HETEROCYCLIC ANALOGS OF PLEIADIENE.

57.* REACTIONS OF ACEPERIMIDYLENES WITH SOME NUCLEOPHILES

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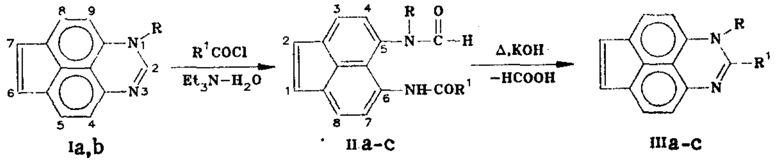
N-Substituted aceperimidylenes were subjected for the first time to a recyclization reaction (the action of aroyl chlorides in the presence of triethylamine). As a result, their 2-aryl and 2-styryl derivatives were obtained in good yields. The reactions of the N-substituted aceperimidylenes and their quaternary salts with some other nucleophiles were studied.

It has been previously shown that the dehydrogenation of N-substituted aceperimidines with chloranil in benzene is a convenient method for the preparation of N-substituted aceperimidylenes such as Ia [2]. However, in an attempt to obtain 1-methyl-2-phenylaceperimidylene via this method the reaction proceeded with considerably greater complexity, and the yield of the compound, which was difficult to purify, was low. It is known that in the perimidine series the best method for the synthesis of 1-substituted 2-arylperimidines is presently considered to be the so-called recyclization reaction. It consists in the fact that 1-R-perimidine is subject to the action of an aroyl chloride in the presence of moist triethylamine [3]. In the initial stage of the process one observes the formation of an N-acylperimidinium salt, which, in slightly basic media, is converted to the acyclic form of the pseudobase — N-R-N-formyl-N'-aroylnapththylenediamine. Upon heating of the latter compound with alkali, it undergoes cyclization through the aroyl group, and this leads to the corresponding 1-R-2-arylperimidine. The outcome of this reaction is determined, upon the whole, by the greater positive charge on the μ-carbon atom of the starting perimidine [4]. It is precisely this that explains the fact that this reaction does not occur in condensed imidazole systems, in which the positive charge on the μ-carbon atom is considerably lower than in the case of perimidines. Since the positive charge on the μ-carbon atom of aceperimidylenes is even greater than in the case of perimidines, one might have expected that in the aceperimidylene series the recyclization reaction would also proceed readily, which would make it possible to obtain the desired 2-arylaceperimidylenes. In order to verify this assumption we subjected 1-methyl- and 1-allylaceperimidylenes (Ia,b) to the recyclization reaction with benzoyl chloride, and Ia was also subjected to reaction with cinnamoyl chloride.



I—III a, c $R=CH_3$, b $R=CH_2CH=CH_2$; a, b $R^1=C_6H_5$, c $R^1=C_6H_5-CH=CH$

As expected, under the conditions of recyclization of Ia,b one observes the formation, in high yields, of yellow pseudobases IIa-c. Their structures were confirmed by, in addition to the results of elementary analysis, data from the IR and PMR spectra (see the Experimental section). In contrast to the also yellow-colored aceperimidylenes, II do not fluoresce upon irradiation with UV light, and this makes it convenient to use this procedure in their chromatographic identification.

When pseudobases IIa-c are heated with a methanol solution of KOH, they undergo rapid cyclization to give high yields of 1,2-disubstitited aceperimidylenes IIIa-c. In the case of

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*See [1] for Communication 56.

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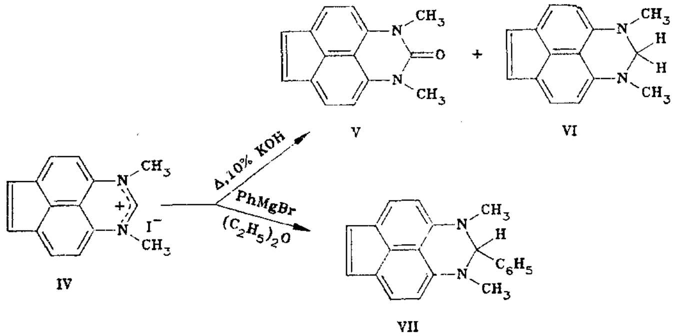
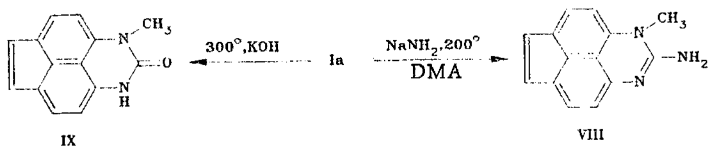
N-allyl-N-formyl-N-benzoyl-5,6-diaminoacenaphthylene (IIb) the cyclization under these conditions proceeds very slowly. All pseudobases IIa-c readily undergo cyclization upon refluxing in 10% aqueous alkyli; however, in this case, in addition to the 1,2-disubstituted aceperimidylenes IIIa-c, one observes the formation of very low yields of starting aceperimidylenes I, i.e., the cyclization of II under these conditions proceeds partially and at the formyl group. The structures of the III obtained were confirmed by the results of elementary analysis and data from the IR and PMR spectra. In addition to this, as in the case of all aceperimidylenes, III gives a yellow-green fluorescence upon radiation with UV light; an exception to this is IIIc, the luminescence of which is expressed extremely weakly.

Considering the success of the recyclization reaction, we considered it to be of interest to investigate the reactions of the aceperimidylenium cation with other nucleophiles. Redox disproportionation of the intermediate pseudobase to give a mixture of 1,3-dimethylaceperimidylenone (V) and 1,3-dimethyl-2,3-dihydroaceperimidylene (VI) in 55 and 35% yields, respectively, was observed when 1,3-dimethyl-aceperimidylenium iodide (IV) was heated with 10% aqueous alkali. Compound VI can also be obtained in higher yield (78%) by reduction of salt IV with lithium aluminum hydride in ether. The reaction of aceperimidylenium cation IV with organomagnesium compounds makes it possible to combine the step involving the hydrogenation of the C=N bond with the simultaneous introduction of a substituent into the 2 position. Thus by the action of phenylmagnesium bromide on salt IV in ether solution one observes the formation, in 75% yield, of 1,3-dimethyl-2-phenyl-2,3-dihydroaceperimidylene (VII).



2,3-Dihydroaceperimidylenes VI and VII are unstable compounds that fluoresce upon irradiation with UV light. In contrast to the dihydro derivatives of perimidine and aceperimidine, they are not soluble in concentrated or dilute hydrochloric acid in the cold or upon heating, and this constitutes evidence for their lower basicities.

Our investigation demonstrated that aceperimidylenium salts do not differ fundamentally in their reactivities from perimidinium and aceperimidinium salts [4]. In addition, as we have established in the present research, aceperimidylenes themselves, as compared with perimidines, react with nucleophiles with considerably greater difficulty. Thus, whereas 1-methylperimidylene is aminated by sodium amide at the 2 position at 130-140°C, Ia undergoes this reaction only at 200°C (the course of the reaction was monitored from the liberation of gaseous hydrogen), and 2-amino derivative VIII was obtained in only 7% yield. Similarly, whereas 1-methylperimidine is hydroxylated by anhydrous alkali at 200°C to give 1-methylperimidone in high yield, Ia undergoes hydroxylation only at 300°C, and the yield of 1-methylaceperimidylenone (IX) does not exceed 10%. The bulk of the starting substance undergoes resinification under such severe conditions.*



The difficulty in the amination and hydroxylation of 1-methylaceperimidylene can be explained by its reduced basicity (p$K_a \approx 4$ as against pH 6 for perimidines) [4]; this hinders a favorable reaction of coordination of the alkali metal ion with the pyridine nitrogen atom. Another explanation, which does not necessarily contradict the former explanation, undoubtedly consists in the lower hydride lability of the intermediate σ complexes based on aceperimidylene, in connection with which, a higher temperature is required for their aromatization.

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*The experiments on the amination and hydroxylation of 1-methylaceperimidylene were carried out by T. I. Vinokurova.

EXPERIMENTAL

The IR spectra were measured with a UR-20 spectrometer. The PMR spectra of solutions in dueterochloroform were obtained with a Tesla BS-487 spectrometer (80 MHz) with hexamethyldisiloxane (HMDS) as the internal standard. The individuality of the compounds obtained was monitored by means of TLC on activity II neutral aluminum oxide.

1-Methylaceperimidylene (Ia). This compound was obtained by dehydrogentation of 1-methylaceperimidine with activated manganese dioxide. This method is preferable to dehydrogenation by means of chloranil [2], since, in this case, deeply colored extremely stable π complexes, which hinder the isolation and purification of the reaction products, are not formed.

A 2.7-g (30 mmoles) sample of finely ground activated manganese dioxide was added to a solution of 1 g (5 mmoles) of 1-methylaceperimidine [5] in 30 ml of benzene, and the mixture was heated with stirring on a boiling-water bath for 2 h. It was then cooled, and the precipitated manganese dioxide was removed by filtration and washed with benzene. The filtrate was evaporated to half its original volume and chromatographed with a column packed with Al_2O_3. Compound Ia was eluted with a mixture of chloroform and benzene (1:1) to give 0.8 g (80%) of a product with mp 186-187°C (from alcohol). According to the data in [2], this compound had mp 179-180°C (from CCl_4) and R_f 0.5 [chloroform—benzene(1:1)]. The results of elementary analysis and the data from the IR and PMR spectra were in agreement with structure Ia and with the results in [2].

1-Allylaceperimidylene (Ib). A 0.66-g (0.01 mole) sample of ground KOH and 1.2 g (0.01 mole) of allyl bromide were added with stirring to a solution of 2 g (0.01 mole) of aceperimidylene [2] in 20 ml of dimethyl sulfoxide (DMSO), and the mixture was stirred at room temperature for 2 h and then diluted with 100 ml of water. The resulting precipitate was removed by filtration, washed with water, dissolved in chloroform, and chromatographed with a column packed with Al_2O_3 by elution with chloroform to give 1.4 g (61%) of yellow crystals of Ib with mp 81-82°C (from cyclohexane) and R_f 0.7 (chloroform). IR spectrum (chloroform): 1670, 1690, 1500, 1480, and 1460 cm^{-1} (C=N, aromatic C⎓C). PMR spectrum: 4.50 (2H, d, J = 3 Hz, $N-CH_2-$), 5.10 (2H, m, $CH_2=C-C-$), 5.75 (1H, m, $-C-CH=C-$), 6.80 (1H, d, J = 7.8 Hz, 9-H), 7.52 (2H, s, 6,7-H), 7.62 (1H, d, J = 7.8 Hz, 4-H), 7.90, 8.10 (1H, d, J = 7.8 Hz, 5-H), and 8.23 ppm (1H, d, J = 7.8 Hz, 8-H). Found: C 82.6; H 5.3; N 12.0%. $C_{16}H_{12}N_2$. Calculated: C 82.7; H 5.2; N 12.1%.

General Method for the Synthesis of N-Substituted N-Formyl-N'-aroyl-5,6-diaminoacenaphthylenes (IIa-c). A 0.015-mole sample of benzoyl chloride or cinnamoyl chloride was added with stirring to a solution of 0.01 mole of Ia, b in 50 ml of ether, and the mixture was heated to the boiling point. After 3-5 min, 0.015 mole of triethylamine was added to the resulting suspension, and the mixture was refluxed for 20 min until a copius precipitate formed. The mixture was then cooled, and the precipitate was removed by filtration and washed with water. Compounds IIa-c were purified by chromatography with a column packed with Al_2O_3 by elution with chloroform.

N-Methyl-N-formyl-N'-benzoyl-5,6-diaminoacenaphthylene (IIa). This compound, with mp 218-219°C (from benzene with petroleum ether) and R_f 0.8 (chloroform), was obtained in 87% yield. IR spectrum (chloroform): 3430 (NH); 1700 (C=O); 1630, 1600, 1550, 1510, 1495, 1465 cm^{-1} (aromatic C=C). PMR spectrum: 3.17 (3H, s, $N-CH_3$), 6.87-8.17 (10H, m, 1-4-8-H and C_6H_5), 8.52 (1 H, s, CHO), 8.55 (1H, d, J = 6.4 Hz, 7-H), and 9.40 ppm (1H, broad s, NH). Found: C 76.7; H 5.0; N 8.7%. $C_{21}H_{16}N_2O_2$. Calculated: C 76.8; H 4.9; N 8.5%.

N-Allyl-N-formyl-N'-benzoyl-5,6-diaminoacenaphthylene (IIb). This compound, with mp 179-180°C (from benzene with petroleum ether) and R_f 0.8 (chloroform), was obtained in 85% yield. IR spectrum (chloroform): 3445 (NH); 1720 (C=O); 1640, 1620, 1565, 1525, 1510, 1480 cm^{-1} (C=C, aromatic C⎓C). PMR spectrum: 4.62 (2H, d, J = 3 Hz, $N-CH_2-$), 5.10 (2H, m, $CH_2=C-C-$), 5.50 (1H, m, $-C-CH=C-$), 6.85-7.92 (10H, m, 1-4-8-H and C_6H_5), 8.52 (1H, s, CHO), 8.55 (1H, d, J = 6.4 Hz, 7-H), and 9.40 ppm (1H, broad s, NH). Found: C 77.7; H 5.0; N 7.9%. $C_{23}H_{18}N_2O_2$. Calculated: C 77.9; H 5.1; N 7.9%.

N-Methyl-N-formyl-N'-cinnamoyl-5,6-diaminoacenaphthylene (IIc). This compound, with mp 220-221°C (from isobutyl alcohol) and R_f 0.75 (chloroform), was obtained in 93% yield. IR spectrum (mineral oil): 3250 (NH); 1685 (C=O); 1630, 1550, 1510, 1465 cm^{-1} (C=C, aromatic C⎓C). Found: C 77.6 H 4.9; N 7.6%. $C_{23}H_{18}N_2O_2$. Calculated: C 77.9; H 5.1; N 7.9%.

General Method for the Preparation of Aceperimidylenes IIIa-c. A) A 10-ml sample of a 10% methanol solution of KOH was added to a solution of 5 mmoles of IIa-c in 10 ml of methanol. The color of the solution changed rapidly from yellow to dark red. The reaction mixture was refluxed for 5 min until precipitation commenced, after which it was cooled, and the precipitated IIIa-c were removed by filtration. Compounds IIIa-c were purified by chromatography with a column packed with Al_2O_3 by elution with benzene. Substances IIIa-c were obtained in 90, 33, and 91% yields, respectively. In the case of IIb the reaction proceeds slowly under these conditions. Prolonged refluxing of an alkaline methanol solution of IIb does not lead to a significant increase in the yield of IIIb, inasmuch as it is accompanied by resinification of the reaction mixture.

B) A suspension of 5 mmoles of IIa-c in 20 ml of 10% aqueous KOH solution was refluxed with stirring for 1 h, after which it was cooled, and the precipitate was removed by filtration and washed with water. Substances IIIa-c were purified by method A. Compounds IIIa-c were eluted first by means of benzene [R_f 0.8 (benzene)]. Starting compound I, with $R_f \approx 0.3$ (benzene), which was formed in small amounts, was the second substance to be eluted. The yield was ≈5%. The melting points and IR and PMR spectra were in agreement with structure I.

1-Methyl-2-phenylaceperimylidene (IIIa). This compound, with mp 174-175°C (from alcohol) [according to [2], mp 164-165°C [from CCl_4 with petroleum ether], was obtained in 85% yield in the form of bright-yellow crystals. IR spectrum (chloroform): 1645, 1590, 1565, 1500, and 1460 cm^{-1} (C=N, aromatic C⎓C). PMR spectrum: 3.60 (3H, s, $N\text{—}CH_3$), 6.95 (1H, d, J = 7.8 Hz, 9-H), 7.25 (5H, s, C_6H_5), 7.52 (2H, s, 6,7-H), 7.68 (1H, d, J = 7.8 Hz, 9H), 7.25 (5H, s, C_6H_5), 7.52 (2H, s, 6,7-H), 7.68 (1H, d, J = 7.8 Hz, 4-H), 8.11 (1H, s, 5-H), and 8.25 ppm (1H, d, J = 7.8 Hz, 8-H). Found: C 85.0; H 5.0; N 9.7%. $C_{20}H_{14}N_2$. Calculated: C 85.1; H 5.0; N 9.9%.

1-Allyl-2-phenylaceperimidylene (IIIb). This compound, with mp 176-177°C (from alcohol), was obtained in 83% yield in the form of bright-yellow crystals. IR spectrum (chloroform): 1650, 1590, 1560, 1490, and 1470 cm^{-1} (C=N, C=C, aromatic C⎓C). PMR spectrum: 4.63 (2H, d, J = 3 Hz, $N\text{—}CH_2\text{—}$), 5.05 (2H, m, $CH_2\text{=}C\text{—}C\text{—}$), 5.75 (1H, m, $\text{—}C\text{—}CH\text{=}C\text{—}$), 6.97 (1H, d, J = 7.8 Hz, 9-H), 7.45 (5H, s, C_6H_5), 7.52 (2H, s, 6,7-H), 7.67 (1H, d, J = 7.8 Hz, 4-H), 8.11 (1H, d, J = 7.8 Hz, 5-H), and 8.25 ppm (1H, d, J = 7.8 Hz, 8-H). Found: C 85.7; H 5.2; N 9.1%. $C_{22}H_{16}N_2$. Calculated: C 85.7; H 5.2; N 9.1%.

1-Methyl-2-styrylaceperimidylene (IIIc). This compound, with mp 206-207°C (from isobutyl alcohol), was obtained in 87% yield in the form of crimson crystals. IR spectrum (mineral oil): 1640, 1560, 1490, and 1450 cm^{-1} (C=N, C=C, aromatic C⎓C). PMR spectrum: 3.62 (3H, s, $N\text{—}CH_3$) and 6.77-8.25 ppm (13H, m, 4-9-H, C_6H_5, —CH=CH—). Found: C 85.6; H 5.0; N 9.2%. $C_{22}H_{16}N_2$. Calculated: C 85.7; H 5.2; N 9.1%.

1,3-Dimethylaceperimidylenium Iodide (IV). A solution of 1 g (5 mmoles) of Ia and 1.4 g (10 mmole) of methyl iodide in 5 ml of dimethylformamide (DMF) was heated on a boiling-water bath for 20 min, after which it was cooled, and the precipitated yellow methiodide IV was removed by filtration to give a product with mp 299-300°C (from alcohol) in quantitative yield. Found: N 7.8%. $C_{15}H_{13}IN_2$. Calculated: N 8.0%.

Reaction of 1,3-Dimethylaceperimidylenium Iodide with a Solution of Alkali. A suspension of methiodide IV [1.7 g (5 mmoles)] in 50 ml of water was treated, as it was heated on a boiling-water bath, with 10 ml of a 10% aqueous solution of KOH, after which the mixture was maintained under these conditions for 10-15 min. It was then cooled, and the precipitate, which was a mixture of V and VI, was removed by filtration. For separation of the substances the precipitate was dissolved in 20 ml of benzene, and the solution was chromatographed with a column packed with Al_2O_3 by elution with benzene. The first substance to be eluted was VI [0.39 g (35%)] in the form of orange crystals with mp 138-139°C (from alcohol) and R_f 0.9 (benzene). IR spectrum (chloroform): 1660, 1630, 1590, 1510, and 1460 cm^{-1} (aromatic C⎓C). PMR spectrum: 2.87 (6H, s, $N\text{—}CH_3$), 4.11 (2H, s, $\text{—}CH_2\text{—}$), 6.38 (2H, d, J = 8.0 Hz, 4,9-H), 6.78 (2H, s, 6,7-H), and 7.50 ppm (2H, d, J = 8.0 Hz, 5,8-H). Found: C 81.2; H 6.5; N 12.8%. $C_{15}H_{14}N_2$. Calculated: C 81.0; H 6.4; N 12.6%.

The second substance to be eluted was V [0.65 g (55%)] in the form of yellow crystals with mp 188-189°C (from alcohol) [according to [6], mp 172-173°C (from heptane)], and R_f 0.7 (benzene). IR spectrum (chloroform): 1660 (C=O); 1680, 1590, 1490 cm^{-1} (aromatic C⎓C). PMR spectrum: 3.45 (6H, s, $N\text{—}CH_3$), 6.52 (2H, d, J - 7.8 Hz, 4,9-H), 7.09 (2H, s, 6,7-H), and 7.70 ppm (2H, d, J = 7.8 Hz, 5,8-H). Found: C 76.1; H 5.0; N 12.0%. $C_{15}H_{12}N_2O$. Calculated: C 76.2; H 5.1; N 11.9%.

Reduction of 1,3-Dimethylaceperimidylenium Iodide with Lithium Aluminum Hydride. A 1.7-g (5 mmoles) sample of methiodide IV was added with stirring to a solution of 0.57 g (15 mmoles) of lithium aluminum hydride in 50 ml of absolute ether, after which the mixture was refluxed with stirring for 1 h. It was then cooled and treated cautiously with 10 ml of water. The ether layer was separated, and the aqueous layer was extracted with ether (three 30-ml portions). The combined ether extracts were evaporated, and the residue was crystallized from alcohol to give 0.86 g (78%) of orange crystals with mp 138-139°C and R_f 0.9 (benzene). No melting-point depression was observed for a mixture of samples of 1,3-dimethyl-2,3-dihydroaceperimidylene (VI) obtained by both methods, and the IR and PMR spectra of the samples were identical.

1,3-Dimethyl-2-phenyl-2,3-dihydroaceperimidylene (VII). A 1.1-g (3 mmoles) sample of methiodide IV was added to a solution of phenylmagnesium bromide, obtained from 0.24 g (0.01 g-atom) of magnesium turnings and 1.6 g (0.01 mole) of bromobenzene in 50 ml of absolute ether, and the suspension was refluxed with stirring for 30 min. The mixture was then cooled and treated with 20 ml of water. The precipitate and the ether solution were separated, and the ether was evaporated. The residue was combined with the precipitate and dissolved in benzene. The solution was purified by chromatography with a column packed with Al_2O_3 by elution with benzene to give 0.75 g (75%) of orange crystals with mp 188-189°C (from benzene with petroleum ether) and R_f 0.9 (benzene). Found: C 84.3; H 6.2; H 9.2%. $C_{21}H_{18}N_2$. Calculated: C 84.5; H 6.1; N 9.4%.

1-Methyl-2-aminoaceperimidylene (VIII). A) A solution of 1 g (5 mmoles) of Ia in 5 ml of dry dimethylaniline was added with stirring to a suspension of 1 g (25 mmoles) of sodium amide in 5 ml of dimethylaniline, and the mixture was heated to 200°C and maintained at this temperature for 2 h until the liberation of gaseous products ceased. The mixture was then cooled and treated cautiously with 10 ml of water. The resulting amine and the resinification products were removed by filtration and washed with water and benzene. The amine was isolated by chromatography with a column packed with aluminum oxide with collection of the second fraction by elution with alcohol to give 0.08 g (7%) of amine VIII in the form of yellow crystals with mp 240-241°C (from xylene). IR spectrum (mineral oil): 3420 and 3310 cm^{-1} (NH_2). Found: C 75.8; H 5.1; N 18.9%. $C_{14}H_{11}N_2$. Calculated: C 76.0; H 5.0; N 19.0%.

B) A mixture of 1.1 g (5 mmoles) of 1-methyl-2-aminoaceperimidine [7] and 1.2 g (5 mmoles) of chloranil in 50 ml of chlorobenzene was refluxed for 20 min, after which the solvent was evaporated, and the residue was treated with 30 ml of a 10% solution of KOH. The precipitate was removed by filtration and washed with water. The amine was purified by method A to give 0.4 g (36%) of a product with mp 240-241°C (from xylene). No melting-point depression was observed for a mixture of the amination products, and the IR spectra of the samples obtained by both methods were identical.

1-Methyl-2-oxo-2,3-dihydroaceperimidylene (IX). A mixture of 1 g (5 mmoles) of Ia and 1.2 g (20 mmoles) of anhydrous powdered KOH was heated to 300°C and maintained at this temperature for 1 h until hydrogen evolution ceased. The melt was cooled and treated with 20 ml of 5% HCl solution until it gave an acidic reaction with respect to Congo Red. The precipitate was removed by filtration and washed with water. Oxo derivative IX was isolated by chromatography with a column packed with Al_2O_3 with collection of the second fraction (elution with alcohol) to give 0.12 g (9%) of yellow crystals with mp 275-276°C (from butanol), in agreement with the data in [6]. The product had R_f 0.5 (alcohol). IR spectrum (mineral oil): 1677 cm^{-1} (C=O).

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