Synthesis of some substituted adamantane-2,4-diones from 4, 4-disubstituted cyclohexanone enamines and methacryloyl chloride

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The reaction of methacryloyl chloride with the morpholine enamine **4a** derived from 4-acetyl-4-isopropenylcyclohexanone **3a** gave 4,6-anti-6-hydroxy-5,6-dimethyl-7-isopropenyladamantane-2,4-dione **6a** and 4,6-syn-6-hydroxy-5,6-dimethyl-7-isopropenyladamantane-2, 4-dione **7a** as racemates epimeric at 6-C. Comparable results were found for the corresponding phenyl and benzyl substituted cyclohexanones **3b** and **3c**. In the case of the methyl-substituted cyclohexanone **3d** 4,6- anti-alcohol **7d** was isolated in pure form.

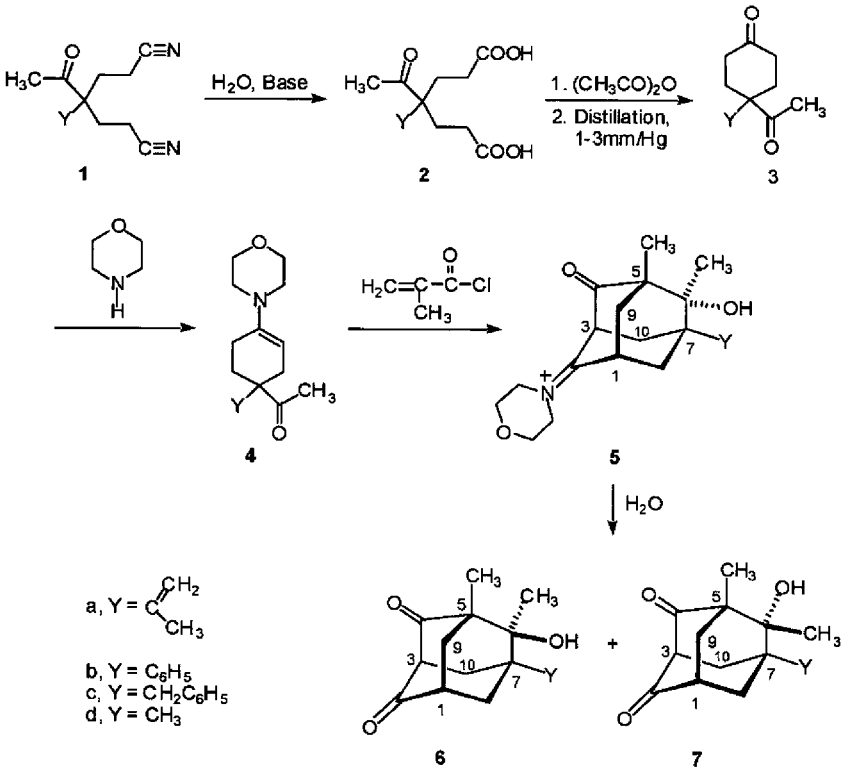
Keywords: adamantane-2,4-diones 4,4-disubstituted cyclohexanone enamines, methacryloyl chloride

A literature review shows that besides the interesting chemistry of adamantane derivatives from both the mechanistic and synthetic points of view, suitably substituted adamantanes also show considerable biological activity.[1-5] With this background, we have been extending our work on the synthesis of substituted adamantane-2,4-diones.

In continuation of our previous reports[6-8] on the synthesis of substituted adamantane-2,4-diones, we now report the synthesis of seven new substituted adamantane-2,4-diones. The synthesis is based on a general reaction of 4,4-disubstituted cyclohexanone enamines with methacryloyl chloride.

For this synthesis, we first prepared 4,4-disubstituted cyclohexanones **3a–d** following literature methods[8-10] in which one of the substituents is an acetyl group (Scheme 1). The corresponding enamines **4a–d** were prepared in accordance with the general procedure reported earlier[6,7] without using any catalyst.

The morpholine enamine **4a**, reacted with methacryloyl chloride yielding a mixture of isomeric 6-hydroxy-5,6-dimethyl-7-isopropenyladamantane-2,4-diones **6a** and **7a** which are epimeric at position 6. For reference alcohols in the series 6 are named as the 4,6-anti alcohols and those with



Scheme 1

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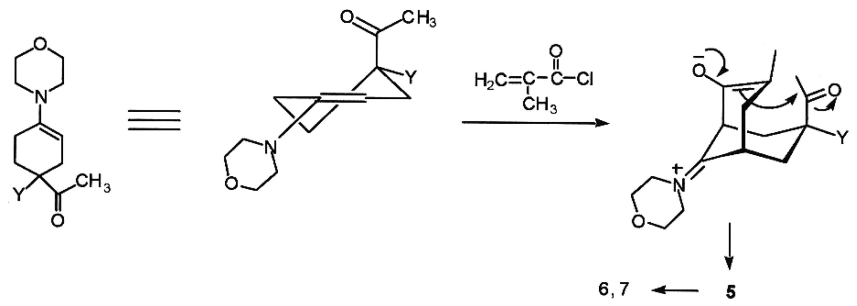

Scheme 2

7 series as the 4,6-syn alcohols depicting the orientation of the 6-hydroxy group with respect to the 4-ketone. The reaction of **4b** with methacryloyl chloride also yielded a mixture of the epimeric adamantanediones, 6-hydroxy-5,6-dimethyl-7-phenyladamantane-2,4-diones **6b** and **7b**. The same acid chloride reacted with **4c** to give two epimeric adamantanediones, 6-hydroxy-5,6-dimethyl-7-benzyladamantane-2,4-diones **6c** and **7c**. Methacryloyl chloride reacted with **4d** to give 4,6-syn-6-hydroxy-5,6,7-trimethyladamantane-2, 4-dione **7d** in pure form.

All the aforementioned adamantane -2,4-diones are racemic but only one enantiomer is shown (Scheme 1). The adamantanediones were obtained as pure racemates with the 4,6-anti configuration in **6a, 6b** and **6c** and the 4,6-syn configuration in the compounds **7a, 7b, 7c** and **7d**.

The formation of adamantanediones **6a, 7a, 6b, 7b, 6c, 7c** and **7d** may be explained, by analogy with the reported mechanism,[11-13] by the axial attack of the acid chloride syn to the acetyl group shown in the conformation of the enamine **4** (Scheme 2). The structures of compounds **6a, 7a, 6b, 7b, 6c, 7c** and **7d** were determined by their elemental analysis, IR spectra ^{1}H and ^{13}C NMR, ^{1}H—^{1}H NMR COSY, ^{1}H—^{13}C NMR COSY, HMBC and DEPT. The stereochemistry at position 6-C of **6a** was further clarified with the help of NOESY. X-ray crystallography afforded additional proof for the structures **6b** and **7c.**

The ^{1}H NMR spectral data and the corresponding coupling constants of the compounds **6a, 7a, 6b, 7b, 6c, 7c** and **7d** are presented in Tables 1 and 2 respectively. By running two-dimensional (^{1}H—^{1}H, COSY and ^{1}H—^{13}C, COSY) NMR spectra it was possible to assign all the protons in these compounds and the corresponding coupling constants were determined from one-dimensional ^{1}H NMR spectral data.

Of the alicyclic part 3-H resonated downfield considerably (δ 3.00-3.54) in all compounds. This is because the protons at 3-C are adjacent to two carbonyl groups. The 9-H protons in compounds assigned in the Table 1 are shifted downfield[11,14,15] due to 1,3-diaxial interaction with the axial OH at position 6 in **6a**, **6b** and **6c**. Similar 1,3-interaction with the axial 6-CH_3 provides smaller deshielding effect[11,16] in **7a,7b, 7c** and **7d**.

The stereochemistry of the 6- and 5- positions of compound **7a** also became clear from its NOESY. In NOESY the intensity of the peak 5-CH_3 was affected significantly upon the irradiation of 6-CH_3 protons in **7a**. This clearly shows that

Table 1 ^{1}H NMR spectral data of the adamantanediones **6a**, **7a**, **6b**, **7b**, **6c**, **7c** and **7d** (chemical shifts in δ)

Protons	6a	7a	6b	7b	6c	7c	7d
1-H	2.69	2.75	2.80	2.92	2.61	2.67	2.68
3-H	3.38	3.39	3.54	3.53	3.33	3.00	3.37
8-H^e	2.89	2.43	3.28	2.86	2.39	2.92	2.10
8-H^a	1.78	2.20	1.94	2.43	1.54	2.62	2.00
9-H^e	2.49	1.95	2.63	2.11	2.42	1.96	1.96
9-H^a	1.25	1.49	1.37	1.57	1.26	1.49	1.50
10-H^e	2.40	3.07	2.82	3.48	2.95	2.65	2.72
10-H^a	2.19	1.98	2.38	2.16	2.64	1.67	1.89
6-OH	1.30	1.58	1.56	1.63	1.67	1.76	1.66
5-CH_3	1.12	1.14	1.17	1.21	1.14	1.15	1.14
6-CH_3	1.13	1.31	0.92	1.09	1.31	1.49	136
7-C_6H_5	–	–	7.25–7.41(m)	7.26–7.43(m)	7.06–7.28 (m)	7.04–7.28(m)	–
7-$CH_2C_6H_5$	–	–	–	–	2.06	2.07	–
7-C–H^c	8.84	8.84	–	–	–	–	–
7-C–H^t	5.09	5.09	–	–	–	–	–
7-C–CH_3	1.87	1.86	–	–	–	–	–
7-CH_3	–	–	–	–	–	–	0.99

Table 2 Coupling constants (*J* in Hz) of the adamantanediones **6a**, **7a**, **6b**, **7b**, **6c**, **7c** and **7d**

Protons	6a	7a	6b	7b	6c	7c	7d
8H^a, 1H	2.0	2.8	2.5	2.8	2.3	2.6	2.75
8H^e, 1H	3.0	3.5	3.65	3.4	2.7	2.9	3.05
8H^a, 8H^e	13.5	13.6	13.2	13.0	13.2	13.1	13.75
9H^a, 1H	–	2.7	2.5	2.8	2.3	2.7	2.75
9H^e, 1H	3.0	2.9	2.9	2.9	2.75	2.8	3.05
9H^a, 9H^e	13.75	14.3	13.7	14.1	13.6	14.2	14.35
10H^a, 3H	3.0	2.3	2.8	2.5	2.9	2.9	2.75
10H^e, 3H	4.0	3.9	3.1	3.8	2.9	2.6	3.65
10H^a, 10H^e	13.75	12.9	13.3	12.6	13.15	12.9	12.9
8H^e, 10H^e	4.0	4.2	3.7	4.2	–	–	4.3

Table 3 ^{13}C NMR spectral data of the adamantanediones **6a**, **7a**, **6b**, **7b**, **6c**, **7c** and **7d** (chemical shifts in δ)

Carbons	**6a**	**7a**	**6b**	**7b**	**6c**	**7c**	**7d**
1-C	44.76	44.59	44.83	44.60	44.64	44.62	44.80
2-C	208.45	208.22	208.14	207.84	207.84	207.71	
208.40							
3-C	65.81	66.35	65.91	66.31	66.04	66.33	66.73
4-C	206.33	206.67	206.16	206.46	206.75	207.33	
207.17							
5-C	54.74	53.87	54.85	53.90	54.99	53.93	53.53
6-C	77.35	80.32	76.50	80.40	78.35	80.08	80.32
7-C	44.92	45.05	44.30	44.33	40.80	40.97	37.84
8-C	38.15	39.37	38.80	39.58	36.02	39.44	42.26
9-C	33.00	34.47	33.08	34.71	33.06	34.57	34.90
10-C	40.57	42.50	40.49	42.88	39.61	41.37	44.89
5-CH_3	15.16	15.33	15.40	15.42	15.25	15.32	15.10
6-CH_3	21.09	19.74	21.16	19.80	19.64	18.08	18.51
7-CH_3	–	–	–	–	–	–	20.74
7-C_6H_5	—	–	141.27(C)	141.07(C_1)	–	–	–
			128.24(C)	128.24(C_2)			
			127.63(C)	127.40 (C_2)			
			127.19(C)	127.12(C_1)			
7-$CH_2C_6H_5$	–	–	–	–	40.24	38.66	–
7-$CH_2C_6H_5$	–	–	–	–	136.65(C_1)	136.67(C_1)	
					130.69(C_2)	130.64(C_2)	
					128.20 (C_2)	128.22 (C_2)	
					126.66(C_1)	126.67(C_1)	
7-C-CH_3	23.39	23.38	–	–	–	–	–
7-C-CH_2	146.91	146.71	–	–	–	-	–
7-C-CH_2	115.42	115.39					

the CH_3 groups at the 5-and 6-positions in the ring (567819) are in close proximity indicating their relative equatorial-axial conformation. The irradiation of the axial 6-CH_3 in **7a** (567819) affected the intensities of the peaks of 8-H axial and 9-H axial remarkably. This is confirming further the axial conformation of 6-CH_3 with respect to the ring (567819). Likewise in the 6-series compounds the conformational relationship of the CH_3-groups should be equatorial-equatorial.

In ^{13}C NMR spectral data, the chemical shift values for 6-C and 6-CH_3 carbons (Table 3) of the compounds **6a, 6b**, and **6c**, compare well with the reported[17] values of δ 73.80 and 27.50 for 2-C and 2-CH_3 of 2-methyl-2-adamantanol where OH is axial and CH_3 is equatorial. 6-C of **6a, 6b** and **6c** resonated δ 2.97, δ3.9 and δ1.73 ppm up-field than that of the corresponding epimers **7a, 7b** and **7c** respectively, probably due to shielding operating in **6a**, **6b** and **6c** resulting from steric compression[18] between the axial OH at 6-C and equatorial isopropenyl, phenyl and benzyl groups respectively at the adjacent bridgehead position (7-C).

The evidence in support to the axial orientation of the OH group at position 6 in the relevant compounds is also provided by downfield shift (1.69—3.67ppm) of 10-C in comparison to 8-C in these compounds by the γ-anti effect.[19] This downfield γ-anti SCS (Substitution chemical shift) due to the OH substituent at 6-C increased by 3.13 ppm in the case of **7a** and by 3.30 ppm in the case of **7b** indicating their OH equatorial orientation where the hetero atom O, C_α, C_β, C_γ and H_δ were compressed in the same plane.[19] The CH_3 group either axial or equatorial would have very little SCS due to γ-anti effect. Downfield shift due to the γ-anti effect by 1.47 ppm, 1.63 ppm and 1.51 ppm of 9-C has been observed in the cases of **7a, 7b** and **7c** as compared to those in **6a, 6b** and **6c** respectively. It may be mentioned that in the parent hydrocarbon the bridgehead and methylene carbons resonate[20] at δ 28.50 and 37.80 respectively. The downfield shift of the 1, 5 and 7 carbons in all these compounds were observed due to SCS effect. The NMR spectral data compare well with those of structures reported earlier.

Table 4 Crystallographic data for structure (**6b**)

Crystal data	
Empirical formula	$C_{18}H_{20}O_3$
Formula weight	284.35
Crystal colour, habit	Colourless, needle
Crystal dimensions (mm)	0.50 x 0.25 x 0.25
Crystal system	Monoclinic
Lattice type	Primitive
Indexing images	6 oscillations @ 5.0 s
Detector position	54.42 mm
Pixel size	0.068 mm
Lattice parameters	*a*= 6.6495 (8)Å
	b=29.963 (3) Å
	c=15.426 (2) Å
	β = 108.633 (4)°
	V=2912.3 (6) Å^3
Space group	$P2_1$ (#4)
Z value	8
D_{calc}	1.297 g/cm^3
*F*ooo	1216.00
μ (MoKα)	0.87 cm^{-1}

X-ray analysis

The crystal of the compound **6b** is monoclinic (Table 4) with four molecules per unit-cell. All atoms are in general positions. The ORTEP diagram of this compound is shown in Fig. 1.

The numbering of carbons in the structures of the adamantane derivatives mentioned in the present paper is different from those in ORTEP diagram. The numbering of the equivalent carbons is shown below

Numbering in the paper	Numbering in ORTEP diagram	Numbering in the paper	Numbering in ORTEP diagram	Numbering in the paper	Numbering in ORTEP diagram
C_1	C_7	C_5	C_3	C_9	C_{10}
C_2	C_8	C_6	C_4	C_{10}	C_9
C_3	C_1	C_7	C_5		
C_4	C_2	C_8	C_8		

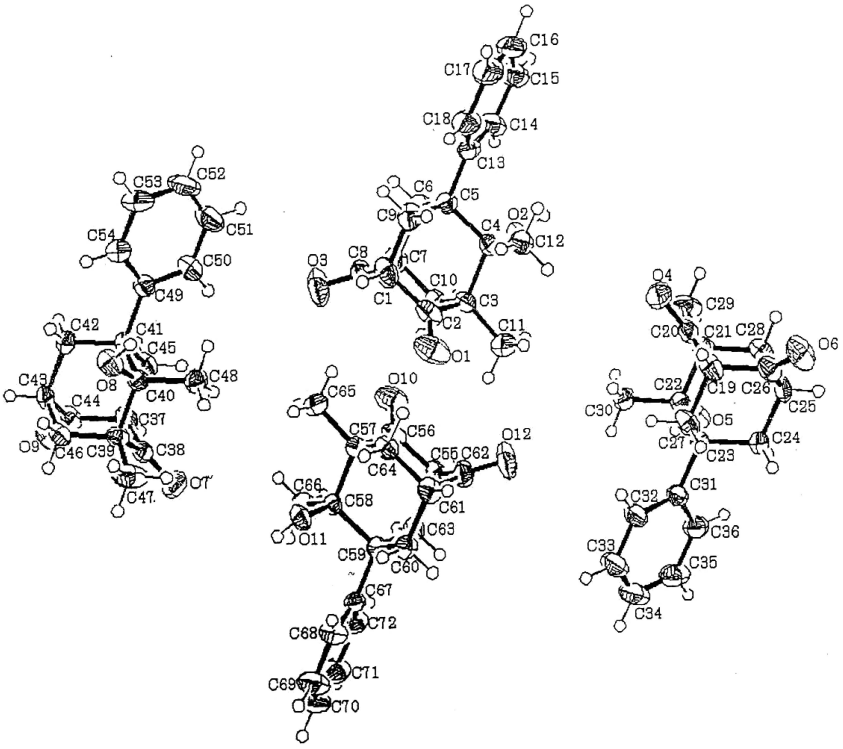

Fig. 1 Structure of **6b**.

The general details of the structure **7c** determination are summarised in Table 5. Figure 2 shows the ORTEP stereoscopic view of the compound **7c**.

The numbering of carbons in the structures of the adamantine derivatives mentioned in the present paper is different from those in ORTEP diagram. The numbering of the equivalent carbons is shown below.

Numbering in the paper		Numbering in diagram	Numbering in the paper		Numbering in diagram	Numbering in the paper		Numbering in diagram
C_1	≡	C_3	C_5	≡	C_{10}	C_9	≡	C_8
C_2	≡	C_2	C_6	≡	C_9	C_{10}	≡	C_6
C_3	≡	C_1	C_7	≡	C_5			
C_4	≡	C_7	C_8	≡	C_4			

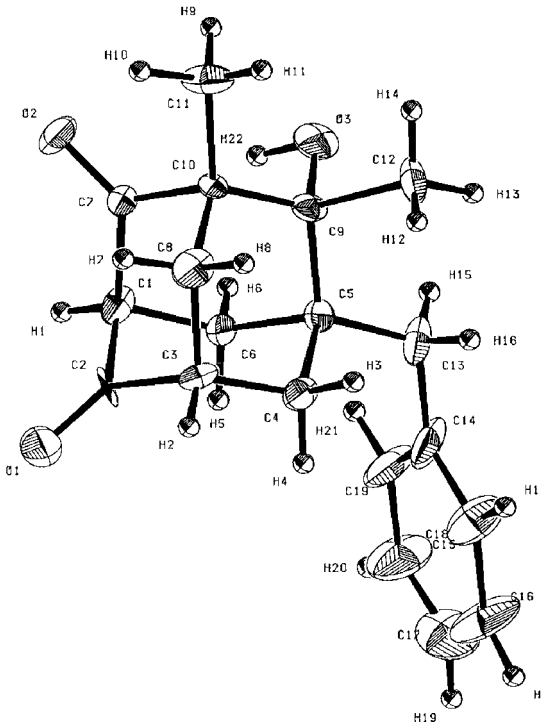

Fig. 2 Structure of **7c**.

Experimental

^{1}H and ^{13}C NMR spectra were recorded on Bruker 500 MHz and 300 MHz instruments at the University of Wisconsin-Milwaukee, Department of Chemistry, USA. A number of NMR spectra were also recorded on JEOL 500 MHz and 400 MHz instruments at the Kyoto, Kanazawa and Showa Pharmaceutical Universities in Japan. Some of NMR and mass spectra were also recorded at the H.E.J Research Institute of Chemistry, Karachi University, Pakistan and a number of mass spectra were also recorded in the Department of Chemistry, University of George Mason University, USA. All ^{1}H and ^{13}C NMR spectra were recorded in $CDCl_3$ if not otherwise mentioned. IR spectra were run as KBr pellets in the case of solids and solution in the case of liquids; sequences of absorptions are expressed in cm^{-1} For column chromatography silica gel 100 (supplied by E Mark) and light petroleum (60─80°): chloroform = 10: 1 were used.

X-ray experiments were performed at the University of Kanazawa in Japan. In each case a suitable size of crystal was chosen for the X-ray diffraction studies. The crystal was mounted on a glass fibre. Intensity data were measured in a RIGAKU AFCSR four circle diffractometer with graphic monochromated cuKα radiation (λ = 0,71069 Å) and a 12 kW rotating anode generator using ω–2θ scan technique at a temperature of 23 ±1°C to a maximum of 2θ value of 120.0°. The intensities were reduced and corrected for Lorentz and polaristion effects by routine procedures. No decay and absorption corrections were applied. The structure was solved by the direct method.[21] The non-hydrogen atoms were refined anisotropically. The final cycle of full-matrix least-squares refinement was based on 700 observed reflections (I>3.00 σ (I)) and 199 variable parameters and converged (largest parameter shift was 0.11 times its ESD) with unweighted and weighted agreement factors of:

Table 5 Crystallographic data and refinement details for structure (**7c**)

A. Crystal data	
Empirical formula	$C_{19}H_{22}O_3$
Formula weight	298.38
Crystal colour, habit	Colourless, needle
Crystal dimensions (mm)	0.100 × 0.100 × 0.300
Crystal system	Orthorhombic
No. Reflections used for unit cell determination (2j range)	5(29.8–38.0°)
Omega scan peak width at half-height	0.36
Lattice parameters	*a*= 8.0932 (8)Å *b*=23.559 (6) Å *c*=7.6044 (9) Å *v*=1593.2 (4) Å^3
Space group	$P2_12_12_1$ (#19)
Z value	4
D_{calc}	1.244 g/cm^3
*F*ooo	640
μ (CuKα)	6.26 cm^{-1}
B. Intensity measurements	
Diffractometer	Rigaku AFC5R
Radiation	CuKα (λ =1.54178Å)
Temperature	23°C
Attenuators	Ni foil (factors=3.0,8.1,23.4)
Take –off angle	6.0°
Detector aperture	6.0 mm (horizontal), 6.0 mm (vertical)
Crystal to detector distance	40 cm
Scan type	ω-2θ
Scan rate	6.0°/ min (in omega) (2 rescans)
Scan width	(0.84+0.30 tanθ)°
$2\theta_{max}$	120.0
No. of reflections measured	Total : 1416
Corrections	Lorentz-polarisation
C. Structure solution and refinement	
Structure solution	Direct methods
Refinement	Full-matrix least-squares
Function minimised	∑ w (|Fo| -|Fo|)^2
Least-square weight	4Fo^2/σ^2 (Fo)^2
P-factor	0.03
Anomalous dispersion	All non-hydrogen atoms
No. observation	700
No. variables	199
Reflection/parameter ratio	3.52
Residuals: *R*; R_w	0.117, 0.129
Goodness of fit indicator	4.09
Max. shift/error in final cycle	0.11
Maximum peak in final diff. map	–0.42e^{-1}/Å^3
Minimum peak in final diff.map	–0.46e^{-1}/Å^3

$$R = \sum | \, | Fo| - | Fc| \, | \, / \sum | Fo| = 0.117$$

$$R_w = [(\sum w (| Fo |) - (| Fc^2 |)^2 / \sum w Fo^2)]^{1/2} = 0.129$$

The standard deviation of an observation of unit weight was 4.09. The weighting scheme was based on counting statistics and included a factor (P = 0.03) to down weight the intense reflections. Plots of $\sum w (| F_o |) - (| F^2 |)^2 / | Fo|$, reflection order in data collection, sinθ / λ, and various classes of indices showed no unusual trends. The maximum and minimum peaks on the final difference Fourier map corresponded to 0.42 and −0.46e^{-1}/Å^1 respectively. Neutral atom scattering factors were taken from Cromer and Waber.[22] Anomalous dispersion effects were included in *F*calc[23]; the values for Δf′ and Δf″ were those of Cromer.[24] All calculations were performed using the TEXSAN[25] crystallographic software package of the Molecular Structure Corporation.

Preparation of 4,4-disubstituted cyclohexanones: 4-Acetyl-4-isopropenylcyclohexanone (**3a**),[9] 4-acetyl–4-phenylcyclohexanone (**3b**),[10] 4-acetyl-4 benzylcyclohexanone (**3c**),[6] 4-acetyl-4-methylcyclohexanone (**3d**)[9] and their precursors (**1a**),[26] (**2a**),[26] (**1b**),[27] (**2b**),[27] (**1c**),[6] (**2c**),[6] (**1d**)[27] and (**2d**)[27] were prepared essentially by following the literature methods.

Preparation of enamines: general method: A mixture of the 4, 4-disubstituted cyclohexanone (17.47—32.2 mmol) and a slight excess of morpholine (17.47—32.2 mmol) in toluene (75—80 ml) was heated to reflux under a Dean and Stark head for 12 h. On cooling, the solvent and the excess of morpholine were removed under reduced pressure and the crude enamine was used without further purification since extensive decomposition occurred on distillation. In this way the following enamines were obtained.

4-Acetyl-4-isopropeniyl-1-morpholinocychohexene (**4a**), γ_{max} in cm^{1}: 1700 (C=O) 1655, 1638 (C=C)

4-Acetyl-4-phenyl-1-morpholinocyclohexene (**4b**), γ_{max} in cm^{-1}: 1700 (C=O), 1638 (C=C)

4-Acetyl-4-benzyl-1-morpholinocyclohexene **(4c**), γ_{max} in cm^{-1}: 1700 (C=O), 1638 (C=C).

4-Acetyl-4-methyl-1-morpholinocyclohexene (**4d**), γ_{max} in cm^{-1}: 1700 (C=O), 1638 (C=C).

Synthesis of 4,6-anti-6-hydroxy-5,6-dimethyl-7-isopropenyladamantane–2,4-dione (**6a**), *4,6-syn-6-hydroxy-5,6-dimethyl-7-isopropenyl-adamantane-2, 4-dione* (**7a**), *4,6-anti-6-hydroxy-5, 6-dimethyl-7-phenyladamantane-2,4-dione* (**6b**), *4,6-syn-6-hydroxy-5,6-dimethyl-7-phenyladamantane-2,4-dione* (**7b**),*4,6-anti-6-hydroxy-5,6-dimethyl-7-benzyladamantane-2,4-dione* (**6c**), *4,6-syn-6-hydroxy-5,6-dimethyl-7-benzyladamantane-2,4-dione* (**7c**) *and 4,6-syn-6-hydroxy-5,6,7-trimethyladamantane-2,4-dione* (**7d**).

General method: The methacryloyl chloride (21.72—35.40 mmol) in dry toluene (40—45 ml) was added dropwise to a boiling solution of the enamine (21.5—35.45 mmol) in dry toluene (130—160 ml) over 2 h. During the addition a solid was slowly precipitated from

the reaction mixture. The mixture was then heated under reflux with stirring for 5h, cooled and the precipitated iminium salt was filtered off, washed with dry toluene and hydrolysed by stirring with ice cold water (50 ml) for 10 h. The crude adamantane derivatives were isolated by extraction with ether (5 × 25 ml) and purified with the help of column chromatography (silica gel column) and were eluted initially with light petroleum (60─80 °C) followed by gradual addition of chloroform. The following results were obtained:

Methacryloyl chloride reacting with (**4a**) gave a 15% yield of one isomer (**6a**) and a 10% yield of another isomer (**7a**) which were separated in pure forms with the help of column chromatography. The compound (**6a**), m.p. 120─121 °C, R_f in TLC 0.56 (chloroform and ethyl acetate, 6: 1); IR γ_{max}: 3500(OH), 1725, 1700(C=O). Ms *m/z* 248 (M^+), 205, 173, 163, 121, 93, 55, 43, 15.

Anal. Calcd for C_{15} $H_{20}O_3$: C,72.5; H,8.1 Found: C, 72.8; H, 8.15%

The compound (**7a**) m.p. 139─140 °C, R_f in TLC 0.47 (chloroform and ethyl acetate, 6:1); IRγ_{max} 3400(OH), 1725, 1695 (C=O). MS *m/z* 248 (M^+), 233, 205, 191, 163, 124, 93, 55, 43, 15.

Anal. Calcd for $C_{15}H_{20}O_3$: C, 72.6; H, 8.1%. Found: C, 72.3; H, 8.1%.

Methacryloyl chloride reacting with (**4b**) gave a 14% yield of one isomer (**6b**) and a 10% yield of another isomer (**7b**), which were separated in pure forms with the help of column chromatography. The compound (**6b**), m.p. 173─174 °C, R_f in TLC 0.52 (chloroform and ethyl acelate 5:1); IR γ_{max}: 3492 (OH), 1725, 1700 (C=O), MS *m/z* 284 (M^+), 241, 223, 171, 144, 129, 91, 55, 43, 15.

Anal. Calcd for $C_{18}H_{20}O_3$: C, 76.0; H, 7.0%. Found: C, 75.6; H, 7.0%.

The compound **(7b),** m.p. 182─183 °C, R_f in TLC 0.42 (chloroform and ethyl acetate 5:1); IRγ_{max} 3450 (OH), 1725, 1700 (C=O). MS *m/z* 284 (M^+), 269, 241, 195, 171, 144, 129, 91, 55, 43, 18.

Anal. Calcd for $C_{18}H_{20}O_3$: C, 76.0; H, 7.0%. Found: C, 74.70; H, 7.0%.

Methacryloyl chloride reacting with (**4c**) gave a 14% yield of one isomer (**6c**) and a 12% yield of another isomer (**7c**), which were separated in pure form with the help of column chromatography. The compound (**6c**), m.p. 140─141 °C, R_f in TLC 0.51 (chloroform and ethyl acetate 5:1); IR$_{\gamma max}$: 3505 (OH), 1730, 1695(C=O). MS *m/z* 298 (M^++1), 255, 207, 189, 179, 165, 149, 137, 131, 115, 107.

The compound (**7c**), m.p. 192─193 °C, R_f in TLC 0.47 (chloroform and ethyl acetate 5:1), IR$_{\gamma max}$: 3400 (OH), 1720, 1692 (C=O). MS *m/z* 298 (M^++1), 255, 207, 189, 184, 165, 149, 137, 131, 115, 105.

As there are no elemental analyses for **6c** and **7c** these structural assignments must be regarded formally as tentative.

Methacryloyl chloride reacting with (**4d**) gave a 10% yield of (**7d**), which was isolated in pure form with the help of column chromatography, m.p. 192─193 °C, R_f in TLC 0.42 chloroform and ethyl acetate 5:1); IR$_{\gamma max}$: 3400(OH), 1722, 1698(C=O). MS *m/z* 22 (M^+), 179, 141, 121, 109, 55, 15.

Anal. Calcd for C_{13} $H_{18}O_3$: C, 70.3; H, 8.1%. Found: C, 70.1; H, 8.2%.

CCDC contains the supplementary crystallographic data for this paper. They can be obtained free of charge from the Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request.cif

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