Studies with tissue cultures of the Chinese herbal plant, *Tripterygium wilfordii*. Isolation of metabolites of interest in rheumatoid arthritis, immunosuppression, and male contraceptive activity

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This paper is dedicated to Professor Zdenek (Denny) Valenta on the occasion of his 65th birthday

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A detailed study of metabolites produced by the plant cell culture line of *Tripterygium wilfordii*, a Chinese herbal plant, is presented. Eighteen compounds within the diterpene and triterpene families have been isolated and fully characterized. Of these, five are novel compounds, and their structures were determined by a combination of spectral analysis, chemical correlation and single crystal X-ray diffraction. The interest of these compounds in the treatment of rheumatoid arthritis, skin allergies, and for male contraception is noted.

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On rapporte une étude détaillée des métabolites produits par une lignée de culture cellulaire du *Tripterygium wilfordii*, un plante galénique chinoise. On a isolé et caractérisé 18 composés des familles des di- et des triterpènes. Cinq de ces produits sont de nouveaux composés; on a déterminé leur structure par une combinaison d'analyses spectrales, de corrélations chimiques et de diffraction des rayons X par des cristaux uniques. On a noté l'intérêt de ces composés pour le traitement de l'arthrite rhumatismale, d'allergies de la peau et comme contraceptifs pour les males.

[Traduit par la rédaction]

Tripterygium wilfordii Hook f is a perennial twining vine of the family Celastraceae, which is cultivated in many parts of southern China such as Zhejiang, Anhui, Jiangxi, Fujian, and Guangdong provinces and also in Taiwan. The herb is commonly known in China as Lei Gong Teng (Thunder God vine) or Mang Cao (rank grass). Its use in Chinese traditional medicine dates back many centuries, and it is first mentioned in the Saint Peasant's Scripture of Materia Medica (1), written about two thousand years ago, as being used for the treatment of fever, chills, oedema, and carbuncle. Chinese gardeners used the powdered root to protect their crops from chewing insects. Most recently, crude extracts and refined extracts (a so-called multi-glycoside extract, or GTW) have been used increasingly to treat such disorders as rheumatoid arthritis, ankylosing spondilitis, and a variety of dermatological disorders (2-4).

In 1972, Morris Kupchan *et al.* first isolated the novel diterpenoid triepoxides, tripdiolide (1), triptolide (2), and triptonide (2a) from the roots of *Tripterygium wilfordii* (5) and showed that 1 and 2 have significant antileukaemic activity. The biological properties of 1 and 2 stimulated studies in our laboratory directed at developing a plant cell culture line that would hopefully produce these compounds in higher yield and under laboratory controlled conditions. The earlier studies, with these objectives in mind, have been published (6, 7) and the stable cell line, coded as TRP4a, was shown to produce 1 in yields 40 times that of the living plant. As these studies were underway, we became aware of more recent research data from various laboratories in the People's Republic of China that revealed an increasing interest in the clinical use of extracts from T. wilfordii plants. Various disorders (rheumatoid arthritis, skin disorders) have been treated with hot water or alcohol extracts of the dried root xylem (8). Toxic side effects are minimal (9-12).

Observed effects of these extracts on the reproductive system have stimulated a great deal of research, particularly relating to the male reproductive system, and their possible use as a birth control agent. Studies in animals (13-15) and in humans (16-18) have provided considerable encouragement for the development of a novel non-steroidal male contraceptive agent.

In view of the increased current interest, the present investigation is aimed at a more comprehensive investigation of the metabolites present in the tissue culture cell line TRP4a than that published earlier (6, 7).

To isolate sufficient quantities of extracts (and later, metabolites) from the tissue culture cells (TRP4a cell line) for biological screening, it was necessary to produce large-scale quantities of the suspension culture. Batch fermentations were carried out on 10-17 L scale in glass or in steel air-lift fermentors. Suspension cultures were grown according to the procedure described earlier (6, 7). The cells were separated from the spent medium (that is, the supernatant liquid obtained after cells were removed by filtration).

A general extraction procedure was developed in which the cells and the spent medium were extracted separately (Figs. 1 and 2).

Samples of the extracts from an initial 15-L bioreactor experiment (TRP#221, Tables 1 and 2) were submitted for preliminary screening of biological activity to laboratories in Shanghai and Nanjing, People's Republic of China (see Acknowledgement). Assays for immunosuppressive activity and antifertility activity were carried out.

The results of the preliminary screening of the crude extracts showed that the ethyl acetate extracts had both immunosuppressive activities and antifertility activity while the methanol extracts were inactive in both cases.

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Three further batches of the TRP4a cell suspension cultures were grown and harvested in the same way (Table 1). Extraction of the cells and the spent medium was carried out as above to give ethyl acetate and methanol extracts (Table 2). These data illustrate the relative weights of the extracts (EtOAc and MeOH) obtained to illustrate the production capabilities of the stable TRP4a cell line. The ethyl acetate extracts from batches TRP#222, TRP#224, and TRP#225 were combined to give 3.73 g of cell extract and 1.71 g of spent medium extract. The methanol extracts were not further investigated since no biological activity of interest was detected. The ethyl acetate extracts were subjected to partial separation in order to give crude fractions for further preliminary biological screening.



Partial separation of the cell extract was carried out by vacuum liquid chromatography (vlc) as described by Pelletier *et al.* (19) and Coll and Bowden (20) (see Experimental) to afford eight crude fractions containing complex mixtures of metabolites. Fractions 2–7 were yellow to orange-brown solids containing sterols, diterpenes, and triterpenes (0.39, 0.27, 0.27, 0.51, 0.29, and 0.18 g respectively). Fraction 8 was a dark brown solid (1.22 g) containing the polar material.

Biological screening of the fractions showed that fractions 6 and 7 were active in antifertility and in inhibition of lymphocyte proliferation (immunosuppressive activity). Further studies, as noted below, revealed that fractions 6 and 7 contained triterpenes as the major constituents.

Partial separation of the spent medium extract was similarly conducted by means of vlc to afford ten fractions containing complex mixtures of compounds. Fractions 1-5consisted of complex mixtures of diterpenes, sterols, etc. (4, 24, 14, 61, and 129 mg respectively), and were all yellowbrown solids. Fraction 6 (ethyl acetate elution) consisted of triptolide (2) and a number of triterpenes as the major constituents (206 mg). Fraction 7 (ethyl acetate elution) consisted of tripdiolide (1) and triterpenes as the major con-

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FIG. 1. Extraction procedure for the TRP4a cells.

stituents (205 mg). Elution with ethyl acetate – methanol (1:1) provided fractions 8, 9, and 10 (brown solids, 52, 304, and 77 mg respectively). Fraction 8 contained triterpenes as minor components and other polar material, while fractions 9 and 10 contained only polar material.

Biological screening of the spent medium fractions showed that fractions 6 and 7 possessed the highest antifertility activity while fraction 8 showed moderate activity. Fractions 6 and 7 also demonstrated inhibitory activity against lymphocyte proliferation.

In summary, the screening data on the above crude fractions suggested that interesting biological activity resides in both the "diterpene" and "triterpene" fractions, thus demanding a further study to complete structural elucidation of the "active" compounds. For this purpose, additional fermentations (total, 78 L of broth) were carried out to obtain sufficient quantities of cell and broth-derived extracts for proper chromatographic separation and purification. Figures 3 and 4 illustrate the overall separation and purification of the various metabolites isolated from the cells (Fig. 3) and broth (Fig. 4) of the fermentation experiments. Table 3 summarizes the yields of the various metabolites (structures 1-6; 12-25) isolated from the 78-L fermentation experiment. A total of 18 compounds (5 new and 13 known) were isolated and characterized. Tripdiolide (1), triptolide (2), oleanolic acid (23), β -sitosterol (24), pulpunonic acid (25), the diterpene 20, dehydroabietic acid (21), and celastrol (22) were isolated in our previous study (6, 7) so it is now appropriate to discuss the additional and novel compounds obtained in the present study.

The triterpene **3** was isolated as optically active $([\alpha])^{22}$ +92.9) colourless prisms (mp 268–270°C) with a molecular formula of C₃₀H₄₆O₄ (high-resolution mass spectrometry) and with characteristic ir adsorption bands for hydroxyl and carboxylic acid functions. Strong evidence for an oleanene-type triterpene skeleton is given in the fragmentation pattern of the mass spectrum of **3**. A retro Diels–Alder (RDA) fragmentation is characteristic of the oleanene skeleton where the DE ring fragment maintains the positive charge. The AB ring fragment also maintains the positive charge, but to a much lesser extent (21, 22). This fragmentation places the double bond at C12.

Nuclear magnetic resonance spectra (¹Hmr and ¹³Cmr) revealed characteristic signals for an oleanene-type system (see Experimental) and final confirmation of structure was established through chemical correlation with triterpene **6** (Fig. 6), the latter having been subjected to X-ray analysis (see later).

The triterpene **4**, isomeric with **3**, was isolated as optically active ($[\alpha]^{22} + 84.4$) colourless prisms (mp 289–290°C). Its spectroscopic data revealed a close relationship to **3** and its structure was also correlated with that of **6** (Fig. 6).

The dihydroxy triterpene 5 was isolated as optically active $([\alpha]^{22} + 55.0)$ colourless prisms (mp 281–283°C) with a molecular formula of $C_{30}H_{48}O_4$. Again, nmr data (¹H and ¹³C) supported the structure indicated but final confirmation was established via chemical correlation with 3 and 6 (Fig. 6).

The dihydroxy triterpene 6 was isolated as optically active ($\left[\alpha\right]^{22}$ +93.5) colourless prisms (mp 293–298°C) with a molecular formula of $C_{30}H_{48}O_4$. Spectroscopic data revealed an oleanene-type structure closely related to the above triterpenes.







HO, HO

19





21



22







The structure and relative stereochemistry of 6 were confirmed by a single crystal X-ray analysis (Fig. 5). The computer-generated X-ray structure depicts ring E in a chair conformation placing the C20 α carboxylic acid and the C22 α hydroxyl group in equatorial orientations. The C3 hydroxyl group is also shown to be equatorial (C3 β) as predicted from the 'Hmr spectrum. The crystal exists as the 1:1 methanol solvate, with the methanol oxygen coordinating with the hydroxyl groups of the triterpene.

With the complete structure of 6 available from the above studies, the chemical correlations between 3-5 and 6 were now considered (Fig. 6).

The triterpenes 3 and 4 were both reduced with sodium borohydride to the corresponding alcohols. Triterpene 3 yielded a compound with identical tlc, mp, ir, ms, and 'Hmr spectra to those of 5, while 4 yielded a compound with identical tlc, mp, ir, ms, and ¹Hmr spectra to those of 6. Esterification of 6-10 followed by oxidation with pyridinium



MeOH extract

FIG. 2 Extraction procedure for the TRP4a spent medium.

TABLE 1. Volumes and growth times for initial batches of TRP4a suspension cultures for preliminary biological screening

Batch no.	Culture vol. (L)	Incubation time (days)	R.I. on harvesting
TRP#221	15.0	33	1.3345
TRP#222	10.0	48	1.3338
TRP#224	16.0	42	1.3345
TRP#225	10.5	30	1.3335

chlorochromate yielded the diketone, **11**, as an optically active ($[\alpha]^{22} + 5.7$) white solid (mp 180.5–182°C) with a molecular formula of C₃₁H₄₆O₄. Its ir spectrum shows carbonyls at 1721 and 1698 cm⁻¹ and C-O absorption at 1218 cm⁻¹. The ¹Hmr spectrum shows four signals corresponding to protons adjacent to the carbonyl at δ 2.39 (1H, ddd, C2 α H), 2.48 (1H, d, C21 β H), 2.56 (1H, ddd, C2 β H), and 2.99 (1H, d, C21 α H).

Esterification and oxidation of 5 in the same manner

yielded a compound with identical tlc, mp, ir, ms, and ¹Hmr spectra to those of **11**.

The spectral data and chemical interconversions establish that **3** is 22β -hydroxy-3-oxoolean-12-en-29-oic acid, **4** is 22α -hydroxy-3-oxoolean-12-en-29-oic acid, **5** is 3β , 22β -dihydroxyolean-12-en-29-oic acid, and that **6** is 3β , 22α -dihydroxyolean-12-en-29-oic acid.

The known triterpenes α -amyrin (12) and β -amyrin (13), isolated for the first time from the TRPa cell line, were established via spectral comparison with authentic samples.

The abietane-type diterpene, **14**, was isolated as optically active $([\alpha]^{22} + 44.4)$ colourless needles (mp 157–158°C) with a molecular formula of C₂₁H₃₂O₂. The mass spectrum of **14** has a molecular ion peak at m/z 316 and a base peak at m/z283 corresponding to M⁺ –CH₃, H₂O. The remaining peaks are of low intensity; however, diagnostic peaks are observed at m/z 215 and 189 (Fig. 7) (23). In the ¹Hmr spectrum, signals are present for 3 tertiary methyl groups (δ 0.96, 1.05, and 1.20), an isopropyl group (δ 1.20, d, CH₃; δ 1.21, d, CH₃ and δ 3.28, septet, benzylic methine), and a methoxyl group at δ 3.72. Also observed are signals at δ 2.76 (1H, ddd, H7 α) and 3.02 (1H, br dd, H7 β) indicating a benzylic methylene, δ 3.51 (1H, br t, $W_{1/2} = 7.0$ Hz, CHOH) indicating an axially oriented hydroxyl functionality, and two aromatic signals at δ 7.04 (1H, s) and 7.05 (1H, s).

The characteristic signals in the ¹³Cmr spectrum of **14** are seen at δ 60.2 (OCH₃), 75.5 (CHOH), and 6 aromatic signals at δ 120.4, 123.7, 128.5, 137.9, 148.9, and 154.8. The APT spectrum confirms the presence of 6 methyl groups (δ 22.1, C10-CH₃; 23.9, 24.0, isopropyl methyl groups; 24.7, 25.9, C4 methyl groups and 60.2, OCH₃), a secondary alcohol (δ 75.5), and a tetrasubstituted benzene ring (the signals at δ 120.4 and 123.7 are inverted).

A 2D ¹H–¹H COSY spectrum of **14** shows coupling of the downfield proton at δ 3.51 with 2 other protons (3 β /2, 3 β /2') that show geminal coupling (2/2') and show cross peaks to 2 other protons (2'/1, 2'/1', 2/1, and 2/1'). The benzylic proton at C15 shows the expected coupling with a cross peak to the isopropyl methyl groups (15/16, 17) while the benzylic protons at C7 show cross peaks to the protons at C6 (7 β /6, 7 β /6', 7 α /6, and 7 α /6'). Coupling of H5 with H6 and H6' is obscured by diagonal crowding.

A SINEPT experiment was carried out on **14** to determine whether the methoxyl group is attached to C11 or C12. Irradiation of the signal at δ 3.28 (H15) in the ¹Hmr spectrum was expected to enhance carbons 12 and 14 in the ¹³Cmr spectrum (enhancement of carbon through three bonds (³J_{C,H}) via polarization transfer from hydrogen). Irradiation of the signal at δ 3.28 (H15), however, resulted in enhancement of signals in the ¹³Cmr spectrum at δ 123.7, 128.5, 137.9,

TABLE 2. Weights of extracts from TRP4a suspension cultures

	Wet wt	Spent	EtOAc	EtOAc extract (g)		MeOH extract (g)	
cellsmediumBatch no.(kg)vol. (L)	medium vol. (L)	Cells	Spent medium	Cells	Spent medium		
TRP#221	1.51	12.0	0.84	0.48	17.13	36.10	
TRP#222	0.97	8.2	1.00	0.70	1.53	3.24	
TRP#224	1.41	11.8	0.87	0.37	6.53	59.89	
TRP#225	1.03	9.0	1.85	0.10	"		

"Extraction with methanol was not performed in this case.



FIG. 3. Chromatographic separation of the cell extract.



FIG. 4. Chromatographic separation of the spent medium extract.

148.9, and 154.8. Since the experiment was set up to enhance the ${}^{3}J_{C,H}$ coupled carbons (i.e., C12 and C14), the result was rather surprising. Nevertheless, the result indicates that attachment of the methoxyl group is at C12 since only one of the unsubstituted benzene carbons is enhanced (δ 123.7). Also, the quaternary carbon at δ 154.8 (the most

TABLE 3. Yields of the metabolites isolated from78 L of TRP4a suspension culture

	Yield (mg)					
Compound	Cells	Spent medium	Total			
1		200	200			
2		179	179			
3	83	13	96			
4	355	22	377			
5	202	9	211			
6	624	104	728			
12, 13	122		122			
14	50		50			
15	29		29			
16	14		14			
17	29		29			
18	51		51			
19	28		28			
20		135	135			
23	1109	60	1169			
24	553		553			
25	247		247			

deshielded carbon) is not observed in the ¹³Cmr spectrum, but is quite strongly enhanced in the SINEPT spectrum, placing the methoxyl group at C12.

A series of nOe difference experiments were carried out

Meriski Natista



FIG. 5. Computer generated X-ray structure of triterpene 6.

in order to confirm that the hydroxyl group is situated at C3 and to provide further evidence for the location of the methoxyl group at C12. Irradiation of OCH₃ at δ 3.72 shows enhancement of the isopropyl methine proton at δ 3.28 while irradiation of the latter produced enhancement of the OCH₃ signal. This evidence supports the assignment of the OCH₃ group to C12. Irradiation of the signal at δ 3.51 (CHOH) produced enhancements of both the C4 methyl groups at δ 0.96 and 1.05, confirming the location of the hydroxyl group at C3 α (axial).

In summary, the spectral evidence confirms the structure of **14** as 12-methoxyabieta-8,11,13-trien- 3α -ol, a novel diterpene isolated for the first time from the tissue cultures of *Tripterygium wilfordii*.

The quinone methide, **15**, was isolated as optically active $([\alpha]^{22} - 82.6)$ dark orange crystals (mp 140–142°C) with a molecular formula of C₂₈H₃₆O₃. The uv spectrum provided maxima typical of a quinone methide (λ_{max} 225 (ϵ 5.13 × 10³), 256 (ϵ 8.20 × 10³), and 424 nm (ϵ 8.72 × 10³)). The mass spectrum of **15** shows a strong molecular ion peak at m/z 420, and principal fragment ions occurring at m/z 406, 405, 267, 253, 241, 227, 202, and 201, consistent with fragmentation at rings C and D of quinone methide triterpenes (23). The remaining spectral data (¹Hmr, COSY, see Experimental) were in support of structure **15** but a single crystal X-ray analysis established the structure and relative stereochemistry shown in **15** (Fig. 8). This compound is therefore identical to tingenone, and comparison with an authentic sample confirmed its identity.

The isolation of tingenone constitutes its first isolation from tissue cultures of *T. wilfordii*. Furthermore, the present X-ray study establishes, unambiguously, the relative stereochemistry of this quinone methide, a matter that was not entirely clear from the earlier isolations of this compound (24, 25). The X-ray structure shows rings C, D, and E in the chair conformation and the incorporation of ethyl acetate (crystallization solvent) in the crystal lattice.



FIG. 6. Chemical correlation of the triterpenes 3, 4, 5, and 6.

The friedelane methyl ester, **16**, was isolated as optically active $([\alpha]^{22} + 101.4)$ yellow crystals (mp 150–151°C) with a molecular formula of C₃₀H₄₆O₅. Confirmation of the structure of **16** was achieved by a single crystal X-ray analysis. The absolute stereochemistry (by anomalous dispersion) is that shown in the computer-generated X-ray structure (Fig. 9). The methyl ester is established at C5 and all the rings are in the expected chair conformation. The friedelane methyl ester, **16**, is a novel triterpene exhibiting an unusual oxidation at C5.

The quinone methide, **17**, was isolated as optically active $([\alpha]^{22} - 484.6)$ dark orange crystals (mp 220–224°C) with a molecular formula of $C_{28}H_{36}O_4$. Its spectral data (see Experimental) revealed a close relationship to tingenone but the unambiguous assignment of an additional hydroxyl function, as suggested by the mass and ¹Hmr spectral data, was established by a single crystal X-ray analysis (Fig. 10) to be 22 β -hydroxytingenone, the first isolation of this triterpene from the tissue cultures of *T. wilfordii*. Previous studies with several plants of the *Celastraceae* family, including





FIG. 7. Mass spectral fragmentation for diterpene 14.

Euonymus tingens and various *Maytenus* species (24–30), have indicated the isolation of **17**, but an authentic sample could not be obtained.

The dihydroxyoleanene, **18**, was isolated as optically active $([\alpha]^{22} + 115.9)$ colourless prisms (mp 241–242°C) with a molecular formula of C₃₀H₅₀O₂. Although the extensive spectral data obtained for this compound (see Experimental) strongly suggested an oleanene-type structure, the conclusive location of the hydroxyl groups, particularly the hydroxymethyl group, was established via X-ray analysis (Fig. 11).

The isolation of 18 constitutes its first isolation from tissue cultures of T. wilfordii. A compound with a similar structure is reported to be isolated from *Celastrus paniculatus* and given the name paniculatadiol (31) but no spectral data are presented and an authentic sample could not be obtained for comparison.

Extensive studies into the pharmacological effects of oleanene-type compounds by Shibata and coworkers (32–36) have revealed the importance of a hydroxymethyl group in such compounds in terms of their ability to inhibit stress-induced peptic ulcer, activity against allergies, anti-tumour and analgesic activity, etc. As yet, no data are available with respect to **18**.

The dihydroxy triterpene, **19**, was isolated as optically active ($[\alpha]^{22}$ +55.3) colourless prisms (mp 230–234°C) with a molecular formula of C₃₀H₅₀O₂. Spectral data (see Experimental) suggested a β-amyrin type system. Final confirmation of structure and relative stereochemistry of **19** as 11α-hydroxy-β-amyrin was provided by a single crystal X-ray analysis (Fig. 12). A previous isolation of a compound corresponding to **19** has been reported in the gummy secretion of *Salvia glutinosa* (37) but again an authentic sample was unavailable.

In summary, the extraction of the TRP4a suspension cultures and separation of the extracts led to the isolation of 18 compounds, mainly triterpenes and also some diterpenes. Twelve of the compounds, of which five are new com-

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FIG. 8. Computer generated X-ray structure of 15.



FIG. 9. Computer generated X-ray structure of **16** (the absolute stereochemistry is shown).

pounds (3, 4, 5, 14, and 16), were not isolated previously from the TRP4a cultures. Pharmacological evaluation of some of these in terms of male contraceptive, immunosuppressive, and other activities is presently in progress and these results will be published elsewhere.

Experimental

TRP4a cell suspension cultures were grown in glass or in steel air-lift fermentors (Microferm, New Brunswick Scientific or an in-



FIG. 10. Computer generated X-ray structure of 17.



FIG. 11. Computer generated X-ray structure of 18.

house fabricated fermentor, respectively). The spent medium was freeze-dried using a Dura-Dry freeze-dryer with a Dura-Top Bulk Tray Dryer (FTS Systems Inc.).

The ¹Hmr spectra were run at 300 and 400 MHz using Varian XL 300 and Bruker WH 400 spectrometers, respectively. Tetramethylsilane was used as the internal standard and all peaks are recorded in ppm (δ) relative to TMS (δ 0.00 ppm). The ¹³Cmr spectra were run at 75.3 MHz using a Varian XL 300 spectrometer, using the ¹³C signals of the deuterated solvents as the internal standards.

Low-resolution mass spectra were recorded using Kratos



This is a typical procedure followed for the various bioreactor experiments, for example, TRP#221.

Cells (compare Fig. 1)

The cells were thawed and homogenized in a Waring blender with ethyl acetate (1 L). The cells were then filtered using Celite, and washed with ethyl acetate (300 mL). The filtrate was separated and the aqueous layer was extracted with ethyl acetate (3×200 mL) and discarded. The ethyl acetate layers were combined, dried over sodium sulphate (anhydrous), and the solvent was evaporated. The orange-brown extract was dried under vacuum and kept frozen until further use.

The filtered cell homogenate was suspended in methanol (500 mL) and sonicated for 2 h. Filtration and solvent evaporation gave a brown gummy extract which was dried under vacuum and kept frozen until further use.

Spent medium (compare Fig. 2)

The freeze-dried spent medium was reconstituted in water (300– 500 mL) and extracted with ethyl acetate (3×200 mL). The organic layers were combined, dried over sodium sulphate (anhydrous), and the solvent was evaporated. The dark brown extract was dried under vacuum and frozen until further use. The aqueous layer was evaporated and the residue was sonicated with methanol (200 mL) and filtered. The filtrate was evaporated and the brown extract was dried under vacuum and frozen until further use.

Extraction of batches TRP#221, 222, 224, and 225, according to the above procedures, provides the weights of the extracts as given in Tables 1 and 2.

Preparation of crude samples for bioassay

Samples of the crude TRP#221 culture extracts were forwarded for immunological assay and for antifertility assay to the laboratories indicated in the Acknowledgement.

The solids obtained from the ethyl acetate extracts were prepared in a manner (see below) so as to generate emulsions in water (*vide infra*) while the solids obtained from the methanol extracts were forwarded without further preparation.

The ethyl acetate cell extract (0.84 g) from batch TRP#221 was dissolved in ethanol (15 mL) and polyvinylpyrrolidone (PVP, 4.20 g) was added. The solvent was evaporated and the residue was dried under vacuum to give 5.03 g of a water emulsifiable solid. The procedure was repeated with the ethyl acetate spent medium extract (0.44 g, with 2.19 g of PVP) to give 2.65 g of a water emulsifiable solid.

Partial separation of the ethyl acetate cell extracts for biological assay

The remaining ethyl acetate cell extracts (from batches TRP#222, 224, and 225) were combined (3.73 g) and separated into 8 partially purified fractions by vacuum liquid chromatography using Merck silica gel 60G (80 g) packed into a sintered glass funnel (150 mL, medium frit), attached to a bell jar with a sidearm, which was connected to a water aspirator. Fifty-milliliter fractions were collected and stepwise elution was carried out using: (*i*) hexanes – ethyl acetate 4:1 (6 × 50 mL); (*ii*) hexanes – ethyl acetate 3:1 (6 × 50 mL); (*iii*) hexanes – ethyl acetate 1:1 (6 × 50 mL); and (*v*) ethyl acetate (6 × 50 mL). The column was flushed with ethyl acetate – methanol 1:1 (250 mL) to elute the polar material.

Elution with hexanes – ethyl acetate 4:1 yielded an oily fraction (378.76 mg) containing fatty acid-like compounds (fraction 1). Further elution with hexanes – ethyl acetate 4:1 and hexanes – ethyl acetate 3:1 yielded fraction 2 (389.66 mg), containing nonpolar diterpenes and sterols. Elution with hexanes – ethyl acetate 3:1 and 2:1 yielded fraction 3 (273.60 mg) as a brown solid containing several terpenoid components. Further elution with hexanes – ethyl acetate 2:1 gave fraction 4 (267.59 mg) while elution with hexanes – ethyl acetate 1:1 yielded fraction 5 (505.63 mg). Both fractions contained triterpenoid components. Elution with ethyl acetate gave fraction 6 (291.01 mg) as a light brown solid con-



FIG. 12. Computer generated X-ray structure of 19.

MS 50 and MS 80 mass spectrometers. High-resolution mass spectra were run on a Kratos MS 50 mass spectrometer. Chemical ionization mass spectra were recorded on a Delsi–Nermag R10-10C mass spectrometer using isobutane as the carrier gas.

The ir spectra were recorded on a Perkin Elmer 710B infrared spectrophotometer, and Fourier transform ir spectra were recorded on a Perkin Elmer 1710 infrared Fourier transform spectrophotometer. Optical rotations were recorded on a Perkin Elmer 141 polarimeter at the sodium D line. The uv spectra were recorded on a Unicam SP 800B ultraviolet spectrophotometer.

All melting points were recorded on a Reichert melting point apparatus or a Fisher–Johns melting point apparatus and are uncorrected.

Column chromatography was carried out using Merck silica gel 60, 230–400 mesh, while analytical and preparative tlc was performed using Merck precoated silica gel 60 F_{254} tlc plates. Vacuum liquid chromatography (vlc) was carried out using Merck silica gel 60G in sintered glass funnels with medium glass frits. Preparative hplc separations were performed on a Waters Associates Prep LC/System 500 installed with PrepPAK-500/silica cartridges and a refractive index detector. All solvents used for chromatography were BDH Omnisolv glass-distilled spectro-grade solvents.

Synthetic samples were visualized on analytical tlc plates (Merck) by uv and by spraying with a 5% solution of ammonium molybdate in 10% sulphuric acid, followed by heating at 125°C until blue spots developed. Tissue culture extracts were visualized on tlc spraying first with a 30% solution of concentrated sulphuric acid in glacial acetic acid, then with a 5% solution of anisaldehyde in isopropanol, followed by heating at 125°C for approximately 10 min.

Growth conditions for the TRP4a cell suspension cultures

The cultures were grown and maintained as discussed previously (6, 7) in PRD₂Co₁₀₀ medium at 26°C for 22 days and then resuspended as a 10% inoculum in MSNA_{0.5}K_{0.5} production medium. The cultures were incubated at 26°C in air-lift fermentors for 33–48 days before harvesting. The cells were harvested by filtration through Miracloth (Calbiochem) and were frozen until the time of extraction. The spent medium was freeze-dried and stored frozen until the time of extraction.

taining polar triterpenes. Elution with ethyl acetate and ethyl acetate – methanol 1:1 gave fraction 7 (175.80 mg) as a light brown solid containing polar triterpenes. Fraction 8 (1.22 g) was eluted with ethyl acetate – methanol 1:1, yielding polar material as a dark brown solid.

Partial separation of the spent medium ethyl acetate extracts for biological assay

The remaining ethyl acetate spent medium extracts (from batches TRP#222, 224, and 225) were combined (1.17 g) and partially separated by vacuum liquid chromatography using a sintered glass funnel (60 mL, medium frit, Merck silica gel 60G, 30 g). Thirty-milliliter fractions were collected to give 10 partially purified fractions. Stepwise elution was carried out using: (*i*) hexanes (5 × 30 mL); (*ii*) hexanes – ethyl acetate 19:1 (5 × 30 mL); (*iii*) hexanes – ethyl acetate 9:1 (5 × 30 mL); (*iv*) hexanes – ethyl acetate 4:1 (5 × 30 mL); (*v*) hexanes – ethyl acetate 1:1 (5 × 30 mL); and (*vi*) ethyl acetate (5 × 30 mL). The polar material was eluted from the column using ethyl acetate – methanol 1:1 (150 mL).

Elution with hexanes and hexanes - ethyl acetate 19:1 gave fraction 1 (4.32 mg) as a yellow solid containing nonpolar terpenoid components. Elution with hexanes – ethyl acetate 19:1, 9:1, and 4:1 gave fraction 2 (23.89 mg) and elution with hexanes - ethyl acetate 4:1 gave fraction 3 (14.28 mg). Both fractions contained several terpenoid components. Further elution with hexanes - ethyl acetate 4:1 and 1:1 yielded fraction 4 (60.64 mg) as a light brown solid containing diterpenoid and triterpenoid metabolites. Elution with hexanes – ethyl acetate 1:1 and ethyl acetate yielded fraction 5 (128.52 mg) as a brown solid containing diterpenoids and triterpenoids. Elution with ethyl acetate gave fraction 6 (206.21 mg) as a yellow-brown solid containing triptolide (2) and several triterpenes. Further elution with ethyl acetate yielded fraction 7 (204.75 mg) as a yellow-brown solid containing tripdiolide (1) and several triterpenes. Elution with ethyl acetate and ethyl acetate – methanol 1:1 gave fraction 8 (52.43 mg) as a brown solid containing triterpenes and polar material. Elution with ethyl acetate methanol 1:1 gave fraction 9 (303.69 mg) while further elution with ethyl acetate - methanol 1:1 yielded fraction 10 (76.54 mg) as polar material in the form of brown solids.

Preparation of the partially purified extracts for biological assay All the fractions were treated as above with polyvinylpyrrolidone (5:1, PVP:fraction, w/w) in order to obtain samples capable of forming emulsions in water. The samples were then forwarded

Isolation of pure metabolites from the TRP4a cell suspension cultures

for immunological and antifertility assays.

To obtain large quantities of cells and spent medium, 6 batches (10-17 L) were grown in bioreactors for 25–39 days to afford a total of 78 L (Table 3). The batches were combined on harvesting and filtered through Miracloth. The cells (wet weight 8.94 kg) were frozen and the spent media (60.6 L) were concentrated to 1.4 L by freeze-drying.

Extraction of the combined cells and the combined spent media was performed as described above, with the 5-fold increase of the extraction solvent and omission of a sonication with methanol. Cell extraction yielded 13.08 g of a dark orange extract. Spent media extraction gave 14.73 g of an orange-brown extract.

Chromatographic separation of the cell extract metabolites

Initial purification of the cell extract (13.08 g) was carried out by filtration through silica gel (Merck silica gel 230–400 mesh, 60 mL) using ethyl acetate, to remove the polar material. Evaporation of the solvent yielded 9.04 g of crude extract as an orange solid; 3.01 g of this extract was purified following the procedure described as Method A, 5.83 g was purified by Method B (compare Fig. 3).

Method A

The cell extract (3.01 g) was partially separated by vacuum liquid chromatography using a 150-mL sintered glass funnel (medium frit, Merck silica gel 60G, 90 g). Stepwise elution using (*i*) benzene (5 × 30 mL); (*ii*) benzene-acetone 4:1 (25 × 30 mL); (*iii*) benzene-acetone 3:1 (15 × 30 mL); (*iv*) benzene-acetone 2:1 (18 × 30 mL); and (*v*) ethyl acetate (300 mL) gave 10 fractions. Fractions 1 (349.11 mg) and 2 (45.70 mg) were colorless oily fractions consisting of fatty acid-like compounds. Fraction 3 (1.17 g), a dark orange fraction, contained diterpenes, sterols, triterpenes, and quinone methides (see below for the separation of this fraction). Fraction 4 yielded oleanolic acid (23, 432.26 mg). Fraction 5 (162.39 mg) consisted of triterpenes 3 and 4 and fraction 6 (147.96 mg) contained triterpenes 3, 4, 5, and 6. Fraction 7 (92.80 mg) contained triterpenes 4, 5, and 6, while fraction 8 (75.03 mg) contained a small quantity of triterpenes 5 and 6. Fractions 9 and 10 (347.58 and 52.42 mg respectively) consisted of triterpene 6 and some polar material.

Separation of fractions 5–8 was carried out by preparative tlc (Merck silica 60G, 6×0.5 mm silica gel plates) using methylene chloride – methanol-acetic acid 100:2:1 (the plates were eluted four times) to give triterpene **3** (27.25 mg), triterpene **4** (65.77 mg), triterpene **5** (20.85 mg), and triterpene **6** (21.80 mg). Fractions 9 and 10 were combined and washed with methanol to give a further quantity of **6** (157.13 mg).

In summary, chromatographic separation yielded oleanolic acid (23, 432.26 mg) and triterpenes 3 (27.25 mg), 4 (65.77 mg), 5 (20.85 mg), and 6 (157.13 mg).

Method B

The cell extract (5.83 g) was partially separated by vacuum liquid chromatography using a 150-mL sintered glass funnel (medium frit, Merck silica gel 60G, 90 g). Stepwise elution was carried out using: (i) benzene (5 \times 30 mL); (ii) benzene-acetone 4:1 $(15 \times 30 \text{ mL})$; (iii) benzene-acetone 3:1 ($10 \times 30 \text{ mL}$); (iv) benzene-acetone 2:1 (30 mL); (v) benzene-acetone 1:1 (10 \times 30 mL); and (vi) ethyl acetate (250 mL), yielded 10 crude fractions. Fraction 1 (756.14 mg) was an oily fraction consisting of fatty acid-like compounds. Fraction 2 (2.38 g) containing diterpenes, sterols, triterpenes, and quinone methides was subsequently combined with fraction 3 from Method A for further separation (vide infra). Fraction 3 (126.58 mg) was a mixture of oleanolic acid (23) and triterpene 3, while fraction 4 (281.26 mg) contained triterpenes 3 and 4. Fractions 5 and 6 (74.93 mg and 62.50 mg respectively) consisted of mainly triterpene 4 and a small quantity of triterpene 5. Fraction 7 (219.67 mg) contained triterpenes 4 and 5, while fraction 8 (106.61 mg) contained triterpenes 4, 5, and 6. Fractions 9 and 10 (569.53 mg and 534.98 mg respectively) contained triterpene 6 and polar material.

Fractions 3–8 were combined and separated by column chromatography (Merck silica gel 230–400 mesh, methylene chloride – methanol acetic acid 100:2:1) to give oleanolic acid (23, 101.97 mg), a mixture of 3 and 4 (101.97 mg), triterpene 4 (167.69 mg), triterpene 5 (181.17 mg), and triterpene 6 (85.34 mg). The mixture of 3 and 4 was separated by further column chromatography (Merck silica gel 230–400 mesh, methylene chloride – methanol – acetic acid 100:1:1) to give 3 (55.80 mg) and a further quantity of 4 (121.74 mg). Fractions 9 and 10 were combined and washed with methanol to give 6 (359.65 mg).

In summary, chromatographic separation via Method B yielded oleanolic acid (23, 101.97 mg) and triterpenes 3 (55.80 mg), 4 (289.43 mg), 5 (181.17 mg), and 6 (444.99 mg).

22β -Hydroxy-3-oxoolean-I2-en-29-oic acid (3)

Colourless prisms (ethyl acetate); mp 268–270°C; $[\alpha]^{22}$ +92.9 (*c* 0.70, MeOH); uv (MeOH) λ_{truax} 217 (ϵ 726); ir (CHCl₃) cm⁻¹: 3618 (OH), 2938 (CH), 2640 (OH), 1698 (C=O); ¹Hmr (CDCl₃) δ : 0.91 (3H, s), 1.04 (3H, s), 1.07 (3H, s), 1.09 (3H, s), 1.11 (3H, s), 1.15 (3H, s), 1.41 (3H, s), 0.86–2.32 (2OH, m), 2.39 (1H, ddd, H2 α , *J* = 4, 6, 16), 2.55 (1H, ddd, H2 β , *J* = 4, 11, 16), 3.50 (1H, s, OH), 3.58 (1H, dd, H22 α , *J* = 3.5, 7.0), 5.33 (1H, t, H12); ¹³Cmr (C₅D₅N) δ : 15.4, 17.2, 19.9, 21.1, 21.8, 24.0, 25.3, 25.4, 26.4, 26.7, 29.1, 32.7, 34.5, 36.9, 38.0, 38.2, 39.4, 39.9, 41.7, 42.6, 44.9, 47.1, 47.5, 55.3, 75.4, 122.9, 144.2, 181.6, 217.8; ms m/z (rel. int., %): 470 (M⁺, 3.8), 452 (7.0), 437 (2.7), 426 (4.4), 424 (5.5), 408 (15.7), 391 (3.2), 340 (11.1), 325 (4.1), 264 (43.7), 246 (67.8), 217 (79.9), 205 (57.3), 201 (38.3), 189 (46.0), 171 (44.5), 159 (42.7), 147 (55.9), 135 (82.3), 119 (95.1), 107 (90.5), 81 (89.8), 69 (71.4), 55 (100), 43 (53.4). High-resolution mass measurement: calcd. for C₃₀H₄₆O₄: 470.3398; found: 470.3414. Anal. calcd. for C₃₀H₄₆O₄: C 76.55, H 9.85; found: C 76.02, H 9.97.

22α -Hydroxy-3-oxoolean-12-en-29-oic acid (4)

Colourless prisms (meOH); mp 289–290°C; $[\alpha]^{22}$ + 84.4 (c 1.09. MeOH); uv (MeOH) λ_{max} 212 (ϵ 1938); ir (CHCl₃) cm⁻¹: 3615 (OH), 2976 (CH), 2630 (OH), 1698 (C=O), ¹Hmr (CDCl₃) δ: 1.02 (3H, s), 1.04 (3H, s), 1.07 (3H, s), 1.08 (3H, s), 1.10 (3H, s), 1.18 (3H, s), 1.29 (3H, s), 1.26–2.27 (21H, m), 2.38 (1H, ddd, H2a, J = 4, 6, 16, 2.55 (1H, ddd, H2 β , J = 4, 11, 16), 3.60 (1H, dd, H22β, J = 4, 12), 5.29 (1H, t, H12); ¹³Cmr (CDCl₃) δ: 15.3, 16.7, 19.2, 19.7, 20.4, 21.6, 23.7, 24.5, 25.5, 26.1, 26.5, 32.0, 34.2, 36.5, 36.6, 38.3, 39.3, 39.6, 39.9, 42.2, 42.7, 46.3, 46.8, 47.5, 55.2, 75.3, 123.1, 142.6, 183.3, 217.8; ms m/z (rel int., %): 470 $(M^+, 0.6), 452 (11.8), 437 (2.0), 408 (1.5), 391 (1.3), 353 (0.6),$ 340 (0.5), 326 (1.7), 299 (1.2), 285 (2.2), 264 (3.7), 246 (100.0), 228 (12.2), 218 (25.1), 205 (35.8), 201 (20.0), 185 (20.9), 173 (14.2), 159 (16.9), 145 (23.6), 131 (31.0), 119 (38.0), 107 (29.3), 95 (34.3), 81 (22.1), 69 (14.4), 55 (24.6), 43 (21.7). High-resolution mass measurement: calcd. for C₃₀H₄₆O₄: 470.3398; found: 470.3417. Anal. calcd. for C₃₀H₄₆O₄: C 76.55, H 9.85; found: C 76.40, H 9.90.

3B,22B-Dihydroxyolean-12-en-29-oic acid (5)

Colorless prisms (MeOH-H₂O); mp 281–283°C; $[\alpha]^{22}$ +55.0 (*c* 0.60, MeOH); uv (MeOH) λ_{max} 216 (ϵ 835); ir (KBr) cm⁻¹: 3467 (OH), 3422 (OH), 2976 (CH), 2640 (OH), 1698 (C=O); ¹Hmr (C₅D₅N) δ: 0.76 (3H, s), 0.85 (6H, s), 1.02 (3H, s), 1.03 (3H, s), 1.08 (3H, s), 1.63 (3H, s), 0.62-2.63 (24H, m), 3.22 (1H, dd, $H_{3}\alpha$, J = 6, 9.5, 3.80 (1H, brd, H22 α , J = 4.5), 5.21 (1H, t, H12); 13 Cmr (C₅D₅N) δ : 15.8, 16.6, 17.2, 18.7, 21.0, 23.8, 24.9, 25.5, 26.3, 28.0, 28.7, 28.8, 30.7, 33.2, 37.2, 37.7, 38.0, 39.1, 39.3, 39.9, 41.5, 42.4, 44.6, 48.0, 55.7, 75.3, 77.9, 123.1, 144.2, 181.0; ms m/z (rel. int., %): 472 (M⁺, 6.1), 454 (5.0), 439 (2.6), 426 (2.0), 411 (2.1), 393 (1.5), 264 (99.7), 246 (53.0), 231 (15.4), 217 (100.0), 207 (59.9), 190 (45.2), 175 (39.3), 161 (22.7), 147 (37.9), 135 (74.1), 119 (49.9), 107 (48.2), 95 (52.4), 81 (49.9), 69 (48.6), 55 (48.7), 43 (30.7). High-resolution mass measurement: calcd. for C₃₀H₄₈O₄: 472.3554; found: 472.3567. Anal. calcd. for C₃₀H₄₈O₄·H₂O: C 73.43, H 10.27; found: C 73.53, H 10.40.

3β -22 α -Dihydroxyolean-12-en-29-oic acid (6)

Colourless prisms (MeOH); mp 293–298°C (subl.); $[\alpha]^{22}$ +93.5 (c 0.46, MeOH); uv (MeOH) λ_{max} 212 (ϵ 1509); ir (KBr) cm⁻¹: 3475 (OH), 3387 (OH), 2946 (CH), 2550 (OH), 1698 (C=O); ¹Hmr (C₅D₅N) δ: 0.98 (3H, s), 1.03 (3H, s), 1.04 (3H, s), 1.23 (3H, s), 1.28 (3H, s), 1.37 (3H, s), 1.58 (3H, s), 0.82-2.74 (24H, m), $3.42 (1H, dd, H3\alpha, J = 6, 10), 4.01 (1H, dd, H22\beta, J = 5.5, 13),$ 5.38 (1H, t, H12); ¹³Cmr (C₅D₅N) δ: 15.8, 16.6, 17.0, 18.8, 19.9, 21.4, 23.9, 25.4, 26.1, 26.3, 28.0, 28.7, 32.9, 37.2, 38.6, 39.1, 39.4, 40.2, 41.2, 42.4, 47.2, 47.9, 55.6, 74.7, 78.0, 123.1, 144.2, 181.1; ms m/z (rel int., %): 472 (M⁺, 0.2), 454 (2.6), 436 (1.7), 421 (1.3), 410 (0.6), 393 (1.2), 342 (1.1), 325 (0.6), 314 (0.9), 299 (2.0), 264 (2.7), 246 (100.0), 218 (21.6), 207 (18.1), 201 (15.5), 190 (35.6), 175 (20.3), 159 (14.8), 145 (20.1), 131 (22.5), 119 (32.2), 107 (23.2), 95 (25.9), 81 (17.7), 69 (12.2), 55 (14.7). High-resolution mass measurement: calcd. for C₃₀H₄₈O₄: 472.3554; found: 472.3540. Anal. calcd. for C₃₀H₄₈O₄:² C 76.23, H 10.23; found: C 76.10, H 10.33.

Oleanolic acid (7)

The isolated sample was compared (mp, identical ir, ¹Hmr, and ms spectra) with an authentic sample available in our sample collection.

Reduction of 22a-hydroxy-3-oxoolean-12-en-29-oic acid (4)

The acid **4** (11.24 mg, 0.02 mmol) was dissolved in ethanol (1 mL) and sodium borohydride (4.52 mg, 0.12 mmol) was added. The reaction mixture was stirred at room temperature for 30 min and ethyl acetate (30 mL) was added. The solution was washed with 10% HCl (2×5 mL) and water (2×10 mL) and the solvent was evaporated to give 8.63 mg (76.4%) of **6** as a white solid (tlc, mp, ¹Hmr, and ms were identical with those of isolated **6**).

Reduction of 22\beta-hydroxy-3-oxoolean-12-en-29-oic acid (3)

The acid **3** (6.18 mg, 0.01 mmol) was treated as above with sodium borohydride, which yielded, after work-up, 5.92 mg (95.3%) of **5** as a white solid (tlc, mp, ¹Hmr, and ms were identical with those of isolated **5**).

Esterification of 3, 4, 5, and 6

Suspensions of the triterpenes 3, 4, 5, and 6 in ether (3 mL) were treated with an ethereal solution of excess diazomethane at room temperature overnight. Evaporation of the solvent gave the methyl esters 7, 8, 9, and 10 as white solids. They were then crystallized (MeOH as solvent) to provide the pure compounds with constant melting points.

Methyl-22\u03b3-hydroxy-3-oxoolean-12-en-29-oate (7)

White solid; mp 195–197°C; $[\alpha]^{22}$ +82.3 (*c* 1.15, CHCl₃); ir (CHCl₃₃) cm⁻¹: 3425 (OH), 2910 (CH), 1719 (C=0), 1698 (C=0); ¹Hmr (CDCl₃) & 0.90 (3H, s), 1.04 (3H, s), 1.06 (3H, s), 1.08 (3H, s), 1.10 (3H, s), 1.14 (3H, s), 1.36 (3H, s), 0.82–2.27 (20H, m), 2.38 (1H, ddd, H2 α , *J* = 4, 6, 16), 2.55 (1H, ddd, H2 β , *J* = 4, 11, 16), 3.55 (1H, dd, H22 α , *J* = 3, 4), 3.69 (3H, s, OCH₃), 5.33 (1H, t, H12); ms *m*/*z* (rel. int., %): 484 (M⁺, 42.5), 469 (4.6), 466 (7.9), 453 (10.4), 425 (16.9), 407 (4.7), 391 (3.5), 375 (6.3), 278 (100.0), 265 (57.1), 260 (25.7), 247 (43.3), 231 (83.2), 219 (35.5), 205 (40.5), 200 (41.7), 187 (27.9), 171 (58.1), 161 (16.9), 144 (40.7), 125 (60.7), 112 (37.7), 95 (26.7), 81 (20.1), 69 (16.7), 55 (15.7). High-resolution mass measurement: calcd. for C₃₁H₄₈O₄: 484.3552; found: 484.3554.

$Methyl-22\alpha-hydroxy-3-oxoolean-12-en-29-oate$ (8)

White solid; mp 149–151°C; $[\alpha]^{22}$ +92.9 (*c* 0.85, CHCl₃); ir (CHCl₃) cm⁻¹: 3600 (OH), 2930 (CH), 1718 (C=O), 1698 (C=O); ¹Hmr (CDCl₃) &: 1.02 (3H, s), 1.04 (3H, s), 1.07 (3H, s), 1.08 (3H, s), 1.11 (3H, s), 1.18 (3H, s), 1.26 (3H, s), 1.35–2.23 (20H, m), 2.38 (1H, ddd, H2 α , *J* = 4, 6, 16), 2.55 (1H, ddd, H2 β , *J* = 4, 11, 16), 3.59 (1H, dd, H22 β , *J* = 4, 12), 3.68 (3H, s, OCH₃), 5.28 (1H, t, H12); ms *m*/*z* (rel. int., %): 484 (M⁺, 18.5), 466 (5.0), 452 (21.2); 437 (3.4), 406 (3.4), 391 (3.5), 340 (2.3), 326 (4.1), 299 (1.9), 278 (43.3), 265 (6.8), 260 (13.3), 246 (100.0), 231 (28.9), 218 (18.2), 205 (29.8), 185 (21.6), 171 (23.0), 159 (13.1), 147 (21.0), 131 (19.2), 120 (22.3), 107 (17.8), 95 (27.9), 81 (10.5), 69 (1.9), 55 (9.1). High-resolution mass measurement: calcd. for C₃₁H₄₈O₄: 484.3552; found: 484.3570.

Methyl-3\beta,22\beta-dihydroxyolean-12-en-29-oate (9)

White solid; mp 228–229°C; $[\alpha]^{2^2}$ +64.0 (*c* 0.88, CHCl₃); ir (CHCl₃) cm⁻¹: 3665 (OH), 3586 (OH), 2900 (CH), 1718 (C=O); ¹Hmr (CDCl₃) & 0.80 (3H, s), 0.90 (3H, s), 0.96 (3H, s), 0.99 (3H, s), 1.01 (3H, s), 1.13 (3H, s), 1.36 (3H, s), 0.73–2.27 (23H, m), 3.23 (1H, dd, H3 α , *J* = 4, 10), 3.55 (1H, dd, H22 α , *J* = 4, 8), 3.68 (3H, s, OCH₃), 5.30 (1H, t, H12); ms *m/z* (rel. int., %): 486 (M⁺, 13.3), 471 (1.2), 468 (3.0), 455 (3.6), 427 (2.0), 409 (1.5), 354 (1.4), 330 (1.4), 304 (1.3), 292 (3.4), 278 (100.0), 260 (23.6), 246 (23.3), 231 (79.5), 219 (23.3), 207 (47.9), 200 (47.3), 189 (25.6), 171 (60.2), 144 (43.0), 135 (34.8), 119 (37.3), 112 (37.6), 107 (28.1), 95 (27.3), 81 (23.1), 69 (17.0), 55 (18.5). High-res-

²All the data for this compound were obtained on a sample that was recrystallized from ethanol, except for the X-ray analysis. Recrystallization from methanol was shown by X-ray analysis to yield crystals as the 1:1 methanol solvate.

olution mass measurement: calcd. for $C_{31}H_{50}O_4$: 486.3711; found: 486.3722.

Methyl-3a-22a-dihydroxyolean-12-en-29-oate (10)

White solid; mp 118–121°C; $[\alpha]^{22}$ +74.9 (*c* 0.90, CHCl₃); ir (CHCl₃) cm⁻¹: 3655 (OH), 3600 (OH), 2932 (CH), 1718 (C=O); ¹Hmr (CDCl₃) & 0.80 (3H, s), 0.94 (3H, s), 0.98 (3H, s), 1.00 (6H, s), 1.17 (3H, s), 1.26 (3H, s), 0.73–2.22 (23H, m), 3.23 (1H, dd, H3 α , *J* = 4, 10), 3.58 (1H, dd, H22 β , *J* = 4, 12), 3.67 (3H, s, OCH₃), 5.26 (1H, t, H12); ms *m/z* (rel. int., %): 486 (M⁺, 3.1), 468 (1.1), 454 (4.7), 436 (1.9), 421 (1.2), 409 (0.7), 393 (1.0), 342 (0.8), 328 (1.1), 314 (0.9), 300 (1.7), 278 (16.9), 246 (100.0), 231 (14.9), 218 (17.6), 207 (24.1), 190 (35.0), 175 (15.6), 159 (11.9), 147 (15.8), 131 (16.1), 119 (20.6), 107 (14.5), 95 (22.5), 81 (9.3), 69 (7.5), 55 (7.7). High-resolution mass measurement: calcd. for C₃₁H₅₀O₄: 486.3711; found: 486.3695.

Methyl-3,22-dioxoolean-12-en-29-oate (11)

Excess pyridinium chlorochromate was added to a stirred solution of 9 (10.00 mg, 0.02 mmol) in methylene chloride (1.0 mL) and the reaction mixture was stirred at room temperature for 30 min. The reaction mixture was filtered through Florisil (30 mL) and the Florisil was washed with ether. The washing and the filtrate were combined and the solvent was evaporated to give 8.23 mg (83.0%) of **11** as a white solid, mp 180.5–182°C; $[\alpha]^{22}$ +5.7 (c 4.75, CHCl₃); ir (CHCl₃) cm⁻¹: 3000 (CH), 2940 (CH), 1721 (C=O), 1698 (C=O); ¹Hmr (CDCl₃) δ: 1.03 (3H, s), 1.04 (3H, s), 1.07 (3H, s), 1.09 (3H, s), 1.11 (3H, s), 1.16 (3H, s), 1.24 (3H, s), 1.21-2.11 (20H, m), 2.32 (1H, dd, H19 β , J = 3.5, 15), 2.39 (1H, ddd, H2 α , J = 4, 6, 16), 2.48 (1H, d, H21 β , J = 14.5), 2.56 (1H, ddd, H2 β , J = 4, 11, 16), 2.99 (1H, d, H21 α , J = 14.5), 3.71 (3H, s, OCH₃), (1H, t, H12); ms m/z (rel. int., %): 482 (M⁺, 18.4), 467 (2.3), 464 (2.7), 451 (1.8), 423 (2.0), 405 (1.6), 339 (1.7), 298 (0.8), 276 (100.0), 263 (11.1), 247 (16.4), 215 (17.6), 205 (13.5), 199 (16.7), 187 (13.8), 173 (9.8), 159 (9.9), 142 (25.5), 134 (24.3), 119 (20.5), 114 (68.7), 105 (13.2), 93 (9.4), 81 (8.8), 69 (4.9), 55 (10.3). High-resolution mass measurement: calcd. for H₃₁H₄₆O₄: 482.3398; found: 482.3405.

Oxidation of 10

Excess pyridinium chlorochromate was added to a stirred solution of 10 (5.03 mg, 0.01 mmol) in methylene chloride (1.0 mL) and the reaction mixture was stirred at room temperature for 30 min. The reaction mixture was filtered through Florisil (30 mL) and the Florisil was washed with water. The washings and the filtrate were combined and the solvent was evaporated to give 3.76 mg (75.4%) of **11** as a white solid.

Separation and identification of the metabolites from fraction 3 (from Method A) and fraction 2 (from Method B) (compare Fig. 3)

Fraction 3 (1.17 g) from Method A and fraction 2 (2.38 g) from Method B (vide supra) were combined (3.55 g) and partially separated by column chromatography (Merck silica gel 230-400, 350 g). Stepwise elution was carried out using: (i) hexanes (250 mL); (ii) hexanes - ethyl acetate 9:1 (500 mL); (iii) hexanes - ethyl acetate 4:1 (1500 mL); (iv) hexanes - ethyl acetate 3:1 (1000 mL); (v) hexanes - ethyl acetate 2:1 (1000 mL); and (vi) ethyl acetate (1000 mL) to give 12 crude fractions. Fractions A and B (126.30 and 178.25 mg respectively) were complex mixtures of minor components and were not further investigated, while fractions C and D (198.84 and 49.34 mg respectively) consisted of two major components (see below for the separation). Fractions E and F (489.19 and 64.06 mg respectively) yielded B-sitosterol (24), while fractions G, H, and I (69.81, 46.35, and 38.15 mg respectively) were complex mixtures and were not further investigated. Fractions J and K (815.16 and 195.71 mg respectively) contained orange-coloured quinone methides and polpunonic acid (25) (see

below for the separation), and fraction L yielded oleanolic acid (23, 564.65 mg).

The identities of β -sitosterol, polpunonic acid, and oleanolic acid were confirmed by comparison with authentic samples.

Separation of fractions C and D

Fractions C and D were subjected to preparative tlc (Merck silica gel 60 F_{254} , 2 mm) using methylene chloride – ethyl acetate 19:1 (the plate was eluted twice) and a further separation using methylene chloride – hexanes 1:1 (the plate was eluted three times), to give an inseparable mixture (121.81 mg) of two compounds that spectral data suggests is a mixture of α -amyrin (12) and β -amyrin (13), and the diterpene 14 (49.68 mg).

α -Amyrin (12) and β -amyrin (13)

The identity of this mixture was confirmed by comparing a 1:1 mixture of authentic α - and β -amyrins by nmr spectroscopy (¹Hmr and ¹³Cmr).

12-Methoxyabieta-8,11,13-trien-3α-ol (14)

Colourless needles (hexanes); mp 157–158°C; $[\alpha]^{22}$ +44 (*c* 0.72, CHCl₃); ir (CHCl₃) cm⁻¹: 3620 (OH), 2951 (CH); ¹Hmr (CDCl₃) δ : 0.96 (3H, s, C4-CH₃), 1.05 (3H, s, C4-CH₃), 1.20 (3H, s, C10-CH₃), 1.20 (3H, d, CH(CH₃)₂, *J* = 7), 1.21 (3H, d, CH(CH₃)₂, *J* = 7), 1.26–2.17 (11H, m), 2.76 (1H, ddd, H7 α , *J* = 2, 7, 16), 3.02 (1H, dd, H7 β , *J* = 7, 16), 3.28 (1H, septet, H15), 3.51 (1H, brt, H3 β , *W*_{1/2} = 7), 3.72 (3H, s, OCH₃), 7.04 (1H, s, H11), 7.05 (1H, s, H14); ¹³Cmr (CDCl₃) δ : 18.2, 22.1, 23.9, 24.0, 24.7, 24.8, 25.9, 26.0, 28.1, 29.7, 31.7, 37.7, 43.3, 60.2, 75.5, 120.4, 123.7, 128.5, 137.9, 148.9, 154.8; ms *m*/*z* (rel. int., %): 316 (M⁺, 20.9), 301 (4.7), 283 (100.0), 241 (4.6), 215 (5.1), 199 (3.6), 189 (6.9), 173 (5.7), 159 (4.1), 147 (4.8), 129 (4.5), 115 (3.9), 91 (4.1), 81 (2.0), 69 (3.4), 55 (5.6), 43 (9.8). High-resolution mass measurement: calcd. for C₂₁H₃₂O₂: 316.2404; found: 316.2411.

Separation of fractions J and K

Fractions J (815.16 mg) and K (195.71 mg) were combined (1.01 g) and partially separated by column chromatography (Merck silica gel 230–400 mesh, 100 g). Gradient elution was carried out using: (*i*) methylene chloride – ethyl acetate 19:1 (750 mL); (*ii*) methylene chloride – ethyl acetate 9:1 (700 mL); and (*iii*) ethyl acetate (200 mL) to give 9 fractions. Fractions 1 and 2 (13.18 and 36.17 mg respectively) contained a major orange-coloured compound and a minor compound, while fraction 3 (62.11 mg) consisted of two orange-coloured compounds. Fractions 4 and 5 (25.97 and 21.21 mg respectively) consisted of a major orange-coloured compound and a minor component. Fractions 6 and 7 (28.69 and 232.43 mg respectively) showed two compounds on tlc, while fractions 8 and 9 (411.67 and 40.97 mg respectively) consisted of one major compound and several minor compounds.

Separation of fractions 1 and 2 by preparative tlc (Merck silica F_{254} , 0.5 mm, chloroform-methanol 98.2), followed by a further separation using toluene - ethyl acetate - chloroform - formic acid 35:15:16:1 yielded tingenone (15, 15.30 mg) and the friedelane methyl ester (16, 13.62 mg). Separation of fraction 3 by preparative tlc (Merck silica F254, 0.5 mm, toluene - ethyl acetate chloroform - formic acid 35:15:16:1, plate eluted twice) gave tingenone (15, 14.00 mg) and 22β -hydroxytingenone (17, 13.04 mg). Fractions 4 and 5 were separated by preparative tlc (Merck silica F254, 0.5 mm, chloroform-methanol 98:2) to yield 22β-hydroxytingenone (17, 15.55 mg) and an unidentified mixture (9.12 mg). Column chromatography of fraction 7 (Merck silica gel 230-400 mesh, 25 g, methylene chloride - ethyl acetate 5:1) gave the dihydroxy triterpene, 18 (50.75 mg), an unidentified mixture (27.27 mg), and the triterpene, 19 (28.48 mg). Column chromatography of fractions 8 and 9 (Merck silica gel 230-400 mesh,

50 g, methylene chloride – ethyl acetate 5:1) gave polpunonic acid (**25**, 247.13 mg).

In summary, chromatographic separation yielded tingenone (15, 29.30 mg), the friedelane methyl ester, 16 (13.62 mg), 22β -hydroxytingenone (17, 28.59 mg), the dihydroxy triterpenes, 18 (50.75 mg) and 19 (28.48 mg), and polpunonic acid (25, 247.13 mg).

Tingenone (15)

The identity of the isolated sample was confirmed by comparison of the physical and spectral data with those of the authentic sample.

*Methyl-22β-hydroxy-3,21-dioxo-D:A-friedo-29-noroleanan-*24-oate (16)

Yellow crystals (EtOH); mp 250–251°C; $[\alpha]^{22}$ +101.4 (*c* 0.22, MeOH); uv (meOH) λ_{max} 203 (ϵ 1810); ir (CHCl₃) cm⁻¹: 3460 (OH, br), 3010, 2950 (CH), 1725 (C=O, sh), 1710 (C=O), 1700 (C=O, sh); ¹Hmr (CDCl₃) δ : 0.80 (3H, s), 0.84 (3H, s), 0.91 (3H, d), 0.94 (3H, s), 1.07 (3H, d), 1.36 (3H, s), 3.64 (3H, s, OCH₃), 1.16–1.85 (14H, m), 2.02 (1H, m), 2.15–2.38 (5H, m), 2.60–2.65 (2H, m), 2.77 (1H, m, H20 α), 3.66 (1H, s, OH), 4.61 (1H, brd, H22 α); ms *m/z* (rel. int., %): 486 (M⁺, 100.0), 471 (3.1), 468 (5.2), 426 (75.2), 411 (7.6), 399 (16.7), 398 (16.7), 385 (19.5), 357 (5.7), 340 (13.4), 317 (27.0), 257 (27.5), 231 (15.0), 217 (29.5), 203 (14.0), 189 (16.7), 177 (17.5), 163 (21.2), 149 (25.8), 135 (36.5), 121 (81.1), 109 (67.7), 95 (55.2), 81 (51.3), 67 (44.2), 55 (60.6). High-resolution mass measurement: calcd. for C₃₀H₄₆O₅: 486.3343; found: 486.3352.

22β -Hydroxytingenone (17)

All physical and spectral data of the isolated sample were identical with the data published earlier (26-30).

3β ,29-Dihydroxyolean-12-ene (18)

Colourless prisms (EtOH); mp 241–242°C; $[\alpha]^{22}$ +115.9 (*c* 0.82, MeOH); ir (KBr) cm⁻¹: 3294 (OH), 2946 (CH); ¹Hmr (CDCl₃) δ : 0.80 (3H, s), 0.85 (3H, s), 0.91 (3H, s), 0.94 (3H, s), 0.97 (3H, s), 1.00 (3H, s), 1.14 (3H, s), 0.73–2.02 (25H, m), 3.22 (1H, dd, H3 α , *J* = 3.5, 11), 3.27 (2H, d, H29, *J* = 5.5), 5.21 (1H, t, H12); ms *m/z* (rel. int., %): 442 (M⁺, 6.1), 427 (1.8), 411 (9.6), 393 (0.5), 288 (0.7), 273 (1.0), 234 (100.0), 219 (8.7), 203 (21.1), 201 (21.3), 187 (21.6), 175 (13.1), 161 (8.1), 147 (14.3), 135 (18.5), 119 (19.1), 107 (19.8), 95 (28.0), 81 (22.9), 69 (18.0), 55 (21.9). High-resolution mass measurement: calcd. for C₃₀H₅₀O₂: 442.3813; found: 442.3805.

Chromatographic separation of the spent medium extract metabolites (compare Fig. 4)

The spent medium extract (3.06 g) was partially separated by vlc using a 150-mL sintered glass funnel (medium frit, Merck silica 60G, 90 g). Stepwise elution was carried out using: (i) benzene (5 \times 30 mL); (*ii*) benzene-acetone 5:1 (19 \times 30 mL); (*iii*) benzeneacetone 4:1 (19 \times 30 mL); (iv) benzene-acetone 3:1 (12 \times 30 mL); (v) benzene-acetone 2:1 (230 mL); (vi) benzene-acetone 1:1 (18 \times 30 mL), and (vii) ethyl acetate (250 mL) to give 22 crude fractions. All the fractions were complex mixtures of metabolites. Fractions 3, 4, 5, 6, and 7 (204.68, 117.77, 158.08, 72.62, and 58.75 mg, respectively) were separated further by preparative tlc (Merck silica F_{254} , 4 × 2 mm plates, fractions 6 and 7 were combined) using toluene - ethyl acetate - chloroform-formic acid 35:15:161 (the plates were eluted three times) to give oleanolic acid (23, 59.66 mg), the hydroxy acid, 20 (134.63 mg), triptolide (2, 179.09 mg), and a complex mixture (168.31 mg) that was not further investigated. Fractions 8, 9, 10, 11, 12, and 13 (71.00, 113.66, 44.34, 84.0, 63.94, and 222.09 mg, respectively) were separated by preparative tlc (Merck silica F_{254} , 5 × 2 mm plates, 1×0.5 mm plate (fraction 10), toluene – ethyl acetate – chloroform – formic acid 35:15:16:1, the plates were eluted four times) to give 3 (13.22 mg), a mixture of 3 and 4 (10.30 mg), 4 (21.72 mg), a mixture of 4, 5, and 6 (42.48 mg), 5 (8.73 mg), 6 (25.53 mg), tripdiolide (1, 199.77), and a complex mixture (166.65 mg). Fractions 14, 15, and 16 (80.90, 38.65, and 10.96 mg, respectively) were separated by preparative tlc (Merck silica F_{254} , 1 × 2 mm plate (fraction 14), 1 × 0.5 mm plate (fractions 15 and 16), toluene - ethyl acetate - chloroform - formic acid 35:15:16:1, the plates were eluted three times) to give 6 (48.10 mg). Fractions 17 and 18 (56.27 and 151.71 mg, respectively) were separated by preparative tlc (1 \times 0.5 mm plate and 1×2 mm plate, respectively, benzene-methanol - acetic acid 90:5:5, the plates were eluted three times) to give a further quantity of 6 (30.67 mg). Attempted separation of fractions 19-22 (174.08, 83.45, 39.59, and 49.50 mg, respectively) by preparative tlc (Merck silica F_{254} , 2 × 2 mm plates, benzene-methanol – acetic acid 90:5:5, the plates were eluted three times) was unsuccessful due to the complexity of the mixture of polar compounds.

The identity of all isolated compounds was confirmed by comparison of physical and spectral data with those of the original samples and (or) with data published earlier.

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Appendix A

X-ray crystallographic analyses of compounds 6, 15, 16, 17, 18, and 19.

Experimental

X-ray crystallographic analyses of 6·MeOH, 15·1/2EtOAc, 16, 17·1/2 H₂O, 18, and 19·EtOH the remaining compounds throughout the data collections, remained essentially constant except for $15 \cdot 1/2$ EtOAc and $19 \cdot$ EtOH where 4.6% and 19.2% decay, respectively, were noted. The data were processed³ and corrected for Lorentz and polarization effects, linear decay for $15 \cdot 1/2$ EtOAc and $19 \cdot$ EtOH, and absorption for $15 \cdot 1/2$ EtOAc, 16, $17 \cdot 1/2$ H₂O, 18, and $19 \cdot$ EtOH (empirical, based on azimuthal scans for four reflections).

The structure analyses of 16 and 19 EtOH were initiated in the noncentrosymmetric space group $P2_1$ on the basis of the known chirality of these compounds. The structures were solved by direct methods, the coordinates of the non-hydrogen atoms being determined from E-maps and subsequent difference Fourier syntheses. The asymmetric units of 15, 16, and 18 each contain two molecules and those of 6, 15, 17, and 19 contain solvent molecules (methanol, ethyl acetate, water (1/2 molecule), and ethanol respectively). The solution of the structure of 16 by direct methods was not routine. The structure was eventually solved by excluding all h0l reflections from the phase determination. This led to the isolation of one correctly oriented, but incorrectly positioned, molecule. This oriented fragment was then positioned and the atoms of the second molecule in the asymmetric unit were located by direct methods for difference structures using the computer program DIRDIF.3 The ethyl acetate solvate molecule in 15.1/2 EtOAc was disordered. Site occupancy factors were initially estimated from relative Fourier map peak heights and were subsequently adjusted⁴ to result in approximately equal equivalent isotropic thermal parameters for the eight positions included in the model. All non-hydrogen atoms were refined with anisotropic thermal parameters. Oxygen-bound hydrogen atoms were refined with isotropic thermal parameters (6.MeOH and 16) or placed in difference map positions, and for all six structures the carbon-bound hydrogen atoms were fixed in idealized positions ($C(sp^2)$ —H = 0.97, C(sp³)—H = 0.98 Å, $U_{\rm H} \propto U_{\rm bonded atom}$ for 6 MeOH and C—H = 0.98 Å, $B_{\rm H}$ = 1.2 $B_{\rm bonded atom}$ for the other five structures). Neutral atom scattering factors and anomalous dispersion corrections for the non-hydrogen atoms were taken from the International tables for X-ray crystallography (38). The absolute configurations of 6, 15, and 17-19 are based on known configurations for one or more of the chiral centres and that of 16 has been determined by anomalous scattering. Parallel refinements of the opposite enantiomers were carried out for the four structures determined with Cu radiation, resulting in marginally higher residuals in each case. For compound 16, the R and R_w ratios are both 1.003, representing a confidence level of 99.5%. Final atomic coordinates and equivalent isotropic thermal parameters, bond lengths, bond angles, and intra-annular torsion angles appear in Tables A2-A5, respec-

⁴Attempts to refine even some of the population parameters led to nearly singular matrices due to high correlations with the thermal parameters.

Crystallographic data for the six compounds appear in Table A1. The final unit-cell parameters were obtained by least squares on the setting angles for 25 reflections with $2\theta = 34.0-41.3$, 40.1-56.5, 46.6-76.3, 20.0-35.8, 40.4-72.5, and $40.1-70.8^{\circ\circ}$ for **6**·MeOH, **15**·1/2EtOAc, **16**, **17**·1/2 H₂O, **18**, and **19**·EtOH, respectively. The intensities of three standard reflections, measured every hour of X-ray exposure time for **6**·MeOH and every 150 reflections for

³Computer programs used include locally written programs for data processing and locally modified versions of the following for the structure of 6·MeOH: MULTAN80, multisolution program by P. Main, S. J. Fiske, S. E. Hull, L. Lessinger, G. Germain, J. P. Declercq, and M. M. Woolfson; ORFLS, full-matrix least squares, and ORFFE, function and errors, by W. R. Busing, K. O. Martin, and H. A. Levy; FORDAP, Patterson and Fourier syntheses, by A. Zalkin; ORTEP II, illustrations, by C. K. Johnson. The TEXSAN/ TEXRAY structure analysis package, which includes versions of the following, was employed for the other five structures: MITHRIL, integrated direct methods, by C. J. Gilmore; DIRDIF, direct methods for difference structures, by P. T. Beurskens; ORFLS, full-matrix least squares, and ORFFE, function and errors, by W. R. Busing, K. O. Martin, and H. A. Levy; ORTEP II, illustrations, by C. K. Johnson.

Compound	6·MeOH	15-1/2 EtO/Ac	16	17 ·1/2 H ₂ O	18	19-EtOH
Formula	$C_{31}H_{52}O_5$	$C_{30}H_{40}O_{4}$	$C_{30}H_{46}O_5$	C ₂₈ H ₃₇ O _{4.5}	$C_{30}H_{50}O_2$	$C_{32}H_{56}O_3$
fw	504.75	464.64	486.69	445.60	442.74	488.79
Crystal system	Orthorhombic	Orthorhombic	Monoclinic	Orthorhombic	Orthorhombic	Monoclinic
Space group	$P2_{1}2_{1}2_{1}$	$P2_{1}2_{1}2_{1}$	$P2_1$	P21212	C222 ₁	P2 ₁
<i>a</i> , Å	8.1397(5)	14.719(2)	7.282(2)	13.922(5)	19.872(5)	14.640(2)
<i>b</i> , Å	11.9965(8)	28.375(8)	28.742(2)	15.253(2)	19.946(2)	6.695(2)
<i>c</i> , Å	29.161(1)	12.221(2)	12.421(2)	11.067(2)	27.211(3)	15.618(2)
β, deg	-	-	97.23(2)	-	-	98.57(2)
V, Å ³	2847.5(3)	5104(2)	2579.0(7)	2350(1)	10786(3)	1513.6(9)
Ζ	4	8	4	4	16	2
$\rho_{calc}, g/cm^3$	1.18	1.21	1.25	1.26	1.09	1.07
F(000)	1112	2016	1064	964	3936	544
Radiation	Mo	Cu	Cu	Mo	Cu	Cu
μ, cm ⁻¹	0.72	5.83	6.23	0.78	4.66	4.77
Crystal size, mm	$0.20 \times 0.40 \times 0.45$	$0.05\times0.10\times0.25$	$0.10\times0.30\times0.35$	$0.10 \times 0.35 \times 0.35$	$0.15\times0.25\times0.35$	$0.04 \times 0.30 \times 0.4$
Transmission factors	_	0.93-1.00	0.96-1.00	0.97-1.00	0.93-1.00	0.83-1.00
Scan type	ω-θ	$\omega - 2\theta$	$\omega - 2\theta$	$\omega - 2\theta$	$\omega - 2\theta$	$\omega - 2\theta$
Scan range, deg in ω	$0.85 + 0.35 \tan \theta$	$0.95 + 0.30 \tan \theta$	0.95 + 0.30 tan θ	1.26 + 0.35 tan θ	1.00 + 0.30 tan θ	1.10 + 0.30 tan θ
Scan rate, deg/min	1.8-10.0	8	16	16	16	8
Data collected	+h, +k, +l	+h, +k, +l	+h. +k, +l	+h, +k, +l	+h, +k, +l	+h, +k, +l
2θ _{max} , deg	55	150	155	55	150	125
Cryst. decay	Negligible	4.6%	Negligible	Negligible	Negligible	19.2%
Total reflections	3681	5416	5862	3034	5756	2862
Unique reflections	3681	5416	5425	3034	5756	2601
R _{merge}	-	-	0.032	-	-	0.029
Rmerge	-	-	0.032	-	-	0.029
Reflections with $I \ge 3\sigma(I)$	2386	3120	3738	1939	3567	1605
Variables	341	632	639	295	587	316
R	0.047	0.054	0.044	0.046	0.045	0.045
R_w	0.057	0.071	0.056	0.059	0.057	0.059
gof	1.73	2.34	1.51	1.73	1.53	1.88
Max Δ/σ (final cycle)	0.13	0.08	0.06	0.14	0.004	0.01
Residual density e/Å ³	-0.18 to +0.27	-0.18 to +0.38	-0.20 to +0.21	-0.19 to +0.23	-0.24 to $+0.21$	-0.16 to +0.17

TABLE A1. Crystallographic data^a

"Temperature 294 K, function minimized $\Sigma w(|F_o| - |F_c|)^2$ where $w = 4F_o^2/\sigma^2(F_o^2)$, $R = \Sigma ||F_o| - |F_c|/\Sigma |F_o|$, $R_w = (\Sigma w(|F_o| - |F_c|)^2/\Sigma w |F_o|^2)^{1/2}$, and gof $[\Sigma(|F_o| - |F_c|)^2/(m - n)]^{1/2}$. Values given for R, R_w , and gof are based on those reflections with $I \ge 3\sigma(I)$.

^bEnraf–Nonius CAD4-F diffractometer, Mo-K_a radiation ($\lambda K_{\alpha 1} = 0.70930$, $\lambda K_{\alpha 2} = 0.71359$ Å), graphite monochromator, takeoff angle 2.7°, apertu (2.0 + tan θ) × 4.0 mm at a distance of 173 mm from the crystal, scan range extended by 25% on both sides for background measurement, $\sigma^2(I) = C + 2B$ [0.04(C - B)]² (S = scan rate, C = scan count, B = normalized background count).

^cRigaku AFC6S diffractometer, Cu-K_{α}($\lambda = 1.54178$ Å) or Mo-K_{α}($\lambda = 0.71069$ Å) radiation, graphite monochromator, takeoff angle 6.0°, aperture 6.0 6.0 mm at a distance of 285 mm from the crystal, stationary background counts at each end of the scan (scan/background time ratio 2:1, up to 8 rescans $\sigma^2(F^2) = [S^2(C + 4B) + (0.04F^2)^2]/Lp^2(S = scan rate, C = scan count, B = normalized background count).$

tively. Hydrogen atom parameters, anisotropic thermal parameters, stereoviews of the molecules, packing diagrams (where relevant), and measured and calculated structure factor amplitudes for the six structures are included as supplementary material.⁵

Discussion of crystal structures

The crystal structure of $6 \cdot$ MeOH features extensive hydrogen bonding, the methanol solvate molecule being involved in two hydrogen bonds: a very strong hydrogen bond

to the carboxylic acid function and a strong hydrogen bond to a hydroxyl group $(O(4) - H(O4) \cdots O(5)$ and $O(5) - H(O5) \cdots O(1)$, $O \cdots H = 1.65(4)$ and 1.84(6) Å, $O \cdots O = 2.595(4)$ and 2.742(4) Å, $O - H \cdots O = 167(4)$ and $175(5)^\circ$). There are also two weaker hydrogen bonds directly linking each molecule of **6** to four others $(O(1) - H(O1) \cdots O(2)$ and $O(2) - H(O2) \cdots O(3)$, $O \cdots H = 2.07(5)$ and 2.00(6) Å, $O \cdots O = 2.813(4)$ and 2.848(4) Å, $O - H \cdots O = 176(5)$ and $168(4)^\circ$). All of the saturated six-membered rings have chair conformations and the unsaturated C ring has a sofa conformation. The saturated ring fusions A:B, B:C, and D:E are *trans, trans*, and *cis*, respectively.

The crystal structure of $15 \cdot 1/2$ EtOAc consists of molecules of 15 and ethyl acetate, those of the triterpene being linked into infinite chains extending along the *c* axis by O—H···O hydrogen bonds between the O(2) hydroxyl group and the O(1) carbonyl oxygen atom (O(2)—H(36)···O(1') and O(2')—H(36')···O(1), H···O = 1.83 and 1.83 Å, O···O = 2.726(6) and 2.659(7) Å, O—H···O = 153 and 136°,

⁵Supplementary material mentioned in the text may be purchased from: The Depository of Unpublished Data, Document Delivery, CISTI, National Research Council Canada, Ottawa, Canada K1A 0R6.

Tables of hydrogen atom parameters, stereoviews of the molecules, and relevant packing diagrams have also been deposited with the Cambridge Crystallographic Data Centre and can be obtained on request from The Director, Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, Cambridge CB2 1EW, U.K.

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TABLE A2. Final positional (fractional) and equivalent isotropic thermal parameters with estimated standard deviations in parentheses

$\begin{array}{c c c c c c c c c c c c c c c c c c c $	0.2624 0.3458 0.4167 0.5509 0.2788 0.3584 0.3408 0.3408 0.1902 0.3208 0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	0.3438 0.4167 0.5509 0.2788 0.3584 0.3408 0.3408 0.1902 0.3208 0.1700 0.2235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.4167 0.5509 0.2788 0.3584 0.3408 0.3408 0.1902 0.3208 0.1700 0.22707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.5509 0.2788 0.3584 0.3408 0.3408 0.1902 0.3208 0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.2788 0.3584 0.3408 0.3483 0.1902 0.3208 0.1700 0.2235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.3584 0.3408 0.3483 0.1902 0.3208 0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.3408 0.3483 0.1902 0.3208 0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.3483 0.1902 0.3208 0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.1902 0.3208 0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.3208 0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.1700 0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.3235 0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.2707 0.2616 0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.2616
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.1779
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	0.1117
C(9) 0.2595(4) 0.0694(3) 0.2635(1) 31 $C(5')$	0.1131
	0.1235
C(10) 0.2033(4) 0.0466(3) 0.3141(1) 30 $C(6')$	0.0596
C(11) 0.4474(5) 0.0758(4) 0.2582(1) 52 C(7')	0.0706
C(12) 0.5048(5) 0.0729(4) 0.2096(1) 46 $C(8')$	0.1406
C(13) 0.4135(4) 0.0619(3) 0.1727(1) 30 $C(9')$	0.2107
C(14) 0.2262(4) 0.0532(3) 0.1772(1) 29 $C(10')$	0.2046
C(15) 0.1489(5) -0.0103(3) 0.1372(1) 41 $C(11')$	0.3074
C(16) 0.2263(5) 0.0153(3) 0.0900(1) 39 $C(12')$	0.3163
C(17) 0.4119(5) -0.0059(3) 0.0896(1) 33 $C(13')$	0.2501
C(18) 0.4945(4) 0.0704(3) 0.1256(1) 33 $C(14')$	0.1504
C(19) 0.5042(5) 0.1923(3) 0.1111(1) 37 $C(15')$	0.0858
C(20) 0.5912(4) 0.2111(3) 0.0646(1) 34 $C(16')$	0.0934
C(21) 0.4981(4) 0.1395(3) 0.0287(1) 37 $C(17')$	0.1905
C(22) = 0.4865(4) = 0.0181(3) = 0.0415(1) = 35 $C(18')$	0.2632
C(23) = -0.0596(5) = -0.0592(3) = 0.3888(1) = 43 $C(19')$	0.3600
C(24) = -0.2559(5) = 0.0743(4) = 0.3548(1) = 50 $C(20')$	0.3821
C(25) = 0.2766(5) -0.0627(4) = 0.3339(1) 47 $C(21')$	0.3083
C(26) 0.2560(6) -0.1232(3) 0.2260(1) 51 $C(22')$	0.2151
C(27) 0.1580(5) 0.1734(3) 0.1747(1) 42 C(23')	0.0322
C(28) = 0.4463(6) -0.1280(3) = 0.1009(1) 55 $C(24')$	0.1917
C(29) 0.5728(5) 0.3315(3) 0.0504(1) 38 C(25')	0.2687
C(30) = 0.7742(5) = 0.1806(4) = 0.0666(1) = 48 $C(26')$	0.1243
O(5) 0.6454(4) 0.0713(3) 0.4726(1) 76 $C(27')$	0.1868
C(31) = 0.5702(7) = 0.1491(4) = 0.5003(2) = 75 $C(28')$	0.4781
O(4)	0.0678
$15 \cdot 1/2$ EtOAc $Q(5)$	0.0341
O(1) 0.2579(3) 0.2773(2) -0.1597(4) 7.0(3) $C(29)$	0.10002
O(2) 0.4176(3) 0.2336(2) -0.1834(3) 4.7(2) C(30)	0.147(
O(3) 0.3572(5) 0.5847(2) 0.4929(5) 8.6(4) $C(31)$	0.026
C(1) 0.2891(4) 0.3029(2) 0.0195(5) 4.3(3) $C(32)$	-0.0157
C(2) 0.3119(4) 0.2793(2) -0.0812(6) 4.4(3) $C(33)$	0.043(
C(3) 0.3982(4) 0.2569(2) -0.0893(5) 3.7(3) $C(34)$	0.032(
C(4) = 0.4589(4) = 0.2577(2) = -0.0071(6) = 3.8(3)	
C(5) = 0.4372(4) = 0.2824(2) = 0.0942(5) = 3.4(3)	
C(6) = 0.4972(4) = 0.2891(2) = 0.1770(5) = 4.1(3) = O(1)	0.5929
C(7) = 0.4789(4) = 0.3189(2) = 0.2677(5) = 4.2(3) = O(2)	0.8356
C(8) = 0.3975(4) = 0.3375(2) = 0.2889(5) = 3.6(3) = O(3)	1.0781
C(9) = 0.3181(4) = 0.3216(2) = 0.2179(5) = 3.5(3) = O(4)	0 4766
C(10) = 0.3482(4) = 0.3038(2) = 0.1051(5) = 3.4(3) = O(5)	0.6799
C(11) = 0.2417(4) = 0.3574(2) = 0.7057(5) = 4.5(3) = C(1)	0 4376
C(12) = 0.2270(4) = 0.3891(2) = 0.3081(5) = 4.4(3) = C(1)	0 4802
C(13) = 0.3157(4) = 0.4111(2) = 0.3495(5) = 3.7(3) = C(2)	0.4002
C(14) = 0.3807(4) = 0.3708(2) = 0.3854(5) = 4.0(3) = C(4)	0 7786
C(15) = 0.4690(5) = 0.3933(2) = 0.4274(6) = 5.2(4) = C(5)	0 7229
C(16) = 0.4538(5) = 0.4256(3) = 0.5239(6) = 6.2(4) = C(6)	0.8961
C(17) 0.3779(5) 0.4624(2) 0.5135(5) 4.5(3) $C(7)$	0.8671
C(18) = 0.2949(4) = 0.4438(2) = 0.4484(5) = 4.3(3) = C(7)	0 7478
C(19) = 0.2266(5) = 0.4833(3) = 0.4310(6) = 5.4(4) = C(9)	.,

	TA	ABLE A2 (conti	nued)	
Atom	x	y	=	$U_{\rm eq}/B_{\rm eq}^{\ a}$
C(20)	0.2624(5)	0.5316(3)	0.3926(6)	5.5(4)
C(21)	0.3458(6)	0.5443(3)	0.4542(6)	6.0(4)
C(22)	0.4167(5)	0.5071(3)	0.4630(6)	5.6(4)
C(23)	0.5509(5)	0.2330(3)	-0.0208(6)	5.6(4)
C(24)	0.2788(5)	0.2751(3)	0.2714(6)	5.8(4)
C(25)	0.3584(4)	0.4389(2)	0.2527(5)	4.2(3)
C(26)	0.3408(6)	0.3404(2)	0.4816(6)	6.2(4)
C(27)	0.3483(0) 0.1002(7)	0.4/40(3)	0.6302(0)	0.3(4)
O(1')	0.1902(7)	0.3701(3)	0.4003(7)	6.7(3)
O(2')	0.3208(3) 0.1700(3)	0.2103(2)	0.0307(4)	6.2(3)
O(2')	0.1700(3) 0.3235(4)	0.2030(2)	-0.3488(4)	8 1(3)
C(1')	0.3233(4) 0.2707(4)	0.0771(2) 0.1789(2)	0.34699(5)	45(3)
C(2')	0.2707(4) 0.2616(4)	0.2105(2)	0.5597(5)	4 3(3)
C(3')	0.1779(5)	0.2384(2)	0.5653(5)	4.6(3)
C(4')	0.1131(4)	0.2357(2)	0.4887(5)	4.1(3)
C(5')	0.1235(4)	0.2016(2)	0.4020(5)	3.5(3)
C(6')	0.0596(4)	0.1966(2)	0.3219(5)	4.1(3)
C(7')	0.0706(4)	0.1662(2)	0.2310(5)	4.3(3)
C(8')	0.1406(4)	0.1363(2)	0.2185(5)	3.5(3)
C(9')	0.2107(4)	0.1327(2)	0.3122(5)	3.2(2)
C(10')	0.2046(4)	0.1732(2)	0.3951(5)	3.6(3)
C(11')	0.3074(4)	0.1296(2)	0.2641(5)	4.2(3)
C(12')	0.3163(4)	0.0976(2)	0.1642(5)	4.4(3)
C(13')	0.2501(4)	0.1112(2)	0.0715(5)	3.7(3)
C(14')	0.1504(4)	0.1062(2)	0.1166(5)	3.7(3)
C(15')	0.0858(4)	0.1213(2)	0.0239(6)	4.5(3)
C(16')	0.0934(5)	0.0901(3)	-0.0783(6)	5.2(4)
C(17')	0.1905(5)	0.0806(2)	-0.1231(5)	4.6(3)
C(18')	0.2632(4)	0.0771(2)	-0.0300(5)	4.1(3)
C(19')	0.3600(5)	0.0765(2)	-0.0789(5)	4.5(3)
C(20)	0.3821(3)	0.1137(3)	-0.1084(0)	5.8(4)
C(21)	0.3083(0)	0.1102(3) 0.1183(3)	-0.2337(7) -0.2000(6)	5.5(4)
C(22')	0.2131(3) 0.0322(5)	0.1183(3) 0.2680(2)	-0.2099(0) 0.4936(7)	5.3(4)
C(24')	0.0322(3) 0.1917(5)	0.2000(2) 0.0884(2)	0.3824(6)	5 5(4)
C(25')	0.2687(5)	0.1630(2)	0.0428(5)	4.6(3)
C(26')	0.1243(5)	0.0545(2)	0.1460(6)	5.1(3)
C(27')	0.1868(6)	0.0333(3)	-0.1825(7)	6.6(4)
C(28')	0.4781(6)	0.1064(4)	-0.2146(7)	7.6(5)
O(4)	0.0678(7)	0.3510(4)	0.7843(8)	11.5(7)
O(5)	0.0341(9)	0.3814(3)	0.6176(9)	11.2(7)
C(29)	0.100(2)	0.3807(4)	0.698(1)	10(1)
C(30)	0.147(1)	0.4041(6)	0.676(1)	10(1)
C(31)	0.026(1)	0.4052(6)	0.513(1)	10(1)
C(32)	-0.0157(8)	0.4471(5)	0.515(1)	9.6(8)
C(33)	0.043(1)	0.4573(6)	0.679(2)	10(1)
C(34)	0.032(1)	0.433(1)	0.607(2)	10(2)
		16		
O(1)	0.5929(6)	0.5857	0.4792(3)	5.3(2)
O(2)	0.8356(5)	0.1300(1)	0.7155(3)	4.7(2)
O(3)	1.0781(5)	0.1725(2)	0.6100(3)	5.0(2)
O(4)	0.4766(5)	0.5088(2)	0.3115(2)	4.0(1)
O(5)	0.6799(6)	0.4726(2)	0.2215(3)	5.7(2)
C(1)	0.4326(6)	0.4702(2)	0.5187(3)	3.2(2)
C(2)	0.4802(7)	0.5191(2)	0.5624(4)	3.7(2)
C(3)	0.6114(7)	0.5448(2)	0.5010(3)	3.6(2)
C(4)	0.7786(7)	0.5175(2)	0.4/48(4)	3.5(2)
C(3)	0.7229(6)	0.4/02(2)	0.4181(3)	2.9(2)
C(0)	0.8901(6)	0.4416(2)	0.406/(4)	3.3(2)
C(1)	0.0021(0)	0.3912(2)	0.3749(4)	5.4(2) 2 2(1)
	0.7470(3)	0.3003(2) 0.3015(2)	0.4550(5)	2.5(1) 2 $A(1)$
(\mathcal{I})	0.0001(0)	0.5713(2)	0.7007(0)	2.7(1)

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TABLE A2 (continued)

TABLE A2 (continued)

Atom	X	у	Ζ	$U_{\rm eq}/B_{\rm eq}^{a}$	Atom	x	у	Ζ	$U_{ m eq}/B_{ m eq}{}^a$
C(10)	0.6009(6)	0.4427(2)	0.4915(3)	2.5(1)	C(2)	0.4738(3)	0.6496(3)	0.6740(4)	3.1(2)
C(11)	0.4490(6)	0.3669(2)	0.5361(3)	2.8(2)	C(3)	0.4891(3)	0.7314(3)	0.6085(3)	2.9(2)
C(12)	0.4451(6)	0.3133(2)	0.5273(3)	2.7(2)	C(4)	0.4457(3)	0.7469(3)	0.5009(4)	2.9(2)
C(13)	0.6402(5)	0.2914(2)	0.5359(3)	2.4(1)	C(5)	0.3837(3)	0.6801(2)	0.4484(3)	2.5(2)
C(14)	0.7421(6)	0.3123(2)	0.4435(3)	2.5(1)	C(6)	0.3417(3)	0.6915(3)	0.3391(4)	3.1(2)
C(15)	0.9411(6)	0.2924(2)	0.4586(4)	3.2(2)	C(7)	0.2943(3)	0.6234(3)	0.2767(3)	3.2(2)
C(16)	0.9437(6)	0.2394(2)	0.4474(4)	3.4(2)	C(8)	0.2779(3)	0.5442(2)	0.3245(3)	2.6(2)
C(17)	0.8092(6)	0.2112(2)	0.5095(3)	2.8(2)	C(9)	0.2990(3)	0.5304(2)	0.4585(3)	2.5(2)
C(18)	0.6242(5)	0.2373(2)	0.5220(3)	2.5(1)	C(10)	0.3697(3)	0.5973(2)	0.5107(3)	2.5(2)
C(19)	0.5135(6)	0.2111(2)	0.5997(3)	2.8(2)	C(11)	0.3326(3)	0.4359(2)	0.4871(3)	2.9(2)
C(20)	0.0101(0)	0.1926(2) 0.1604(2)	0.7077(4)	3.2(2)	C(12)	0.2919(3)	0.3631(2)	0.4081(3)	2.7(2)
C(21)	0.7901(0)	0.1094(2) 0.1072(2)	0.0634(3)	3.1(2)	C(13)	0.2977(3)	0.3850(2)	0.2720(3)	2.2(1)
C(22)	0.9132(0)	0.1975(2) 0.5475(2)	0.0222(4) 0.4161(5)	5.4(2)	C(14)	0.2331(3)	0.4699(2)	0.2313(3) 0.1154(3)	2.3(2)
C(23) C(24)	0.9072(9)	0.3473(2) 0.4824(2)	0.4101(3)	3.3(3)	C(15)	0.2333(3) 0.1878(3)	0.4900(3)	0.1134(3) 0.0301(4)	3.3(2)
C(24)	0.0274(7) 0.4321(6)	0.4024(2) 0.3914(2)	0.3000(3) 0.3435(3)	3.4(2)	C(10)	0.1876(3) 0.2324(3)	0.4108(3) 0.3258(3)	0.0391(4) 0.0585(3)	3.0(2)
C(25)	0.7361(6)	0.3017(2)	0.5455(3)	3.2(2)	C(18)	0.2524(3)	0.3238(3) 0.3078(2)	0.0385(3) 0.1945(3)	2.3(2) 2.5(1)
C(27)	0.7501(0) 0.6521(7)	0.3037(2) 0.2979(2)	0.0000(3) 0.3291(3)	3.3(2)	C(10)	0.2334(3)	0.3078(2) 0.2201(2)	0.1945(3)	2.3(1) 2.9(2)
C(28)	0.0521(7) 0.7646(7)	0.2575(2) 0.1660(2)	0.3251(3) 0.4458(4)	3.9(2)	C(20)	0.3054(3)	0.2201(2)	0.2080(3) 0.1246(3)	2.9(2)
C(20)	0.7048(7) 0.4928(8)	0.1600(2)	0.7662(4)	4 1(2)	C(21)	0.3748(3)	0.2033(3) 0.2310(3)	-0.0045(3)	2.7(2)
C(30)	0.382(1)	0.5273(2)	0.2123(4)	5.8(3)	C(22)	0.3740(3)	0.2310(3) 0.3183(2)	-0.0206(3)	2.7(2)
0(6)	1.0397(7)	0.1783(2)	-0.0363(3)	6.5(2)	C(23)	0.5255(3) 0.4642(3)	0.3103(2) 0.8318(3)	0.4356(4)	3.5(2)
O(7)	0.5525(6)	-0.2632(2)	-0.1027(3)	5.4(2)	C(24)	0.2037(3)	0.5514(3)	0.5323(4)	3.6(2)
O(8)	0.3915(5)	-0.2133(2)	0.0351(4)	5.9(2)	C(25)	0.4034(3)	0.4060(2)	0.2431(3)	2.7(2)
O(9)	1.0302(6)	0.0818(2)	0.2989(3)	5.2(2)	C(26)	0.1274(3)	0.4574(3)	0.2881(4)	3.5(2)
O(10)	1.1816(5)	0.1191(2)	0.1805(3)	4.3(1)	C(27)	0.1598(3)	0.2565(3)	0.0152(4)	3.5(2)
C(31)	1.1868(7)	0.0582(2)	-0.0076(4)	3.6(2)	C(28)	0.4287(4)	0.1084(3)	0.1317(4)	4.0(2)
C(32)	1.1417(8)	0.1026(2)	-0.0727(4)	4.7(2)	. ,		10	. ,	
C(33)	1.0223(8)	0.1369(2)	-0.0237(4)	4.2(2)			18		
C(34)	0.8652(7)	0.1171(2)	0.0324(4)	4.0(2)	O(1)	0.5317(2)	-0.1026(1)	0.1684(1)	4.8(2)
C(35)	0.9220(6)	0.0744(2)	0.1058(3)	3.1(2)	O(2)	0.1550(2)	0.3796(2)	0.2088(1)	5.1(2)
C(36)	0.7486(7)	0.0528(2)	0.1432(4)	3.6(2)	C(1)	0.5012(2)	0.0822(2)	0.1800(2)	3.6(2)
C(37)	0.7740(6)	0.0038(2)	0.1912(4)	3.3(2)	C(2)	0.5366(2)	0.0142(2)	0.1838(2)	3.5(2)
C(38)	0.8514(5)	-0.0285(2)	0.1107(3)	2.4(1)	C(3)	0.4939(2)	-0.0418(2)	0.1643(2)	3.6(2)
C(39)	1.0451(5)	-0.0115(2)	0.0870(3)	2.6(1)	C(4)	0.4696(2)	-0.0313(2)	0.1108(2)	3.3(2)
C(40)	1.0161(6)	0.0380(2)	0.0368(3)	2.7(2)	C(5)	0.4373(2)	0.0399(2)	0.1080(1)	2.9(2)
C(41)	1.1194(6)	-0.0439(2)	0.0039(3)	3.0(2)	C(6)	0.40/3(2)	0.0570(2)	0.05/9(2)	3.7(2)
C(42)	1.0904(0)	-0.0961(2)	0.0267(4)	2.9(2)	C(7)	0.3597(2)	0.1164(2)	0.0614(2)	3.0(2)
C(43)	0.8932(0)	-0.1099(2) -0.0817(2)	0.0307(3) 0.1337(3)	2.4(1)	C(8)	0.3918(2) 0.4218(2)	0.1804(2) 0.1614(2)	0.0830(1)	3.0(2)
C(44)	0.8331(0)	-0.0817(2)	0.1337(3)	2.4(1)	C(9)	0.4318(2)	0.1014(2)	0.1300(1) 0.1278(1)	3.1(2)
C(45)	0.0298(0)	-0.1456(2)	0.1411(4) 0.1673(4)	3.2(2)	C(10)	0.4600(2)	0.0989(2) 0.2234(2)	0.1278(1) 0.1524(2)	5 2(3)
C(40) C(47)	0.0003(0)	-0.1809(2)	0.1075(4)	2.3(2)	C(12)	0.4000(2)	0.2234(2) 0.2863(2)	0.1324(2) 0.1466(2)	3.2(3)
C(48)	0.8901(0)	-0.1629(2)	0.0975(3)	2.0(2) 2.5(1)	C(12)	0.4207(2)	0.2805(2) 0.2936(2)	0.1400(2) 0.1219(2)	3.0(2)
C(49)	0.0020(5) 0.9448(6)	-0.1958(2)	-0.0260(3)	3 1(2)	C(14)	0.3359(2)	0.2331(2)	0.0982(1)	3.0(2)
C(50)	0.8011(7)	-0.2102(2)	-0.1206(3)	3.4(2)	C(15)	0.2931(2)	0.2538(2)	0.0532(2)	3.8(2)
C(51)	0.6290(7)	-0.2260(2)	-0.0778(4)	3.6(2)	C(16)	0.2553(2)	0.3203(2)	0.0593(2)	3.9(2)
C(52)	0.5506(6)	-0.1939(2)	-0.0005(4)	3.6(2)	C(17)	0.3015(2)	0.3787(2)	0.0724(2)	3.6(2)
C(53)	0.763(1)	0.1547(2)	0.0864(6)	5.8(3)	C(18)	0.3363(2)	0.3626(2)	0.1219(2)	3.3(2)
C(54)	1.0465(6)	0.0910(2)	0.2054(4)	3.2(2)	C(19)	0.2894(2)	0.3691(2)	0.1661(2)	3.5(2)
C(55)	1.1937(6)	-0.0095(2)	0.1879(3)	3.2(2)	C(20)	0.2525(2)	0.4362(2)	0.1706(2)	3.6(2)
C(56)	0.7799(7)	-0.0978(2)	-0.0723(3)	3.3(2)	C(21)	0.2158(2)	0.4491(2)	0.1224(2)	4.2(2)
C(57)	0.9443(7)	-0.0936(2)	0.2439(3)	3.4(2)	C(22)	0.2619(2)	0.4452(2)	0.0780(2)	4.4(2)
C(58)	0.7374(7)	-0.2254(2)	0.1639(4)	4.0(2)	C(23)	0.5268(3)	-0.0434(2)	0.0739(2)	4.7(2)
C(59)	0.8772(9)	-0.2460(2)	-0.1925(4)	4.9(2)	C(24)	0.4142(2)	-0.0835(2)	0.1010(2)	5.0(2)
C(60)	1.3072(8)	0.1379(2)	0.2691(5)	5.2(2)	C(25)	0.5441(2)	0.1124(2)	0.0972(2)	4.5(2)
		17.1/2 U C)		C(26)	0.4388(3)	0.2110(3)	0.0440(2)	4.9(2)
		$1/1/2 \Pi_2 C$,		C(27)	0.2862(2)	0.2040(2)	0.1368(2)	3.4(2)
O(1)	0.5163(2)	0.6371(2)	0.7708(3)	4.5(2)	C(28)	0.3539(3)	0.3896(2)	0.0325(2)	5.1(3)
O(2)	0.5471(2)	0.7922(2)	0.6600(3)	4.3(1)	C(29)	0.2026(2)	0.4327(2)	0.2131(2)	4.2(2)
O(3)	0.4017(2)	0.1890(2)	-0.0912(3)	3.9(1)	C(30)	0.3016(2)	0.4930(2)	0.1836(2)	5.2(3)
U(4)	0.2970(2)	0.3306(2)	-0.1439(2)	4.3(1)	O(1')	-0.0308(2)	0.2757(1)	0.16/5(1)	4.3(1)
O(3)	1/2	1/2	0.9525(6)	11.0(3)	$O(2^{\circ})$	0.3547(2)	-0.2191(2)	0.2240(1)	4.0(2)
C(1)	0.4121(3)	0.5851(2)	0.0185(4)	3.0(2)	$C(\Gamma)$	~0.0007(2)	0.0913(2)	0.1879(1)	2.9(2)

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TABLE A2 (concluded)

Atom	<i>x</i>	у	Z	U_{eq}/B_{eq}^{a}
C(31)	0.5125(8)	0.202(2)	0.8604(5)	11.8(6)
C(32)	0.520(1)	0.055(4)	0.9199(8)	20(1)

"For compound 6 the thermal parameter given is $1000 \times U_{eq} = 1/3$ trace of diagonalized U tensor. For all of the other compounds, the parameter given is $B_{eq} = (8/3)_{\pi}^{2} \Sigma \Sigma U_{ij} a_{i}^{*} a_{i}^{*} (\mathbf{a}_{i} \cdot \mathbf{a}_{i})$.

TABLE A3.	Bond lengths (Å) with	estimated	standard	deviations
	in	parenth	neses		

Bond	Length (Å)	Bond	Length (Å)
	6·N	1eOH	
O(1) - C(3)	1.435(4)	C(10)—C(25)	1.552(5)
O(2) - C(22)	1.439(4)	C(11) - C(12)	1.493(5)
O(3) - C(29)	1.195(4)	C(12)—C(13)	1.313(4)
O(4) - C(29)	1.313(5)	C(13)—C(14)	1.534(4)
C(1) - C(2)	1.527(5)	C(13)—C(18)	1.527(4)
C(1) - C(10)	1.538(5)	C(14) - C(15)	1.530(4)
C(2) - C(3)	1.510(5)	C(14) - C(27)	1.547(5)
C(3) - C(4)	1.538(5)	C(15) - C(16)	1.544(5)
C(4) - C(5)	1.565(4)	C(16) - C(17)	1.532(5)
C(4) - C(23)	1.528(5)	C(17) - C(18)	1.546(5)
C(4) - C(24)	1.531(5)	C(17) - C(22)	1.555(4)
C(5) - C(6)	1.530(5)	C(17) - C(28)	1.526(5)
C(5) - C(10)	1.546(5)	C(18) - C(19)	1.524(5)
C(0) - C(7)	1.536(5)	C(19) - C(20)	1.545(5)
C(7) = C(8)	1.535(5)	C(20) - C(21)	1.551(5)
C(8) = C(9)	1.553(4)	C(20) - C(29)	1.510(5)
C(8) = C(14)	1.592(4)	$C(20) \rightarrow C(30)$	1.535(5)
C(0) = C(10)	1.538(5)	C(21) - C(22)	1.306(5)
C(9) = C(10)	1.369(4)	O(5) - C(31)	1.3/8(5)
O(1) = U(01)	1.340(3)	O(4) $U(04)$	0.0((4)
O(2) - H(02)	0.73(3)	O(4) - H(04)	0.90(4)
$O(2) \Pi(02)$	0.80(4)	O(3)—n(03)	0.91(0)
	15.1/2	2 EtOAc	
O(1)—C(2)	1.247(7)	O(1') - C(2')	1.240(7)
O(2) - C(3)	1.357(7)	O(2') - C(3')	1.363(7)
O(3)—C(21)	1.252(8)	O(3') - C(21')	1.224(9)
C(1) - C(10)	1.362(8)	C(1') - C(10')	1.344(8)
C(1) - C(2)	1.441(8)	C(1') - C(2')	1.425(9)
C(2) - C(3)	1.423(8)	C(2') - C(3')	1.465(9)
C(3) - C(4)	1.345(9)	C(3') - C(4')	1.338(8)
C(4) - C(5)	1.459(8)	C(4') - C(5')	1.444(8)
C(4) - C(23)	1.534(9)	C(4') - C(23')	1.503(9)
C(5) - C(6)	1.357(8)	C(5') - C(6')	1.365(8)
C(5) - C(10)	1.449(8)	C(5') - C(10')	1.444(8)
C(0) - C(7)	1.421(9)	C(6') - C(7')	1.417(9)
C(7) = C(8)	1.335(8)	C(7') - C(8')	1.342(8)
C(8) - C(9)	1.524(8)	C(8') - C(14')	1.517(8)
C(8) - C(14)	1.531(8)	C(8') - C(9')	1.546(8)
C(9) = C(11)	1.521(8)	$C(9^{\circ}) \rightarrow C(10^{\circ})$	1.534(8)
C(9) - C(10)	1.333(8)	$C(9') \rightarrow C(11')$	1.542(8)
C(11) - C(12)	1.382(8)	C(9) - C(24)	1.548(8)
C(12) = C(12)	1.539(9)	C(12) - C(12)	1.328(9)
C(13) - C(13)	1.554(0)	C(12) - C(13)	1.343(0)
C(13) - C(25)	1 555(8)	C(13') - C(14')	1.555(6)
C(13) - C(18)	1.556(8)	$C(13') \rightarrow C(14')$	1.585(8)
C(14) - C(15)	1.537(9)	C(14') - C(15')	1.540(9)

TABLE A2 (continued) $U_{\rm eq}/B_{\rm eq}^{a}$ Atom х Ζ y C(2')-0.0368(2)0.1586(2)0.1877(1)3.1(2) 3.1(2) C(3')0.0064(2)0.2136(2)0.1666(2)C(4') 0.0322(2)0.1994(2)0.1145(1) 3.0(2)C(5') 0.0660(2) 0.1285(2) 0.1155(1) 2.7(2)C(6') 0.0980(2) 0.1066(2) 0.0670(1) 3.3(2) C(7') 0.1458(2) 0.0481(2)0.0743(1)3.4(2) C(8') 0.1139(2) -0.0134(2)0.0993(1)2.6(2) C(9') 0.0741(2)0.0104(2) 0.1447(1)2.4(2)0.0701(2) 0.1372(1) C(10') 0.0240(2) 2.4(2)C(11') 0.0425(2) -0.495(2)0.1722(1)3.3(2) C(12') 0.0801(2) -0.1140(2)0.1675(1)2.9(2) C(13') 0.1359(2) -0.1237(2)0.1420(1) 2.6(2)C(14') 0.1703(2) -0.0645(2)0.1165(1) 2.6(2)C(15') 0.2139(2) -0.0885(2)0.0724(2)3.3(2) C(16') 0.2493(2) -0.1555(2)0.0793(2) 3.3(2) C(17') 0.2007(2) -0.2122(2)0.0936(1) 3.0(2) C(18') 0.1679(2) -0.1933(2)0.1431(1) 2.8(2) C(19') -0.2004(2)0.2163(2) 0.1864(1)3.1(2) C(20') 0.2506(2)-0.2688(2)0.1907(1)3.1(2) C(21') 0.2845(2)-0.2856(2)0.1419(2) 3.6(2) C(22') 0.2378(2) -0.2796(2)0.0981(2)3.5(2) C(23') -0.0246(3)0.2061(2) 0.0765(2) 4.5(2) C(24') 0.0861(3)0.2518(2)0.1027(2)4.7(2) C(25') 0.0519(2) -0.0373(2)0.1063(2)3.4(2)C(26') 0.0665(2)-0.0485(2)0.0621(1) 3.3(2)C(27') 0.2196(2) -0.0337(2)0.1540(2) 3.4(2) C(28') 0.1468(2) -0.2207(2)0.0538(2) 3.7(2) C(29') 0.3027(2)-0.2670(2)0.2317(2)3.9(2)C(30') 0.1998(2)-0.3231(2)0.2050(2)4.5(2)19 · EtOH O(1) 0.2874 0.4637(2)0.2709(2) 4.2(1)O(2) 0.4142(2)0.4790(7) 0.6819(2) 3.8(1)O(3) 0.4661(3) 0.1460(8) 0.7789(2)7.2(2) C(1) 0.4210(3) 0.430(1)0.4955(3) 3.6(2)C(2) 0.4612(3) 0.441(1)0.4104(3) 4.0(2)C(3) 0.4201(3) 0.282(1) 0.3487(3) 3.5(2) 0.293(1) C(4) 0.3159(3) 0.3254(3) 3.3(2) C(5) 0.2903(9) 0.2761(3) 0.4137(2) 3.1(2)C(6) 0.1717(3)0.280(1)0.4039(3) 4.1(2) C(7) 0.1415(3) 0.207(1) 0.4874(3)4.3(2)C(8) 0.1774(3) 0.3337(9) 0.5669(3) 3.0(2) 0.5714(2) C(9) 0.2821(3) 0.3759(8) 2.7(2)0.4836(2) C(10) 0.3151(3)0.4440(8)2.9(2)C(11) 0.5063(8) 0.3167(3)0.6499(2)3.1(2)C(12) 0.2647(3) 0.4805(9) 0.7243(2)3.3(2)C(13) 0.1965(3) 0.3527(9) 0.7297(3) 2.9(2) C(14) 0.1638(3)0.2183(9) 0.6531(3) 3.3(2) C(15) 0.0620(3)0.154(1)0.6499(3)4.7(3)C(16) 0.0344(4) 0.110(1)0.7375(3)5.6(3) C(17) 0.0540(3) 0.286(1) 0.8017(3) 5.2(3)C(18) 0.1584(3)0.326(1) 0.8149(3) 4.2(2) C(19) 0.2146(4) 0.171(1)0.8714(3) 5.5(3) C(20) 0.1836(5)0.129(1)0.9594(4)7.0(4)C(21) 0.0800(5)0.081(2)0.9415(4)8.4(4) C(22) 0.0238(4) 0.235(1)7.1(4) 0.8897(4)C(23) 0.2859(3) 0.473(1)0.2678(3) 4.6(2)

C(24)

C(25)

C(26)

C(27)

C(28)

C(29)

C(30)

0.2832(4)

0.1217(3)

0.2882(4)

0.2230(3)

0.0011(4)

0.2365(7)

0.1987(6)

0.104(1)

0.529(1)

0.660(1)

0.467(2)

0.312(2)

-0.047(2)

0.0245(9)

0.2745(3)

0.5598(3)

0.4588(3)

0.6653(3)

0.7657(4)

1.0028(5)

1.0187(4)

4.8(3)

4.5(2)

4.1(2)

4.1(2)

8.1(4)

11.6(6)

10.0(5)

TABLE A3 (continued)

TABLE A3 (concluded)

Bond	Length (Å)	Bond	Length (Å)	Bond	Length (Å)	Bond	Length (Å)
C(14) - C(26)	1.572(9)	C(14') - C(26')	1.560(9)	C(6) - C(7)	1 411(6)		1 564(5)
C(15) - C(16)	1.51(1)	C(15') - C(16')	1.54(1)	C(7) - C(8)	1.339(5)	C(18) - C(19)	1.544(5)
C(16) - C(17)	1.54(1)	C(16') - C(17')	1.55(1)	C(8) - C(14)	1.526(5)	C(19) - C(20)	1.530(6)
C(17) - C(22)	1.52(1)	C(17') - C(27')	1.526(9)	C(8) - C(9)	1.527(5)	C(20) - C(21)	1.517(5)
C(17) - C(27)	1.53(1)	C(17') - C(22')	1.55(1)	C(9) - C(10)	1.532(5)	C(20) - C(28)	1.522(6)
C(17) - C(18)	1.550(9)	C(17') - C(18')	1.565(9)	C(9) - C(11)	1.549(5)	C(21) - C(22)	1.521(6)
C(18) - C(19)	1.52(1)	C(18') - C(19')	1.544(9)	() ()		-()	
C(19) - C(20)	1.54(1)	C(19') - C(20')	1.55(1)			18	
C(20) - C(21)	1.48(1)	C(20') - C(21')	1.51(1)	O(1) - C(3)	1.431(5)	O(1') - C(3')	1.443(5)
C(20)—C(28)	1.53(1)	C(20')—C(28')	1.54(1)	O(2)—C(29)	1.424(5)	O(2') - C(29')	1.423(5)
C(21)—C(22)	1.49(1)	C(21')—C(22')	1.49(1)	C(1) - C(10)	1.517(6)	C(1') - C(10')	1.523(5)
		16		C(1) - C(2)	1.531(6)	C(1') - C(2')	1.523(5)
		10		C(2) - C(3)	1.499(6)	C(2') - C(3')	1.507(6)
O(1) - C(3)	1.210(5)	O(6) - C(33)	1.208(6)	C(3) - C(4)	1.550(6)	C(3') - C(4')	1.536(6)
O(2) - C(21)	1.226(5)	O(7) - C(51)	1.227(5)	C(4)—C(23)	1.536(6)	C(4') - C(24')	1.531(6)
O(3) - C(22)	1.421(5)	O(8)—(C52)	1.406(6)	C(4) - C(24)	1.538(6)	C(4') - C(23')	1.535(6)
O(4) - C(24)	1.343(5)	O(10) - C(54)	1.340(5)	C(4) - C(5)	1.559(5)	C(4') - C(5')	1.566(5)
O(4) - C(30)	1.436(6)	O(10) - C(60)	1.445(6)	C(5) - C(6)	1.527(6)	C(5') - C(6')	1.529(5)
O(5) - C(24)	1.195(5)	O(9) - C(54)	1.211(5)	C(5) - C(10)	1.549(5)	C(5') - C(10')	1.551(5)
C(1) - C(2)	1.529(6)	C(31) - C(32)	1.523(7)	C(6) - C(7)	1.518(6)	C(6') - C(7')	1.51/(6)
C(1) - C(10)	1.531(6)	C(31) - C(40)	1.333(6)	C(7) - C(8)	1.545(6)	C(7) - C(8')	1.539(5)
C(2) = C(3)	1.491(7)	C(32) - C(33)	1.495(8)	C(8) - C(26)	1.538(6)	C(8') - C(9')	1.545(5)
C(3) - C(4)	1.318(7)	C(33) - C(34) C(34) - C(53)	1.323(7) 1.516(7)	C(8) = C(9)	1.554(5)	C(8') - C(20')	1.349(3)
C(4) - C(23)	1.525(7) 1.561(6)	C(34) - C(33)	1.510(7)	C(0) = C(14)	1.383(3)	C(8) = C(14)	1.380(3) 1.542(5)
C(4) - C(3)	1.501(0)	C(34) - C(33)	1.535(0)	C(9) - C(11)	1.344(0) 1.574(5)	C(9) = C(11)	1.342(3) 1.566(5)
C(5) - C(24)	1.527(6)	C(35) = C(36)	1.530(6)	C(3) - C(10)	1.574(5)	C(9) - C(10)	1.500(5) 1.525(5)
C(5) = C(10)	1.527(6) 1.564(6)	C(35) - C(30)	1.553(6)	C(10) = C(23)	1.492(6)	C(10) = C(23)	1.323(5) 1.493(5)
C(6) - C(7)	1.512(6)	C(36) - C(37)	1.532(6)	C(12) - C(13)	1.327(6)	$C(12') \rightarrow C(13')$	1.323(5)
C(7) - C(8)	1.531(6)	C(37) - C(38)	1.524(6)	C(12) - C(14)	1.524(5)	C(12) - C(18')	1.527(5)
C(8) - C(9)	1.558(5)	C(38) - C(39)	1.556(5)	C(13) - C(18)	1.528(5)	C(13') - C(14')	1.529(5)
C(8) - C(14)	1.562(5)	C(38) - C(44)	1.564(5)	C(14) - C(15)	1.547(6)	C(14') - C(27')	1.543(5)
C(9) - C(11)	1.542(5)	C(39) - C(41)	1.538(5)	C(14) - C(27)	1.554(6)	C(14') - C(15')	1.556(5)
C(9) - C(25)	1.551(6)	C(39)—C(55)	1.550(6)	C(15) - C(16)	1.533(6)	C(15') - C(16')	1.522(6)
C(9) - C(10)	1.563(5)	C(39)—C(40)	1.558(5)	C(16) - C(17)	1.526(6)	C(16') - C(17')	1.536(6)
C(11) - C(12)	1.544(5)	C(41)—C(42)	1.540(6)	C(17)—C(28)	1.520(6)	C(17')C(28')	1.533(6)
C(12)—C(13)	1.546(5)	C(42)—C(43)	1.538(6)	C(17)—C(18)	1.549(6)	C(17')-C(22')	1.537(5)
C(13)—C(26)	1.540(5)	C(43)—C(56)	1.541(5)	C(17)—C(22)	1.549(6)	C(17') - C(18')	1.543(5)
C(13) - C(14)	1.563(5)	C(43) - C(48)	1.559(5)	C(18) - C(19)	1.524(6)	C(18') - C(19')	1.528(5)
C(13) - C(18)	1.569(5)	C(43)—C(44)	1.565(5)	C(19) - C(20)	1.532(6)	C(19') - C(20')	1.529(5)
C(14) - C(27)	1.544(6)	C(44) - C(45)	1.539(6)	C(20) - C(21)	1.523(6)	C(20') - C(29')	1.523(6)
C(14) - C(15)	1.547(6)	C(44) - C(57)	1.539(6)	C(20) - C(29)	1.525(6)	C(20') - C(21')	1.525(6)
C(15) - C(16)	1.532(6)	C(45) - C(46)	1.522(6)	C(20) - C(30)	1.538(6)	$C(20^{\circ}) - C(30^{\circ})$	1.531(6)
C(10) - C(17)	1.349(0)	$C(40) \rightarrow C(47)$	1.332(0)	C(21) - C(22)	1.518(0)	$C(21) \rightarrow C(22)$	1.310(0)
C(17) - C(28)	1.555(0)	C(47) - C(38) C(47) - C(52)	1.556(6)		19	·EtOH	
C(17) - C(22) C(17) - C(18)	1.557(6)	C(47) - C(32)	1.550(0)	O(1) - C(3)	1 455(5)	C(10) = C(26)	1 535(7)
C(18) - C(19)	1.507(0)	C(47) = C(48) C(48) = C(49)	1.574(0) 1.542(6)	O(1) - C(1)	1.451(5)	C(10) = C(20) C(11) = C(12)	1.333(7) 1.492(6)
C(10) = C(20)	1.535(5)	C(49) - C(50)	1.528(6)	O(2) = C(11) O(3) = C(31)	1.431(3) 1.400(9)	C(12) - C(13)	1.327(6)
C(20) - C(21)	1.489(6)	C(50) - C(51)	1.920(0) 1.493(7)	C(1) - C(2)	1.534(6)	C(12) = C(13) C(13) = C(14)	1.516(6)
C(20) - C(29)	1.521(6)	C(50) - C(59)	1.513(7)	C(1) - C(10)	1.537(6)	C(13) - C(18)	1.529(6)
C(21) - C(22)	1.497(6)	C(51) - C(52)	1.495(7)	C(2) - C(3)	1.500(7)	C(14) - C(15)	1.546(7)
0(21) 0(22)	1.1.57(0)			C(3) - C(4)	1.516(6)	C(14) - C(27)	1.556(7)
	17 ·1	$1/2 H_2O$		C(4) - C(23)	1.528(7)	C(15) - C(16)	1.514(7)
O(1) - C(2)	1.238(5)	C(9) - C(24)	1.590(5)	C(4) - C(24)	1.531(7)	C(16) - C(17)	1.547(9)
O(2) - C(3)	1.356(5)	C(11) - C(12)	1.523(5)	C(4) - C(5)	1.576(6)	C(17) - C(28)	1.51(1)
O(3) - C(21)	1.213(4)	C(12) - C(13)	1.548(5)	C(5) - C(6)	1.514(6)	C(17) - C(18)	1.535(7)
O(4) - C(22)	1.426(5)	C(13)—C(25)	1.537(5)	C(5) - C(10)	1.547(6)	C(17)—C(22)	1.545(8)
C(1)—C(10)	1.344(5)	C(13)—C(18)	1.578(5)	C(6)—C(7)	1.520(6)	C(18)—C(19)	1.520(8)
C(1) - C(2)	1.445(5)	C(13)—C(14)	1.585(5)	C(7)—C(8)	1.532(6)	C(19)—C(20)	1.537(7)
C(2)—C(3)	1.459(6)	C(14) - C(15)	1.538(5)	C(8)—C(25)	1.537(7)	C(20)—C(29)	1.51(1)
C(3)—C(4)	1.356(6)	C(14) - C(26)	1.538(6)	C(8)—C(9)	1.550(6)	C(20) - C(30)	1.53(1)
C(4)—C(5)	1.456(6)	C(15) - C(16)	1.536(6)	C(8) - C(14)	1.591(6)	C(20) - C(21)	1.535(9)
C(4)—C(23)	1.506(6)	C(16) - C(17)	1.536(6)	C(9) - C(11)	1.528(6)	C(21)—C(22)	1.48(1)
C(5)—C(6)	1.355(5)	C(17) - C(27)	1.538(6)	C(9) - C(10)	1.587(6)	C(31) - C(32)	1.35(2)
C(5) - C(10)	1.453(5)	C(17) - C(22)	1.546(5)	······			

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TABLE A4. Bond angles (deg) with estimated standard deviations in parentheses

Bonds	Angle (deg)	Bonds	Angle (deg)				
6 ∙MeOH							
C(2)—C(1)—C(10)	112.9(3)	C(12)—C(13)—C(18)	119.0(3)				
C(1) - C(2) - C(3)	112.3(3)	C(14)-C(13)-C(18)	120.7(3)				
O(1) - C(3) - C(2)	111.0(3)	C(8) - C(14) - C(13)	108.4(3)				
O(1) - C(3) - C(4)	111.7(3)	C(8) - C(14) - C(15)	111.4(3)				
C(2) - C(3) - C(4)	113.2(3)	C(8) - C(14) - C(27)	111.8(3)				
C(3) - C(4) - C(5)	108.0(3)	C(13) - C(14) - C(15)	112.2(3)				
C(3) - C(4) - C(23)	110.2(3) 107.4(3)	C(13) - C(14) - C(27)	106.8(3)				
C(3) - C(4) - C(24) C(5) - C(4) - C(23)	107.4(3) 114.8(3)	C(13) - C(14) - C(27)	106.3(3)				
C(5) - C(4) - C(23)	108 6(3)	$C(15) \rightarrow C(16) \rightarrow C(17)$	114.4(3) 112.1(3)				
C(23) - C(4) - C(24)	107.7(3)	C(16) - C(17) - C(18)	109.0(3)				
C(4) - C(5) - C(6)	114.2(3)	C(16) - C(17) - C(22)	111.1(3)				
C(4) - C(5) - C(10)	116.6(3)	C(16) - C(17) - C(28)	109.8(3)				
C(6) - C(5) - C(10)	110.4(3)	C(18) - C(17) - C(22)	109.4(3)				
C(5)-C(6)-C(7)	110.6(3)	C(18) - C(17) - C(28)	110.0(3)				
C(6) - C(7) - C(8)	113.5(3)	C(22)-C(17)-C(28)	107.5(3)				
C(7) - C(8) - C(9)	109.7(3)	C(13) - C(18) - C(17)	112.5(3)				
C(7) - C(8) - C(14)	110.1(3)	C(13) - C(18) - C(19)	109.7(3)				
C(7) - C(8) - C(26)	108.1(3)	$C(17) \rightarrow C(18) \rightarrow C(19)$	113.7(3)				
C(9) - C(8) - C(14)	107.0(3)	C(18) - C(19) - C(20)	114.0(3)				
C(9) - C(8) - C(20)	109.8(3)	C(19) - C(20) - C(21)	100.7(3) 100.5(3)				
C(8) - C(9) - C(10)	107.0(3) 117 7(3)	C(19) - C(20) - C(29)	109.3(3) 112 1(3)				
C(8) - C(9) - C(11)	110.2(3)	C(21) - C(20) - C(29)	107.2(3)				
C(10) - C(9) - C(11)	113.1(3)	C(21) - C(20) - C(30)	111.6(3)				
C(1) - C(10) - C(5)	107.5(3)	C(29) - C(20) - C(30)	109.5(3)				
C(1)-C(10)-C(9)	107.8(3)	C(20) - C(21) - C(22)	113.5(3)				
C(1)-C(10)-C(25)	108.5(3)	O(2) - C(22) - C(17)	111.2(3)				
C(5) - C(10) - C(9)	106.7(2)	O(2) - C(22) - C(21)	109.6(3)				
C(5) - C(10) - C(25)	113.4(3)	C(17) - C(22) - C(21)	115.3(3)				
C(9) - C(10) - C(25)	112.7(3)	O(3) - C(29) - O(4)	121.2(4)				
$C(9) \rightarrow C(11) \rightarrow C(12)$	113.9(3)	O(3) - C(29) - C(20)	124.9(4)				
C(11) - C(12) - C(13)	127.1(3) 110.0(3)	O(4) = C(29) = C(20)	113.9(3)				
C(12) - C(13) - C(14)	119.9(3) 116(4)	C(29) = O(4) = H(O4)	112(3)				
$C(22) \rightarrow O(2) \rightarrow H(O2)$	116(3)	C(31) = O(5) = H(O5)	112(3) 113(4)				
	15 ·1/	2 EtOAc	113(1)				
$C(10) \rightarrow C(1) \rightarrow C(2)$	121 1(5)	C(10') - C(1') - C(2')	122 2(6)				
O(1) - C(2) - C(3)	119.7(6)	O(1') - C(2') - C(1')	122.2(0)				
O(1) - C(2) - C(1)	122.0(6)	O(1') - C(2') - C(3')	119.2(6)				
C(3) - C(2) - C(1)	118.4(6)	C(1') - C(2') - C(3')	117.0(6)				
C(4)-C(3)-O(2)	120.1(6)	C(4') - C(3') - O(2')	120.9(6)				
C(4) - C(3) - C(2)	122.2(6)	C(4') - C(3') - C(2')	122.5(6)				
O(2) - C(3) - C(2)	117.7(6)	O(2') - C(3') - C(2')	116.6(6)				
C(3) - C(4) - C(5)	119.8(5)	C(3') - C(4') - C(5')	118.4(6)				
C(3) - C(4) - C(23)	119.8(6)	C(3') - C(4') - C(23')	120.2(6)				
C(5) - C(4) - C(23)	120.4(6)	C(5') - C(4') - C(23')	121.4(6)				
C(6) - C(3) - C(10)	123.8(5)	C(6) = C(5) = C(4)	121.5(0) 118.0(5)				
C(10) - C(5) - C(4)	123.8(3) 118 5(5)	C(0) = C(3) = C(10)	118.0(3) 120.4(5)				
C(5) - C(6) - C(7)	122.8(5)	$C(5') \rightarrow C(6') \rightarrow C(7')$	120.4(5) 123 1(5)				
C(8) - C(7) - C(6)	123.8(6)	C(8') - C(7') - C(6')	124.2(6)				
C(7) - C(8) - C(9)	117.5(5)	C(7') - C(8') - C(14')	121.5(5)				
C(7) - C(8) - C(14)	122.5(6)	C(7') - C(8') - C(9')	118.1(5)				
C(9)-C(8)-C(14)	119.9(5)	C(14') - C(8') - C(9')	120.5(5)				
C(11)—C(9)—C(8)	114.7(5)	C(10') - C(9') - C(11')	110.3(5)				
C(11) - C(9) - C(10)	111.1(5)	C(10') - C(9') - C(8')	113.6(4)				
C(11) - C(9) - C(24)	108.7(5)	C(10') - C(9') - C(24')	103.4(5)				
$C(8) \rightarrow C(9) \rightarrow C(10)$	112.8(5)	C(11') - C(9') - C(8')	109.7(5)				
C(0) - C(9) - C(24)	100.9(3)	C(11) = C(9) = C(24') C(8') = C(0') = C(24')	109.4(5)				
C(10) C(2) C(24)	101.0(3)	(0) (24)	110.1(5)				

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TABLE A4 (continued)

Bonds	Angle (deg)	Bonds	Angle (deg)		
C(1) - C(10) - C(5)	120.0(5)	C(1') - C(10') - C(5')	119.4(6)		
C(1)—C(10)—C(9)	120.8(5)	C(1') - C(10') - C(9')	119.8(5)		
C(5) - C(10) - C(9)	118.8(5)	C(5') - C(10') - C(9')	120.4(5)		
C(9) - C(11) - C(12)	115.3(5)	C(12') - C(11') - C(9')	114.7(5)		
$C(13) \rightarrow C(12) \rightarrow C(11)$	112.4(4)	C(11') - C(12') - C(13')	112.6(5)		
$C(12) \rightarrow C(13) \rightarrow C(14)$	108.0(3) 107 4(5)	$C(25) \rightarrow C(13) \rightarrow C(12)$	107.1(3) 109.4(5)		
C(12) - C(13) - C(18)	109.3(5)	C(25') - C(13') - C(18')	102.4(5) 112.6(5)		
C(14) - C(13) - C(25)	109.9(5)	C(12') - C(13') - C(14')	108.0(5)		
C(14)-C(13)-C(18)	110.0(5)	C(12') - C(13') - C(18')	110.2(5)		
C(25) - C(13) - C(18)	111.5(5)	C(14') - C(13') - C(18')	109.4(5)		
C(8) - C(14) - C(15)	112.2(5)	C(8') - C(14') - C(15')	112.9(5)		
$C(8) \rightarrow C(14) \rightarrow C(13)$	109.0(3) 107.3(5)	$C(8) \rightarrow C(14') \rightarrow C(26')$	108.5(5) 109.1(5)		
C(15) - C(14) - C(13)	107.3(5) 108.0(5)	$C(15') \rightarrow C(14') \rightarrow C(26')$	109.1(3) 106.2(5)		
C(15) - C(14) - C(26)	107.2(5)	C(15') - C(14') - C(13')	100.2(5) 107.1(5)		
C(13)—C(14)—C(26)	112.7(5)	C(26') - C(14') - C(13')	113.2(5)		
C(16) - C(15) - C(14)	112.8(6)	C(16') - C(15') - C(14')	113.2(5)		
C(15) - C(16) - C(17)	117.1(6)	C(15') - C(16') - C(17')	117.0(5)		
C(22) - C(17) - C(27)	107.2(6)	C(27') - C(17') - C(22')	106.8(6)		
$C(22) \rightarrow C(17) \rightarrow C(18)$	109.1(0) 111.8(5)	$C(27) \rightarrow C(17) \rightarrow C(18')$	108.7(6)		
C(22) = C(17) = C(16) C(27) = C(17) = C(16)	106.4(6)	$C(22') \rightarrow C(17') \rightarrow C(16')$	109.7(6)		
C(27) - C(17) - C(18)	109.3(6)	C(22') - C(17') - C(18')	112.5(6)		
C(16)—C(17)—C(18)	112.6(5)	C(16') - C(17') - C(18')	112.6(5)		
C(19) - C(18) - C(17)	110.0(5)	C(19') - C(18') - C(17')	110.5(5)		
C(19) - C(18) - C(13)	117.5(5)	C(19') - C(18') - C(13')	114.9(5)		
C(17) - C(18) - C(13) C(18) - C(10) - C(20)	110.5(5)	C(17') - C(18') - C(13')	110.3(5)		
$C(18) \rightarrow C(19) \rightarrow C(20)$	111.2(0)	$C(21') \rightarrow C(20') \rightarrow C(20')$	117.3(0) 113.5(7)		
C(21) - C(20) - C(19)	110.0(6)	C(21') - C(20') - C(19')	106.9(6)		
C(28) - C(20) - C(19)	112.3(7)	C(28') - C(20') - C(19')	111.1(6)		
O(3)—C(21)—C(20)	121.5(8)	O(3') - C(21') - C(22')	123.3(8)		
O(3) - C(21) - C(22)	121.9(8)	O(3') - C(21') - C(20')	122.8(8)		
C(20) - C(21) - C(22)	116.5(6)	C(22') - C(21') - C(20')	113.9(7)		
$C(21) \rightarrow C(22) \rightarrow C(17)$	110.9(0)	C(21) C(22) C(17)	110.7(0)		
	110 1(4)		117 (4)		
C(24) = O(4) = C(30)	118.1(4)	C(32) = C(31) = C(60)	117.6(4) 112.1(4)		
C(2) = C(1) = C(10)	113.8(4)	C(32) - C(31) - C(40) C(33) - C(32) - C(31)	112.1(4) 115.8(4)		
O(1) - C(3) - C(2)	122.4(5)	O(6) - C(33) - C(32)	121.5(5)		
O(1) - C(3) - C(4)	121.6(5)	O(6)—C(33)—C(34)	121.6(5)		
C(2) - C(3) - C(4)	115.9(4)	C(32) - C(33) - C(34)	116.6(4)		
C(3) - C(4) - C(23)	111.6(4)	C(53) - C(34) - C(33)	112.0(4)		
C(3) - C(4) - C(5)	112.1(4)	C(33) - C(34) - C(35)	114,4(4)		
$C(23) \rightarrow C(4) \rightarrow C(5)$	114.0(4) 109.2(4)	C(54) - C(34) - C(35)	113.8(4) 108 1(4)		
C(24) - C(5) - C(4)	109.2(4) 106.0(3)	C(54) - C(35) - C(36)	108.6(4)		
C(24) - C(5) - C(10)	115.1(3)	C(54) - C(35) - C(40)	113.5(4)		
C(6) - C(5) - C(4)	109.9(4)	C(36)-C(35)-C(34)	109.2(4)		
C(6) - C(5) - C(10)	108.6(3)	C(36) - C(35) - C(40)	109.4(3)		
C(4) - C(5) - C(10)	108.1(3)	C(34) - C(35) - C(40)	108.0(3)		
C(7) - C(6) - C(5) C(6) - C(7) - C(8)	115.4(4)	$C(35) \rightarrow C(36) \rightarrow C(37)$	115.3(4)		
C(0) - C(1) - C(0)	110 1(3)	C(30) - C(31) - C(30) C(37) - C(38) - C(30)	110.0(4)		
C(7) - C(8) - C(14)	115.2(3)	C(37) - C(38) - C(44)	115.4(3)		
C(9) - C(8) - C(14)	116.5(3)	C(39) - C(38) - C(44)	116.2(3)		
C(11)C(9)C(25)	106.7(3)	C(41)—C(39)—C(55)	107.2(3)		
C(11) - C(9) - C(8)	108.9(3)	C(41) - C(39) - C(38)	109.9(3)		
C(11) - C(9) - C(10)	109.5(3)	C(41) - C(39) - C(40)	109.1(3)		
C(25) - C(9) - C(8)	114.8(3)	C(33) - C(39) - C(38) C(55) - C(30) - C(40)	114.0(3)		
C(8) - C(9) - C(10)	107.0(3)	C(38) - C(39) - C(40)	106.4(3)		
	· · ·		· ·		

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TABLE A4 (continued)

Bonds	Angle (deg)	Bonds	Angle (deg)				
-C(1)-C(10)-C(9)	114.6(3) C(31)—C(40)—C(39)		114.4(3)				
C(1) - C(10) - C(5)	113.4(3)	C(31) - C(40) - C(35)	112.1(3)				
C(9) - C(10) - C(5) C(0) - C(11) - C(12)	114.0(3)	C(39) - C(40) - C(35) C(30) - C(41) - C(42)	116.0(3)				
C(9) - C(11) - C(12) C(11) - C(12) - C(13)	114.7(3) 113.1(3)	C(39) - C(41) - C(42) C(43) - C(42) - C(41)	114.3(3) 113.1(3)				
C(26) - C(13) - C(12)	106.1(3)	C(42) - C(43) - C(56)	106.9(3)				
C(26) - C(13) - C(14)	112.7(3)	C(42) - C(43) - C(48)	110.3(3)				
C(26) - C(13) - C(18)	110.3(3)	C(42) - C(43) - C(44)	107.4(3)				
C(12) - C(13) - C(14)	108.0(3)	C(56) - C(43) - C(48)	110.4(3)				
$C(12) \rightarrow C(13) \rightarrow C(18)$	100.0(3)	C(30) - C(43) - C(44) C(48) - C(43) - C(44)	112.3(3) 109 4(3)				
C(27) - C(14) - C(15)	107.2(3)	C(45) - C(44) - C(57)	107.2(3)				
C(27)—C(14)—C(8)	109.9(3)	C(45)—C(44)—C(38)	110.4(3)				
C(27) - C(14) - C(13)	112.8(3)	C(45) - C(44) - C(43)	107.2(3)				
C(15) - C(14) - C(8)	110.1(3)	C(57) - C(44) - C(38)	109.5(3)				
C(15) - C(14) - C(13)	107.0(3) 100.8(3)	C(57) - C(44) - C(43) C(38) - C(44) - C(43)	113.5(3)				
C(8) - C(14) - C(13)	109.8(3) 112.3(4)	C(38) - C(44) - C(43) C(46) - C(45) - C(44)	109.0(3) 112 2(3)				
C(15) - C(16) - C(17)	117.4(4)	C(45) - C(46) - C(47)	116.8(3)				
C(28) - C(17) - C(16)	107.0(4)	C(58)—C(47)—C(46)	108.4(3)				
C(28) - C(17) - C(22)	107.1(4)	C(58)—C(47)—C(52)	106.8(4)				
C(28) - C(17) - C(18)	109.1(3)	C(58) - C(47) - C(48)	108.2(3)				
C(16) - C(17) - C(22) C(16) - C(17) - C(18)	108.4(3) 113.0(3)	C(46) - C(47) - C(52) C(46) - C(47) - C(48)	107.8(3)				
C(10) - C(17) - C(18)	113.9(3)	C(40) - C(47) - C(48)	113.2(3) 112.2(3)				
C(19) - C(18) - C(17)	110.8(3)	C(49) - C(48) - C(43)	116.0(3)				
C(19) - C(18) - C(13)	117.1(3)	C(49)—C(48)—C(47)	110.1(3)				
C(17) - C(18) - C(13)	115.7(3)	C(43) - C(48) - C(47)	116.7(3)				
C(18) - C(19) - C(20)	118.7(3)	C(50)— $C(49)$ — $C(48)$	117.9(4)				
$C(21) \rightarrow C(20) \rightarrow C(29)$	112.9(4)	C(51) - C(50) - C(59)	112.9(4) 109.4(3)				
C(29) - C(20) - C(19)	111.7(4)	C(59) - C(50) - C(49)	111.8(4)				
O(2) - C(21) - C(20)	124.2(4)	O(7)—C(51)—C(50)	123.4(4)				
O(2) - C(21) - C(22)	119.9(4)	O(7)—C(51)—C(52)	120.1(5)				
C(20) - C(21) - C(22)	115.9(4)	C(50) - C(51) - C(52)	116.5(4)				
O(3) = C(22) = C(21) O(3) = C(22) = C(17)	110.9(4)	O(8) - C(52) - C(51) O(8) - C(52) - C(47)	110.7(4)				
C(21) $-C(22)$ $-C(17)$	110.3(4)	C(51) - C(52) - C(47)	110.9(4) 111.9(4)				
O(5) - C(24) - O(4)	122.1(4)	O(9) - C(54) - O(10)	121.1(4)				
O(5) - C(24) - C(5)	126.2(5)	O(9)—C(54)—C(35)	126.4(4)				
O(4) - C(24) - C(5)	111.5(3)	O(10) - C(54) - C(35)	112.5(4)				
17 ·1/2 H ₂ O							
C(10) - C(1) - C(2)	122.9(4)	C(25) - C(13) - C(14)	110.5(3)				
O(1) - C(2) - C(1)	123.1(4)	C(12) - C(13) - C(18)	110.0(3)				
O(1) - C(2) - C(3) C(1) - C(2) - C(3)	119.5(4)	$C(12) \rightarrow C(13) \rightarrow C(14)$ $C(18) \rightarrow C(13) \rightarrow C(14)$	106.8(3) 108.7(3)				
O(2) - C(3) - C(4)	117.3(3) 121 1(4)	C(18) - C(13) - C(14) C(8) - C(14) - C(15)	108.7(3) 111.7(3)				
O(2) - C(3) - C(2)	117.5(3)	C(8) - C(14) - C(26)	110.1(3)				
C(4) - C(3) - C(2)	121.4(4)	C(8) - C(14) - C(13)	107.2(3)				
C(3) - C(4) - C(5)	119.6(4)	C(15) - C(14) - C(26)	106.5(3)				
C(3) - C(4) - C(23)	119.7(4)	C(15) - C(14) - C(13)	107.5(3)				
C(5) - C(4) - C(23) C(6) - C(5) - C(10)	120.7(4)	C(26) - C(14) - C(13) C(16) - C(15) - C(14)	113.9(3)				
C(6) - C(5) - C(4)	121.5(4)	C(10) - C(15) - C(14) C(17) - C(16) - C(15)	113.1(4) 114 4(3)				
C(10) - C(5) - C(4)	119.9(3)	C(16) - C(17) - C(27)	108.2(3)				
C(5)—C(6)—C(7)	123.0(4)	C(16)-C(17)-C(22)	108.6(3)				
C(8) - C(7) - C(6)	123.4(3)	C(16) - C(17) - C(18)	112.1(3)				
C(7) = C(8) = C(14)	122.1(3) 118.4(3)	$C(27) \rightarrow C(17) \rightarrow C(22)$	108.2(3)				
C(14) - C(8) - C(9)	119.3(3)	C(22) - C(17) - C(18)	111.3(3)				
C(8) - C(9) - C(10)	113.4(3)	C(19) - C(18) - C(17)	110.2(3)				
C(8)-C(9)-C(11)	112.6(3)	C(19)—C(18)—C(13)	114.6(3)				
C(8) - C(9) - C(24)	108.1(3)	C(17) - C(18) - C(13)	117.9(3)				

$\begin{array}{cccccccccccccccccccccccccccccccccccc$	Bonds	Angle (deg)	Bonds	Angle (deg)	
$\begin{array}{cccccc} C(1)-C(2)-C(24) & 102.1(3) & C(21)-C(20)-C(28) & 111.8(3) \\ C(11)-C(9)-C(24) & 109.6(3) & C(21)-C(20)-C(19) & 111.4(4) \\ C(1)-C(10)-C(9) & 121.6(3) & 0(3)-C(21)-C(22) & 122.6(4) \\ C(5)-C(10)-C(9) & 116.7(3) & C(20)-C(21)-C(22) & 120.9(4) \\ C(12)-C(11)-C(9) & 116.7(3) & C(20)-C(21)-C(22) & 110.3(3) \\ C(11)-C(12)-C(13) & 112.2(3) & 0(4)-C(22)-C(17) & 108.6(3) \\ C(25)-C(13)-C(12) & 117.2(3) & 0(4)-C(22)-C(17) & 118.6(3) \\ C(25)-C(13)-C(12) & 117.3(3) & 0(4)-C(22)-C(17) & 118.6(3) \\ C(25)-C(13)-C(12) & 117.3(3) & C(21)-C(22)-C(17) & 112.5(3) \\ \hline \\ $	C(10) - C(9) - C(11)	110.4(3)	C(20) - C(19) - C(18)	118.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(10) - C(9) - C(24)	102.1(3)	C(21) - C(20) - C(28)	111.8(3)	
$\begin{array}{c} C(1) - C(10) - C(5) & 118.9(3) & C(28) - C(20) - C(19) & 111.4(4) \\ C(1) - C(10) - C(9) & 119.1(3) & O(3) - C(21) - C(20) & 122.6(4) \\ C(5) - C(10) - C(9) & 116.7(3) & C(20) - C(21) - C(22) & 116.3(3) \\ C(11) - C(12) - C(13) & 112.2(3) & O(4) - C(22) - C(21) & 110.4(3) \\ C(25) - C(13) - C(12) & 107.3(3) & O(4) - C(22) - C(17) & 118.6(3) \\ C(25) - C(13) - C(12) & 107.3(3) & O(4) - C(22) - C(17) & 112.5(3) \\ \hline \\ C(3) - C(2) - C(1) & 112.0(3) & C(3') - C(2') & C(3') - C(2') & 109.9(3) \\ O(1) - C(3) - C(2) & 107.9(3) & O(1') - C(3') - C(2') & 109.9(3) \\ O(1) - C(3) - C(2) & 107.9(3) & O(1') - C(3') - C(4') & 110.2(3) \\ C(22) - C(4) - C(24) & 108.1(4) & C(24') - C(4') - C(23') & 108.3(4) \\ C(23) - C(4) - C(23) & 111.2(3) & C(2') - C(4') - C(3') & 107.5(3) \\ C(24) - C(4) - C(3) & 111.2(3) & C(2') - C(4') - C(3') & 111.2(3) \\ C(23) - C(4) - C(5) & 114.6(4) & C(24') - C(4') - C(5') & 114.0(3) \\ C(33) - C(4) - C(5) & 107.3(3) & C(3') - C(4') - C(5') & 114.0(3) \\ C(33) - C(4) - C(5) & 107.3(3) & C(3') - C(4') - C(5') & 114.0(3) \\ C(3) - C(4) - C(5) & 107.3(3) & C(3') - C(4') - C(5') & 111.0(3) \\ C(4) - C(5) - C(10) & 110.8(3) & C(6') - C(5') - C(10') & 109.8(3) \\ C(6) - C(5) - C(10) & 110.8(3) & C(6') - C(5') - C(10') & 119.8(3) \\ C(6) - C(5) - C(4) & 116.7(3) & C(10') - C(5') - C(4') & 115.0(3) \\ C(10) - C(5) - C(4) & 116.7(3) & C(10') - C(5') - C(4') & 116.6(3) \\ C(7) - C(8) - C(9) & 108.8(3) & C(9') - C(8') - C(14') & 110.6(3) \\ C(7) - C(8) - C(9) & 108.8(3) & C(9') - C(8') - C(14') & 110.6(3) \\ C(7) - C(8) - C(9) & 108.8(3) & C(9') - C(8') - C(14') & 110.6(3) \\ C(7) - C(8) - C(9) & 108.8(3) & C(9') - C(8') - C(14') & 110.6(3) \\ C(7) - C(8) - C(9) & 108.8(3) & C(9') - C(8') - C(14') & 110.6(3) \\ C(7) - C(8) - C(9) & 108.8(3) & C(9') - C(8') - C(14') & 113.8(3) \\ C(26) - C(8) - C(14) & 110.3(3) & C(1') - C(10') - C(5') & 113.5(3) \\ C(26) - C(8) - C(14) & 110.3(3) & C(1') - C(10') - C(5') & 113.5(3) \\ C(26) - C(8) - C(14) & 113.3(3) & C(25') - C(10') - C(5') & 113.3(3) \\ C(1) - C(10) - C(5) & 113.3(3) & C(13') - $	C(11) - C(9) - C(24)	109.6(3)	C(21) - C(20) - C(19)	111.9(3)	
$\begin{array}{c} C(1) = C(10) = C(9) & 121.6(3) & O(3) = C(21) = C(20) & 122.6(4) \\ C(5) = C(10) = C(9) & 116.7(3) & C(20) = C(21) = C(22) & 116.3(3) \\ C(11) = C(12) = C(13) & 112.2(3) & O(4) = C(22) = C(21) & 110.4(3) \\ C(25) = C(13) = C(12) & 107.3(3) & O(4) = C(22) = C(17) & 118.6(3) \\ C(25) = C(13) = C(12) & 112.0(3) & C(1) = C(22) = C(17) & 112.5(3) \\ \hline \\ C(3) = C(2) = C(1) & 112.0(3) & C(3') = C(2') = C(1') & 112.0(3) \\ O(1) = C(3) = C(2) & 107.9(3) & O(1') = C(3') = C(2') & 113.2(3) \\ C(3) = C(2) = C(1) & 112.0(3) & C(3') = C(2') = C(1') & 112.0(3) \\ O(1) = C(3) = C(4) & 110.5(4) & O(1') = C(3') = C(4') & 110.2(3) \\ C(23) = C(4) = C(24) & 108.1(4) & C(24') = C(4') = C(23') & 108.3(4) \\ C(23) = C(4) = C(3) & 111.2(3) & C(24') = C(4') = C(23') & 107.5(3) \\ C(24) = C(4) = C(3) & 111.2(3) & C(24') = C(4') = C(5') & 108.6(3) \\ C(24) = C(4) = C(5) & 114.6(4) & C(24') = C(4') = C(5') & 108.6(3) \\ C(24) = C(4) = C(5) & 108.3(3) & C(3') = C(4') = C(5') & 114.0(3) \\ C(3) = C(4) = C(5) & 107.3(3) & C(3') = C(4') = C(5') & 110.6(3) \\ C(4) = C(5) = C(10) & 110.8(3) & C(6') = C(5') = C(10') & 109.8(3) \\ C(6) = C(5) = C(10) & 110.8(3) & C(6') = C(5') = C(10') & 109.8(3) \\ C(6) = C(5) = C(10) & 110.8(3) & C(6') = C(5') = C(14') & 115.0(3) \\ C(10) = C(5) = C(4) & 114.3(3) & C(6') = C(5') & 111.6(3) \\ C(7) = C(6) = C(5) & 111.2(3) & C(7') = C(8') = C(26') & 108.8(3) \\ C(26) = C(8) = C(7) & 108.5(4) & C(7') = C(8') = C(26') & 108.8(3) \\ C(7) = C(8) = C(14) & 110.3(3) & C(7') = C(8') = C(14') & 110.6(3) \\ C(7) = C(8) = C(14) & 110.3(3) & C(7') = C(8') = C(14') & 109.4(3) \\ C(11) = C(9) = C(18) & 111.0(3) & C(11') = C(9') = C(16') & 113.2(3) \\ C(3) = C(18) = C(14) & 111.0(3) & C(11') = C(9') = C(14') & 110.8(3) \\ C(10) = C(5) & 113.3(3) & C(25') = C(10') & 117.1(3) \\ C(11) = C(9) = C(18) & 111.0(3) & C(11') = C(9') = C(14') & 113.3(3) \\ C(25) = C(10) = C(5) & 113.3(3) & C(25') = C(10') & -C(5') & 113.3(3) \\ C(25) = C(10) = C(5) & 113.3(3) & C(25') = C(10') = C(5') & 113.3(3) \\ C(11) = C(10) = C(5) & 113.3(3) & C(25') = C(10') = C(5') $	C(1) - C(10) - C(5)	118.9(3)	C(28) - C(20) - C(19)	111.4(4)	
$\begin{array}{c} C(3) = C(1) - C(9) & 119, 1(3) & O(3) = C(2) - C(2) & 116, 3(3) \\ C(12) = C(11) = C(9) & 116, 7(3) & O(4) = C(22) = C(21) & 116, 3(3) \\ C(11) = C(12) = C(13) & 112, 2(3) & O(4) = C(22) = C(17) & 113, 2(3) \\ C(25) = C(13) = C(12) & 117, 3(3) & O(4) = C(22) = C(17) & 112, 5(3) \\ C(25) = C(13) = C(18) & 113, 3(3) & C(21) = C(22) = C(17) & 112, 2(3) \\ C(3) = C(2) = C(1) & 112, 0(3) & C(3') = C(2') = C(1') & 112, 0(3) \\ O(1) = C(3) = C(2) & 112, 0(3) & C(3') = C(2') = C(1') & 112, 0(3) \\ O(1) = C(3) = C(2) & 112, 0(3) & C(3') = C(2') & 110, 0(3) \\ O(1) = C(3) = C(4) & 110, 5(4) & O(1') = C(3') = C(4') & 110, 2(3) \\ C(23) = C(4) = C(24) & 110, 5(4) & O(1') = C(3') = C(4') & 110, 2(3) \\ C(23) = C(4) = C(24) & 110, 81, (4) & C(24') = C(4') = C(3') & 110, 2(3) \\ C(24) = C(4) = C(5) & 114, 6(4) & C(24') = C(4') = C(3') & 110, 2(3) \\ C(24) = C(4) = C(5) & 107, 3(3) & C(3') = C(4') = C(5') & 107, 0(3) \\ C(3) = C(4) = C(5) & 107, 3(3) & C(3') = C(4') = C(5') & 107, 0(3) \\ C(4) = C(4) = C(5) & 107, 3(3) & C(3') = C(4') = C(5') & 107, 0(3) \\ C(6) = C(5) = C(4) & 114, 1(3) & C(6') = C(5') = C(10') & 109, 8(3) \\ C(10) = C(5) = C(4) & 116, 7(3) & C(10') = C(5') = C(10') & 109, 8(3) \\ C(6) = C(5) = C(4) & 116, 7(3) & C(10') = C(5') = C(14') & 117, 0(3) \\ C(7) = C(6) = C(5) & 111, 2(3) & C(7') = C(8') = C(26') & 108, 8(3) \\ C(7) = C(8) = C(14) & 110, 1(3) & C(7') = C(8') = C(26') & 108, 8(3) \\ C(7) = C(8) = C(14) & 110, 1(3) & C(7') = C(8') = C(14') & 110, 6(3) \\ C(7) = C(8) = C(14) & 110, 1(3) & C(7') = C(8') = C(14') & 110, 6(3) \\ C(7) = C(8) = C(14) & 110, 1(3) & C(7') = C(8') = C(14') & 110, 8(3) \\ C(10) = C(5) = C(14) & 110, 1(3) & C(7') = C(8') = C(14') & 110, 8(3) \\ C(10) = C(8) = C(14) & 110, 1(3) & C(7') = C(8') = C(14') & 110, 8(3) \\ C(10) = C(8) = C(14) & 110, 1(3) & C(7') = C(16') & 111, 10(3) \\ C(11) = C(9) = C(10) & 111, 10(3) & C(7') = C(10') = C(5') & 111, 3(3) \\ C(13) = C(14) = C(27) & 106, 8(3) & C(1') = C(10') = C(5') & 111, 3(3) \\ C(13) = C(14) = C(27) & 106, 8(3) & C(13') = C(14') = C(15') & 1111, 3(3) $	C(1) - C(10) - C(9)	121.6(3)	O(3) - C(21) - C(20)	122.6(4)	
$\begin{array}{ccccc} C(12)-C(12)-C(13) & 112.2(3) & C(4)-C(22)-C(17) & 110.4(3) \\ C(25)-C(13)-C(12) & 112.2(3) & C(4)-C(22)-C(17) & 112.5(3) \\ \hline \\ C(25)-C(13)-C(18) & 113.3(3) & C(21)-C(22)-C(17) & 112.5(3) \\ \hline \\ C(10)-C(1)-C(2) & 112.7(4) & C(10')-C(1')-C(2') & 113.2(3) \\ C(3)-C(2)-C(1) & 112.0(3) & C(3')-C(2')-C(1') & 112.0(3) \\ C(3)-C(2)-C(1) & 112.0(3) & C(3')-C(2') & 119.2(3) \\ C(1)-C(3)-C(2) & 107.9(3) & O(1')-C(3')-C(2') & 119.2(3) \\ C(2)-C(3)-C(4) & 110.5(4) & O(1')-C(3')-C(4') & 110.2(3) \\ C(2)-C(3)-C(4) & 114.1(3) & C(2')-C(3')-C(4') & 110.2(3) \\ C(23)-C(4)-C(5) & 114.6(4) & C(24')-C(4')-C(5') & 108.6(3) \\ C(24)-C(4)-C(5) & 114.6(4) & C(24')-C(4')-C(5') & 108.5(3) \\ C(24)-C(4)-C(5) & 107.3(3) & C(3')-C(4')-C(5') & 111.2(3) \\ C(24)-C(4)-C(5) & 107.3(3) & C(3')-C(4')-C(5') & 111.2(3) \\ C(24)-C(4)-C(5) & 107.3(3) & C(3')-C(4')-C(5') & 111.0(3) \\ C(6)-C(5)-C(4) & 116.7(3) & C(10')-C(5')-C(4') & 115.0(3) \\ C(6)-C(5)-C(4) & 116.7(3) & C(10')-C(5')-C(4') & 115.0(3) \\ C(6)-C(5)-C(4) & 116.7(3) & C(10')-C(5')-C(4') & 115.0(3) \\ C(6)-C(5)-C(4) & 116.7(3) & C(10')-C(5')-C(4') & 116.6(3) \\ C(7)-C(8)-C(9) & 108.8(3) & C(7')-C(8')-C(14') & 108.8(3) \\ C(26)-C(8)-C(7) & 108.5(4) & C(7')-C(8')-C(14') & 108.8(3) \\ C(26)-C(8)-C(7) & 108.5(4) & C(7')-C(8')-C(14') & 108.8(3) \\ C(26)-C(8)-C(7) & 108.5(4) & C(7')-C(8')-C(14') & 108.8(3) \\ C(26)-C(8)-C(7) & 108.8(3) & C(9')-C(8')-C(26') & 108.8(3) \\ C(7)-C(8)-C(9) & 108.8(3) & C(9')-C(8')-C(14') & 108.8(3) \\ C(7)-C(8)-C(9) & 108.8(3) & C(9')-C(8')-C(14') & 108.8(3) \\ C(7)-C(8)-C(14) & 110.1(3) & C(7')-C(8')-C(14') & 108.8(3) \\ C(7)-C(8)-C(14) & 110.3(3) & C(25')-C(14') & 108.8(3) \\ C(7)-C(8)-C(14) & 111.0(3) & C(1')-C(10')-C(5') & 108.0(3) \\ C(1)-C(0)-C(9) & 108.3(3) & C(1')-C(10')-C(5') & 113.5(3) \\ C(26)-C(8)-C(14) & 113.3(3) & C(25')-C(10') & 113.2(3) \\ C(26)-C(8)-C(10) & 126.3(3) & C(1')-C(10')-C(5') & 113.5(3) \\ C(1)-C(10)-C(5) & 113.3(3) & C(25')-C(10')-C(8') & 113.3(3) \\ C(1)-C(10)-C(5) & 113.3(3) & C(25')-C(10')-C(8') & 113.3(3) \\ C(1)-C(10)-C(5) & 113.3(3) & C(13')-C(14')-C(8$	C(3) = C(10) = C(9)	119.1(3) 116.7(3)	C(3) = C(21) = C(22)	120.9(4)	
$\begin{array}{c} C(25)-C(13)-C(12) & 107.3(3) & O(4)-C(22)-C(17) & 110.8(6) \\ C(25)-C(13)-C(18) & 113.3(3) & C(21)-C(22)-C(17) & 112.5(3) \\ \end{array}$	C(12) - C(11) - C(13)	110.7(3) 112.2(3)	O(4) - C(22) - C(21)	110.3(3) 110.4(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(25) - C(13) - C(12)	107.3(3)	O(4) - C(22) - C(17)	108.6(3)	
$\begin{array}{c c c c c c c c c c c c c c c c c c c $	C(25) - C(13) - C(18)	113.3(3)	C(21) - C(22) - C(17)	112.5(3)	
$\begin{array}{llllllllllllllllllllllllllllllllllll$			18		
$\begin{array}{llllllllllllllllllllllllllllllllllll$	C(10) - C(1) - C(2)	112.7(4)	C(10') - C(1') - C(2')	113.2(3)	
$\begin{array}{llllllllllllllllllllllllllllllllllll$	C(3) - C(2) - C(1)	112.0(3)	C(3') - C(2') - C(1')	112.0(3)	
$\begin{array}{llllllllllllllllllllllllllllllllllll$	O(1) - C(3) - C(2)	107.9(3)	O(1') - C(3') - C(2')	109.9(3)	
$\begin{array}{llllllllllllllllllllllllllllllllllll$	O(1) - C(3) - C(4)	110.5(4)	$O(1^{\circ}) - C(3^{\circ}) - C(4^{\circ})$	110.2(3)	
$\begin{array}{llllllllllllllllllllllllllllllllllll$	C(2) = C(3) = C(4) C(23) = C(4) = C(24)	114.1(3) 108.1(4)	$C(2) \rightarrow C(3) \rightarrow C(4)$	114.1(3) 108.3(4)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(23) - C(4) - C(24) C(23) - C(4) - C(3)	1112(3)	C(24') - C(4') - C(23')	108.5(4) 107.5(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(23) - C(4) - C(5)	114.6(4)	C(24') - C(4') - C(5')	108.6(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(24) - C(4) - C(3)	107.1(4)	C(23') - C(4') - C(3')	111.2(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(24) - C(4) - C(5)	108.3(3)	C(23') - C(4') - C(5')	114.0(3)	
$\begin{array}{llllllllllllllllllllllllllllllllllll$	C(3) - C(4) - C(5)	107.3(3)	C(3') - C(4') - C(5')	107.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(6) - C(5) - C(10)	110.8(3)	C(6') - C(5') - C(10')	109.8(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(0) = C(3) = C(4)	114.1(3) 116.7(3)	$C(6) \rightarrow C(5) \rightarrow C(4')$	115.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(10) - C(3) - C(4)	110.7(3)	C(10) = C(3) = C(4)	117.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(6) - C(7) - C(8)	114.3(3)	C(6') - C(7') - C(8')	114.4(3)	
$\begin{array}{llllllllllllllllllllllllllllllllllll$	C(26)—C(8)—C(7)	108.5(4)	C(7') - C(8') - C(9')	108.7(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(26) - C(8) - C(9)	110.8(3)	C(7') - C(8') - C(26')	108.8(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(26) - C(8) - C(14)	110.1(3)	C(7') - C(8') - C(14')	110.6(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(7) - C(8) - C(9)	108.8(3)	C(9') - C(8') - C(26')	110.6(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(7) - C(8) - C(14) C(0) - C(8) - C(14)	111.0(3) 107.8(3)	C(9') - C(8') - C(14')	108.8(3) 100.4(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(3) - C(3) - C(14)	107.8(3) 111.0(3)	C(11') - C(9') - C(8')	109.4(3) 111.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(11) - C(9) - C(10)	112.1(3)	C(11') - C(9') - C(10')	113.2(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(8) - C(9) - C(10)	118.3(3)	C(8') - C(9') - C(10')	117.1(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(1) - C(10) - C(25)	108.3(3)	C(1') - C(10') - C(25')	108.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(1) - C(10) - C(5)	108.1(3)	C(1') - C(10') - C(5')	108.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$C(1) \rightarrow C(10) \rightarrow C(9)$	107.9(3)	C(1') - C(10') - C(9')	107.4(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$C(23) \rightarrow C(10) \rightarrow C(3)$	113.3(3) 112.6(3)	$C(25) \rightarrow C(10) \rightarrow C(5)$	113.3(3) 113.5(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(5) - C(10) - C(9)	106.3(3)	C(5') - C(10') - C(9')	106.2(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(12) - C(11) - C(9)	113.2(4)	$C(12') \rightarrow C(11') \rightarrow C(9')$	115.1(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(13) - C(12) - C(11)	126.9(4)	C(13') - C(12') - C(11')	126.1(4)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(12) - C(13) - C(14)	120.3(4)	C(12') - C(13') - C(18')	118.1(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(12) - C(13) - C(18)	118.0(4)	C(12') - C(13') - C(14')	120.0(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(14) - C(13) - C(18) C(13) - C(14) - C(15)	121.0(3) 111.4(3)	$C(13) \rightarrow C(13) \rightarrow C(14')$ $C(13') \rightarrow C(14') \rightarrow C(27')$	106 9(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(13) - C(14) - C(17) C(13) - C(14) - C(27)	106.8(3)	C(13') - C(14') - C(15')	111.3(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(13) - C(14) - C(8)	109.1(3)	C(13') - C(14') - C(8')	108.4(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(15) - C(14) - C(27)	106.6(3)	C(27') - C(14') - C(15')	106.2(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(15) - C(14) - C(8)	110.9(3)	C(27') - C(14') - C(8')	112.8(3)	
C(10) - C(15) - C(14) = 114.4(4) = C(16') - C(15') - C(14') = 115.6(3)	C(27) - C(14) - C(8)	112.0(3)	C(15') - C(14') - C(8')	111.3(3)	
C(17) - C(16) - C(15) = 113 O(4) = C(15') - C(15') = C(15') = 112 O(2)	C(10) - C(15) - C(14)	114.4(4)	$C(16') \rightarrow C(15') \rightarrow C(14')$	112.6(3)	
C(17) = C(10) = C(13) = 112.0(4) = C(13) = C(16) = C(17) = 112.0(3) = C(28) = C(17) = C(16) = 110.0(3)	C(17) = C(10) = C(13) C(28) = C(17) = C(16)	113.0(4) 110.7(4)	C(13) = C(10) = C(17) C(28') = C(17') = C(16')	112.0(3) 110.0(3)	
C(28)-C(17)-C(18) 110.3(4) $C(28')-C(17')-C(22')$ 107.1(3)	C(28) - C(17) - C(18)	110.3(4)	C(28') - C(17') - C(22')	107.1(3)	
C(28)-C(17)-C(22) 107.2(4) $C(28')-C(17')-C(18')$ 110.4(3)	C(28) - C(17) - C(22)	107.2(4)	C(28') - C(17') - C(18')	110.4(3)	
C(16)-C(17)-C(18) 108.2(3) $C(16')-C(17')-C(22')$ 111.3(3)	C(16) - C(17) - C(18)	108.2(3)	C(16')—C(17')—C(22')	111.3(3)	
C(16) - C(17) - C(22) = 111.8(4) = C(16'(-C(17') - C(18')) = 107.9(3)	C(16) - C(17) - C(22)	111.8(4)	C(16'(-C(17')-C(18'))	107.9(3)	
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	C(18) - C(17) - C(22)	108.6(4)	$C(22') \rightarrow C(17') \rightarrow C(18')$	110.3(3)	
C(19)-C(18)-C(17) 113.3(3) $C(13')-C(18')-C(17')$ 112.5(3)	C(19) - C(18) - C(13) C(19) - C(18) - C(17)	113.3(3)	C(13) - C(18) - C(19)	111.2(3) 112.5(3)	

Bonds	Angle (deg)	Bonds	Angle (deg)		
C(13) - C(18) - C(17)	112.3(4)	C(19') - C(18') - C(17')	112.6(3)		
C(18) - C(19) - C(20)	115.5(4)	C(18') - C(19') - C(20')	115.0(3)		
C(21) - C(20) - C(29)	110.5(4)	C(29') - C(20') - C(21')	110.0(4)		
C(21) - C(20) - C(19)	108.0(4)	C(29') - C(20') - C(19')	109.7(3)		
C(21) - C(20) - C(30)	112.1(4)	C(29') - C(20') - C(30')	106.1(3)		
C(29) - C(20) - C(19)	109.4(4)	C(21') - C(20') - C(19')	109.1(3)		
C(29) - C(20) - C(30)	105.8(4)	C(21') - C(20') - C(30')	111.0(3)		
C(19) - C(20) - C(30)	111.1(3)	C(19') - C(20') - C(30')	110.9(3)		
C(22) - C(21) - C(20)	112.9(4)	C(22') - C(21') - C(20')	113.3(3)		
C(21) - C(22) - C(17)	115.4(4)	C(21') - C(22') - C(17')	115.2(3)		
O(2)-C(29)-C(20)	113.9(4)	O(2') - C(29') - C(20')	113.7(3)		
	19	EtOH			
C(2) - C(1) - C(10)	113.8(3)	C(12) - C(11) - C(9)	114.4(4)		
C(3) - C(2) - C(1)	110.6(4)	C(13) - C(12) - C(11)	126.9(4)		
O(1) - C(3) - C(2)	109.6(4)	C(12) - C(13) - C(14)	119.0(4)		
O(1) - C(3) - C(4)	110.4(3)	C(12) - C(13) - C(18)	120.5(4)		
C(2) - C(3) - C(4)	114.5(4)	C(14) - C(13) - C(18)	120.2(4)		
C(3) - C(4) - C(23)	111.6(4)	C(13) - C(14) - C(15)	112.4(4)		
C(3) - C(4) - C(24)	108.3(4)	C(13) - C(14) - C(27)	107.1(3)		
C(3) - C(4) - C(5)	106.3(3)	C(13) - C(14) - C(8)	108.4(3)		
C(23) - C(4) - C(24)	107.7(3)	C(15) - C(14) - C(27)	106.8(4)		
C(23) - C(4) - C(5)	114.2(4)	C(15) - C(14) - C(8)	110.4(4)		
C(24) - C(4) - C(5)	108.6(4)	C(27) - C(14) - C(8)	111.8(3)		
C(6) - C(5) - C(10)	111.2(4)	C(16) - C(15) - C(14)	114.3(4)		
C(6) - C(5) - C(4)	114.4(3)	C(15) - C(16) - C(17)	112.7(5)		
C(10) - C(5) - C(4)	117.8(4)	C(28) - C(17) - C(18)	110.9(6)		
C(5) - C(6) - C(7)	110.3(4)	C(28) - C(17) - C(22)	108.2(5)		
C(6) - C(7) - C(8)	114.0(4)	C(28) - C(17) - C(16)	109.8(5)		
C(7) - C(8) - C(25)	107.5(3)	C(18) - C(17) - C(22)	109.3(4)		
C(7) - C(8) - C(9)	110.9(3)	C(18) - C(17) - C(16)	107.7(4)		
C(7) - C(8) - C(14)	110.2(4)	C(22) - C(17) - C(16)	110.9(5)		
C(25) - C(8) - C(9)	111.0(4)	C(19) - C(18) - C(13)	110.5(4)		
C(25) - C(8) - C(14)	110.0(3)	C(19) - C(18) - C(17)	113.7(5)		
C(9) - C(8) - C(14)	107.3(3)	C(13) - C(18) - C(17)	112.9(4)		
C(11) - C(9) - C(8)	110.3(3)	C(18) - C(19) - C(20)	115.9(5)		
C(11) - C(9) - C(10)	115.0(4)	C(29) - C(20) - C(30)	109.4(6)		
C(8) - C(9) - C(10)	116.0(3)	C(29) - C(20) - C(21)	110.1(7)		
C(26) - C(10) - C(1)	107.7(4)	C(29) - C(20) - C(19)	110.1(6)		
C(26) - C(10) - C(5)	113.3(3)	C(30) - C(20) - C(21)	109.2(7)		
C(26) - C(10) - C(9)	113.0(4)	C(30) - C(20) - C(19)	111.1(6)		
C(1) - C(10) - C(5)	107.7(3)	C(21) - C(20) - C(19)	106.9(5)		
$C(1) \rightarrow C(10) \rightarrow C(9)$	108.1(3)	C(22) - C(21) - C(20)	113.9(6)		
C(3) = C(10) = C(9)	100.9(3)	$C(21) \rightarrow C(22) \rightarrow C(17)$	115.5(5)		
O(2) = C(11) = C(12)	107.9(3)	U(32) - U(31) - U(3)	114(1)		
<u> </u>		· · · · · · · · · · · · · · · · · · ·			

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respectively). The same atoms are also involved in intramolecular hydrogen bonds $(O(2)-H(36)\cdots O(1))$ and O(2')—H(36')···O(1'), H···O = 2.27 and 2.11 Å, O···O= 2.673(6) and 2.683(7) Å, O-H···O = 104 and 113° , respectively). The solvent molecules are not involved in any short intermolecular contacts. The saturated ring junctions C:D and D:E are *trans* and *cis*, respectively. The aromatic A ring deviates slightly from planarity while the B ring has an irregular C(9)-envelope conformation and the C, D, and E rings have chair conformations. The two independent molecules exhibit some structural differences, particularly in the torsion angles (see Table A5). These differences (also noted for the crystallographically independent molecules of 16 and 18) are not chemically significant and most likely arise from asymmetry in the packing arrangement.

The structure of **16** consists of molecules separated by normal van der Waals distances; the most significant intermolecular contact is $O(2) \cdots H(51) = 2.55$ Å. As for compound **15**, there is intramolecular hydrogen bonding between the O(3)/O(8) hydroxyl group and the adjacent O(2)/O(7)carbonyl function $(O(3) - H(1) \cdots O(2)$ and $O(8) - H(47) \cdots$ O(7), $H \cdots O = 1.91(8)$ and 2.09(8) Å, $O \cdots O = 2.628(5)$ and 2.621(6) Å, $O - H \cdots O = 117(6)$ and $116(6)^{\circ}$, respectively). The A:B, B:C, C:D, and D:E ring junctions are *trans, trans, trans,* and *cis,* respectively. All five rings of the triterpene skeleton have chair conformations. Only minor differences are noted for the two crystallographically independent molecules.

The lattice-held water molecule in $17 \cdot 1/2$ H₂O lies on a crystallographic C_2 axis and is hydrogen-bonded to

TABLE A5. Intra-annular torsion angles (deg) with estimated standard deviations in parentheses

Atoms	6 ∙MeOH	15·1/2EtOAc molecule 1	15·1/2ETOAc molecule 2	16 molecule 1	16 molecule 2	17 ·1/2 H ₂ O	18 molecule l	18 molecule 2	19-EtOH
C(10) - C(1) - C(2) - C(3)	-56.7(4)	0(1)	-2(1)	44.2(5)	44.1(6)	0.4(8)	-56.7(5)	-56.2(5)	-56.2(5)
C(1) - C(2) - C(3) - C(4)	55.8(4)	-1(1)	-2(1)	-45.7(5)	-38.9(6)	1.2(6)	55.3(5)	56.3(5)	59.0(5)
C(2) - C(3) - C(4) - C(5)	-51.8(4)	0(1)	5(1)	52.1(5)	43.8(6)	-1.0(6)	-50.9(5)	-51.9(4)	-54.6(5)
C(3) - C(4) - C(5) - C(10)	52.9(4)	2.7(8)	-3.6(9)	-54.6(4)	-52.3(5)	-0.7(5)	51.6(4)	51.9(4)	52.0(5)
C(4) - C(5) - C(10) - C(1)	-53.6(4)	-3.9(8)	-0.3(8)	54.9(4)	58.8(5)	2.2(5)	-54.0(4)	-52.7(4)	-50.6(5)
C(5)-C(10)-C(1)-C(2)	53.3(4)	3(1)	3(1)	-50.5(5)	-55.2(5)	-2.1(6)	53.8(4)	52.5(4)	50.6(5)
C(10)C(5)C(6)C(7)	-63.5(4)	-5(1)	-2(1)	49.8(5)	47.0(5)	-7.6(6)	-62.6(4)	-61.6(4)	-63.3(6)
C(5)C(6)C(7)C(8)	57.6(4)	10(1)	6(1)	~54.8(5)	-55.2(5)	7.1(7)	56.9(5)	55.7(5)	56.9(6)
C(6) - C(7) - C(8) - C(9)	-47.2(4)	6(1)	4(1)	58.9(5)	61.9(4)	8.7(6)	-47.0(5)	-47.3(4)	-47.4(5)
C(7) - C(8) - C(9) - C(10)	46.8(4)	-24.6(7)	-15.1(8)	-59.8(4)	-60.9(4)	-21.4(5)	46.9(5)	49.5(4)	45.9(5)
C(8) - C(9) - C(10) - C(5)	-52.3(4)	29.3(7)	18.7(7)	58.3(4)	55.5(4)	20.7(5)	-52.5(4)	-56.0(4)	-51.1(5)
C(9) - C(10) - C(5) - C(6)	58.5(4)	-15.1(8)	-10.6(8)	~52.4(4)	-48.6(5)	-7.1(5)	57.5(4)	59.0(4)	58.6(5)
C(14)C(8)-C(9)-C(11)	-61.7(4)	31.2(7)	41.9(7)	48.4(4)	47.0(4)	36.2(5)	-61.1(4)	-57.9(4)	-60.8(4)
C(8) - C(9) - C(11) - C(12)	33.4(5)	-31.7(7)	-42.0(7)	~46.9(4)	-45.3(5)	-31.7(5)	34.7(6)	28.8(5)	29.2(5)
C(9) - C(11) - C(12) - C(13)	-2.5(7)	48.8(7)	55.4(7)	55.2(4)	55.2(5)	47.5(5)	-5.3(8)	-0.9(6)	3.3(6)
C(11) - C(12) - C(13) - C(14)	1.4(6)	-61.9(7)	-61.0(7)	-58.3(4)	-60.5(4)	-62.7(4)	3.6(8)	3.9(6)	-1.6(7)
C(12) - C(13) - C(14) - C(8)	-30.2(5)	57.9(6)	56.0(6)	56.8(4)	58.8(4)	63.1(4)	-30.2(5)	-33.0(5)	-31.2(6)
C(13) - C(14) - C(8) - C(9)	59.4(3)	-44.6(7)	-50.1(7)	-55.2(4)	-55.2(4)	-52.7(4)	57.8(4)	59.4(4)	61.5(4)
C(18)-C(13)-C(14)-C(15)	32.9(4)	-60.0(6)	-61.6(6)	-63.9(4)	-62.1(4)	-58.1(4)	32.5(5)	30.1(5)	32.8(6)
C(13) - C(14) - C(15) - C(16)	-39.4(4)	60.1(7)	61.6(7)	62.1(4)	63.3(4)	63.3(4)	-38.1(5)	-35.5(5)	-38.7(6)
C(14)-C(15)-C(16)-C(17)	55.9(4)	-49(1)	-49.2(8)	-46.9(5)	-50.2(5)	-55.2(5)	55.6(5)	54.1(5)	55.4(7)
C(15) - C(16) - C(17) - C(18)	-60.5(4)	36(1)	34.4(8)	31.5(5)	33.9(5)	40.5(5)	-60.9(5)	-61.3(4)	-61.1(6)
C(16) - C(17) - C(18) - C(13)	51.3(4)	-37.3(8)	-36.5(8)	-34.2(5)	-34.4(5)	-39.8(5)	51.6(4)	53.0(4)	52.4(6)
C(17) - C(18) - C(13) - C(14)	-39.8(4)	50.8(7)	51.5(7)	51.5(4)	49.5(4)	49.3(4)	-40.6(5)	-40.7(5)	-41.5(7)
C(22)C(17)C(18)C(19)	47.6(4)	-50.9(7)	-45.5(7)	-47.8(4)	-47.1(4)	-52.1(4)	47.7(5)	48.1(4)	46.2(7)
C(17) - C(18) - C(19) - C(20)	-55.5(4)	45.8(8)	46.6(7)	45.2(5)	47.9(5)	49.1(4)	-53.4(5)	-53.1(5)	-51.9(7)
C(18) - C(19) - C(20) - C(21)	56.3(4)	-43.4(8)	-51.6(8)	-45.6(5)	-48.6(5)	~42.9(5)	54.0(5)	53.4(5)	52.6(9)
C(19) - C(20) - C(21) - C(22)	-55.2(4)	47.7(9)	58.5(8)	51.9(5)	51.3(5)	43.1(4)	-53.8(5)	-52.1(5)	-53.6(9)
C(20) - C(21) - C(22) - C(17)	54.2(4)	-56(1)	-61.9(8)	-59.2(5)	~54.6(5)	-50.5(4)	55.6(5)	52.7(5)	55.7(8)
C(21) - C(22) - C(17) - C(18)	-47.7(4)	56.3(8)	53.5(8)	54.9(4)	51.1(5)	54.3(4)	-50.0(5)	-49.1(5)	-49.3(8)

the carbonyl oxygen atoms O(1) of two molecules of 17(O(5)—H(37)···O(1), H···O = 1.96 Å, O···O = 2.910(6) Å, O—H···O = 176°). O(1) is also hydrogenbonded to the O(4) hydroxyl group (at C(22)) of another molecule of 17 related by a screw axis, forming a one-dimensional H-bonded array of molecules of 17 and water (O(4)—H(36)···O(1), H···O = 1.91 Å, O···O = 2.809(5) Å, O—H···O = 165°). The saturated ring junctions C:D and D:E are *trans* and *cis*, respectively. The aromatic A ring deviates slightly from planarity; the B ring has a flattened C(9)-envelope conformation; and the C, D, and E rings have chair conformations.

The structure of **18** is dominated by O—H···O hydrogen bonding which is not the same for the two independent molecules. All of the hydroxyl groups are hydrogen bond donors, but the unprimed molecule O(1) accepts one strong H-bond and O(2) accepts two (one weak and one strong) while the primed molecule acts as an acceptor for only one hydrogen bond (via O(2')) (O(1)—H(49)···O(2), O(2)— H(50)···O(1), O(1')—H(49')···O(2'), and O(2')—H(50') ···O(2); H···O = 2.41, 1.64, 1.83, and 1.70 Å; O···O = 2.710(5), 2.710(5), 2.693(5), and 2.747(4) Å; O—H···O = 117, 160, 134, and 167°; respectively). The A:B and B:C ring junctions are *trans* and the D:E junction is *cis*. The unsaturated C ring has a C(8)-sofa conformation and the other four rings all have chair conformations.

In the solid state structure of **19**·EtOH, molecules of **19** are directly hydrogen-bonded to one another and to the ethanol solvate molecules, each of the three hydroxyl groups (two from **19** and that of the EtOH solvate) acting as both donor and acceptor $(O(1) - H(54) \cdots O(2), O(2) - H(55) \cdots O(3), and O(3) - H(56) \cdots O(1); H \cdots O = 1.70, 1.66, and 1.80 Å; O \cdots O = 2.758(4), 2.739(5), and 2.768(5) Å; O - H \cdots O = 163, 153, and 169°; respectively). The ring junctions and ring conformations within the triterpene skeleton are as noted above for$ **18**.

Bond lengths and angles for all six structures are generally as expected (see Tables A3 and A4). There is some shortening of distances resulting from thermal motion, for example in the EtOH solvate molecule of **19** EtOH, and some lengthening due to steric effects such as the long bond between fully substituted ring junction atoms in **6**(C(8)—C(14) = 1.592(4) Å).

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