, 4.38; N, 17.38%]; ν_{max}(Nujol) 3490, 3295, 2270, 1700, 1590 cm^{-1}; δ_H (300 MHz, DMSO) 9.3 (1H, s, NH), 7.47 (2H, d, *J*=8.5 Hz, *o*-Ph), 7.1 (2H, d, *J*=8.5 Hz, *m*-Ph), 6.98 (1H, s, OH), 3.82 (3H, s, CH$_3$O), 3.43 (1H, dd, *J*=12.0, 5.0 Hz, CHAr), 2.8 (1H, d, *J*=12.0 Hz, CH$_2$CCN), 2.58 (1H, d, *J*=12.0 Hz, CH$_2$CCN), 2.47 (1H, t, *J*=12.0 Hz, CHC*H*$_2$), 2.05 (1H, dd, 12.0, 5.0, CHC*H*$_2$).

1.6.39. 1-Hydroxy-10-oxo-11-azatricyclo[7.2.1.0^{2,7}]dodecane-8,8,9-tricarbonitrile (8r). (1.4 g, 52%) as a colorless solid, mp 215–216(decomp.)°C; [Found: C, 62.2; H, 5.3; N, 20.7. $C_{14}H_{14}N_4O_2$ requires C, 62.21; H, 5.22; N, 20.73%]; ν_{max}(Nujol) 3480, 3300, 2270, 1725, 1600 cm^{-1}.; δ_H (300 MHz, DMSO) 9.65 (1H, s, NH), 7.6–7.4 (1H, m, PH), 7.0 (1H, s, OH), 2.97 (1H, m, C(OH)C*H*CH$_2$), 2.86 (1H, d, *J*=12.0 Hz, C(OH)C*H*$_2$), 2.73 (1H, d, *J*=12.0 Hz, C(OH)C*H*$_2$), 2.46 (1H, m, C*H*CH$_2$) 2.36–1.85 (8H, m, C*H*$_2$C*H*$_2$C*H*$_2$C*H*$_2$).

1.6.40. 5-Hydroxy-4-methyl-7-oxo-3-phenyl-6-azabicyclo-[3.2.1]octane-1,2,2-tricarbonitrile (8s). (2.54 g, 83%) as a colorless solid, mp 223–224(decomp.)°C; [Found: C, 66.7; H, 4.7; N, 18.3. $C_{17}H_{14}N_4O_2$ requires C, 66.66; H, 4.61; N, 18.29%]; ν_{max}(Nujol) 3525, 3340, 2270, 1705, 1615 cm^{-1}; δ_H (300 MHz, DMSO) 9.65 (1H, s, NH), 7.6–7.4 (1H, m, Ph), 7.0 (1H, s, OH), 2.97 (1H, d, *J*=11.5 Hz, C*H*Ph), 2.9

(1H, d, J=12.0 Hz, CH_2), 2.7 (1H, d, J=12.0 Hz, CH_2), 2.06 (1H, dq, J=11.5, 6.5 Hz, C*H*CH_3), 0.75 (3H, d, J=6.5 Hz, CHCH_3). Crystal data for **8s**: $C_{17}H16N_4O_3$, M=324.34, crystals are orthorombic, at 293(2) K a=11.628(2) Å, b=32.257(5) Å, c=8.641(2) Å, α=90°, β=90°, γ=90°, V=3242.9(11) $Å^3$, d_{calcd}=1.329 g cm^{-3}, Z=8. The space group is *Aba*2. Summary of Data CCDC 153641.

1.6.41. 4-Bromo-5-hydroxy-7-oxo-3-phenyl-6-azabicyclo-[3.2.1]octane-1,2,2-tricarbonitrile (8t). (2.78 g, 75%) as a colorless solid, mp 246–247°C; [Found: C, 51.7; H, 3.3; N, 15.0. $C_{16}H_{12}N_4O_2Br$ requires C, 51.63; H, 3.25; N, 15.05%]; ν_{max}(Nujol) 3450, 3330, 2280, 1710, 1625 cm^{-1}; δ_H (300 MHz, DMSO) 10.0 (1H, s, NH), 7.45–7.67 (6H, m, Ph, OH), 5.15 (1H, d, J=11.5 Hz, CHBr), 3.57 (1H, d, J= 11.5 Hz, CHPh), 3.12 (1H, d, J=12.5 Hz, CH_2), 2.95 (1H, d, J=12.5 Hz, CH_2).

1.6.42. 5-Hydroxy-3-(4-methoxyphenyl)-4-methyl-7-oxo-6-azabicyclo[3.2.1]octane-1,2,2-tricarbonitrile (8u). (2.65 g, 79%) as a colorless solid, mp 228–229(decomp.)°C; [Found: C, 64.3; H, 4.8; N, 16.7. $C_{18}H_{16}N_4O_3$ requires C, 64.28; H, 4.79; N, 16.66%]; ν_{max}(Nujol) 3450, 3330, 2280, 1710, 1625 cm^{-1}; δ_H (300 MHz, DMSO) 9.60 (1H, s, NH), 7.43 (2H, d, J=8.5 Hz, *o*-Ph), 7.0 (2H, d, J=8.5 Hz, *m*-Ph), 6.94 (1H, s, OH), 3.83 (3H, s, CH_3O), 2.92 (1H, d, J=12.5 Hz, CHAr), 2.86 (1H, d, J=13.0 Hz, CH_2), 2.67 (1H, d, J=13.0 Hz, CH_2), 2.50 (1H, m C*H*Me), 0.77 (3H, d, J=6.5 Hz, CHCH_3).

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