Electron Impact Mass Spectra of 3,5,7-Triaryl- and -Trialkyl-4*H*-1,2-Diazepines

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Electron impact mass spectra of 3,5,7-trisubstituted 4*H*-1,2-diazepines indicate that aryl substituents lead to N_2 expulsion while alkyl substituents do not. A common fragmentation pattern is observed and discussed for all alkyldiazepines, most of which are newly reported compounds. Assignments are based on electron impact mass spectra of deuteriated substrates and high resolution mass spectra. A previous interpretation of N_2 expulsion is corrected.

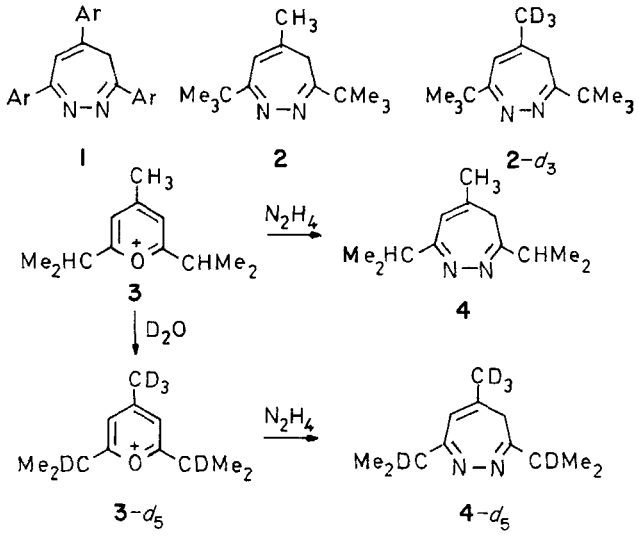
INTRODUCTION

Dinitrogen (N_2) expulsion under electron impact from 3,5,7-triaryl-4*H*-1,2-diazepines (**1**) was reported previously.[1] The absence of the $[M-28]^{+\cdot}$ peak from the electron impact (EI) mass spectrum of 3,7-di-*tert*-butyl-5-methyl-4*H*-1,2-diazepine (**2**) suggested a possible steric inhibition of dinitrogen expulsion by the two *tert*-butyl groups which would become adjacent in a hypothetical $[M-N_2]^{+\cdot}$ cyclic fragment. Compound **2** was the only alkyl-substituted 4*H*-1,2-diazepine examined up until recently. We now report the study of newly synthesized 3,5,7-trialkyl-4*H*-1,2-diazepines which present similar fragmentation patterns, i.e. the loss of N_2 is absent. Thus, the different fragmentation of compounds **1** and **2** may originate in the different nature of their substituents: neighbouring aryl groups have a much higher stabilization effect on unpaired electrons than alkyl groups. The present paper confirms the assignments for **1** by high resolution EI mass spectrometry (EIMS), reports the results of EIMS of 3,5,7-trialkyl-4*H*-1,2-diazepines and corrects accordingly the previous hypothesis of steric inhibition of N_2 expulsion.

RESULTS AND DISCUSSION

EI mass spectra of 3,7-dialkyl-5-methyl-4*H*-1,2-diazepines and deuteriated congeners

3,7-Diisopropyl-5-methyl-4*H*-1,2-diazepine (**4**) affords an EI mass spectrum which reveals at first glance a fairly intense $[M-28]^{+\cdot}$ peak, which, if involving N_2 loss, would indicate less severe steric strain in the fragment, in agreement with the initial hypothesis. However, the deuteriated derivative (**4**-d_5) shows a clear $[M-29]^{+\cdot}$ peak indicating loss of C_2H_3D (and C_2H_4 from **4** respectively) from one of the isopropyl side-chains, instead of N_2 loss. A similar fragmentation is found in **2** which loses C_3H_6 from one of the *tert*-butyl groups.



Further proof of the different fragmentation of **1** on the one hand and of alkyl-substituted 4*H*-1,2-diazepines on the other hand was obtained from the high resolution EI mass spectrum of **4** as shown in Table 1: the $[M-N_2]^{+\cdot}$ fragment peak is indeed absent.

Having established that a second alkyl-substituted 4*H*-1,2-diazepine (**4**) with smaller steric requirements than **2** failed to split off N_2, we then proceeded to synthesize the related compounds: 3,7-diethyl-5-methyl-4*H*-1,2-diazepine (**5**) and 3,5,7-trimethyl-4*H*-diazepine (**6**). The synthesis of diazepines **10** starts from pyrylium salts **7** and requires carefully selected reaction conditions in order to avoid the formation of other products (**8**, **9**, **11**, **12**). Compounds **4**–**6** are new: EI mass spectra are presented in Fig. 1 and Table 2.

Interestingly, the four alkyldiazepines reported in this paper present three different base peaks; however, the fragmentation is very similar as shown in Table 2, which gives the EI mass spectra of the four diazepines and of two deuteriated congeners. The more branched the R group in diazepine **10**, the less abundant is the parent peak: the trimethyl derivative has as base peak the parent peak, for R = Et or Pr^i the base peak is at $m/z = 81$ (probably a 3-methylpyrrole cation structure

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Table 1. High resolution EI mass spectrum of 3,7-diisopropyl-5-methyl-4*H*-1,2-diazepine (4)[a]

Peak obs.	Intensity (%)	Formula	Deviation (mu)	Assignment
193.1633	8.77	$^{13}CC_{11}H_{20}N_2$	+2.7	$[M]^{+\cdot}(^{13}C)$
192.1621	28.62	$C_{12}H_{20}N_2$	+0.5	$[M]^{+\cdot}$
191.1533	8.05	$C_{12}H_{19}N_2$	+1.5	$[M-H]^+$
178.1418	15.03	$C_{11}H_{18}N_2$	+5.1	$[M-CH_2]^{+\cdot}$
177.1390	100.00	$C_{11}H_{17}N_2$	+0.1	$[M-CH_3]^+$
176.1420	3.49	$C_{12}H_{18}N$	+2.0	$[M-NH_2]^+$
165.1333	9.84	$C_{10}H_{17}N_2$	+5.9	$[M-C_2H_3]^+$
164.1310	77.55	$C_{10}H_{16}N_2$	+0.4	$[M-C_2H_4]^{+\cdot}$
163.1224	6.35	$C_{10}H_{15}N_2$	+1.1	$[M-C_2H_5]^+$
149.1084	14.49	$C_9H_{13}N_2$	−0.5	$[M-Pr^i]^+$
135.0925	22.09	$C_8H_{11}N_2$	−0.3	$[M-Me-Pr^i]^+$
123.0984	5.90	$C_8H_{13}N$	+6.4	$[M-Pr^iCN]^{+\cdot}$
108.0803	73.43	$C_7H_{10}N$	+1.0	$[M-Pr^iCN-Me]^+$

[a] The high resolution mass spectra were recorded with minimal $m/z = 100$, therefore in this case the peak at m/z 177 appears as base peak; actually, as is seen in Table 2, the base peak is at $m/z = 81$.

15); for R = t-Bu the base peak is at an m/z value corresponding to $[M-42]^{+\cdot}$, namely to the loss of C_3H_6 as demonstrated earlier by the presence of a metastable peak and by high resolution EIMS.[2]

The 3,7-dialkyl side-chains are fragmented as follows: (i) loss of hydrogen (which does not originate from the 5-methyl group because the intensity of the $[M-2]^+$ peaks in the 5-methyl-deuteriated compounds is not enhanced); (ii) loss of methyl (as indicated by the unique $[M-15]^+$ peak in non-deuteriated compounds; the twin $[M-15]^+$, $[M-18]^+$ peaks in the corresponding deuteriated compounds indicate that the methyl group can be lost either from the 5-position or from the 3- or 7-alkyl side-chain; (iii) loss of C_2H_4 (especially from isopropyl side-chains) and C_3H_6 (especially from *tert*-butyl side-chains); (iv) combinations of the above fragmentations.

The diazepine ring **10** is split by loss of RCN, probably accompanied by ring contraction to a pyrrole system (**13** ⇌ **14**). In turn a second RCN may be lost,

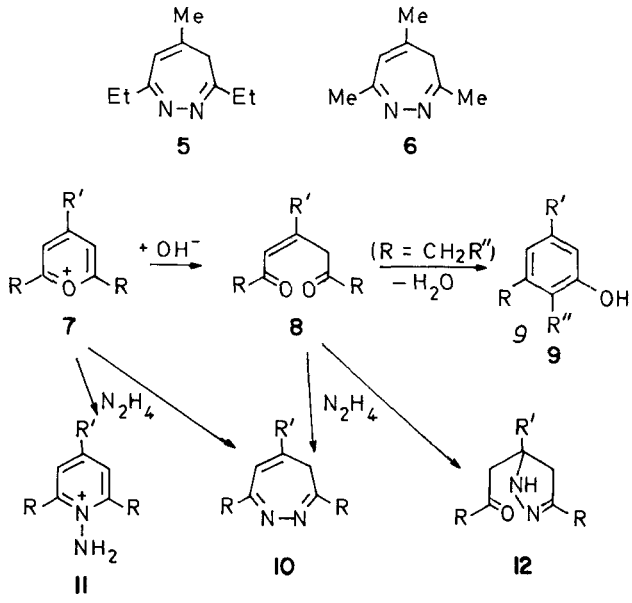


Table 2. EI Mass spectra of 3,5,7-trialkyl-4*H*-1,2-diazepines (intensities are indicated in brackets, %)

2	2-d_3	4	4-d_5	5	6	Assignment
220(29)	223(29)	192(39)	197(53)	164(77)	136(100)	$[M]^{+\cdot}$, **10**
219(6)	222(19)	191(7)	196(32)	163(7)	35(1)	$[M-H]^+$
206(10)		178(13)	183(23)	150(3)	122(2)	$[M-CH_2]^{+\cdot}$
205(62)	208(41)	177(94)	182(50)	149(78)	121(47)	$[M-CH_3]^+$
—	205(40)	—	179(70)	—	—	$[M-CD_3]^+$
204(4)		176(6)	178(15)	148(41)	120(9)	$[M-NH_2]^+$
—	—	165(9)	169(38)	—	—	$[M-C_2H_3(C_2H_2D)]^+$
—	—	164(70)	168(82)	136(1)	—	$[M-C_2H_4(C_2H_3D)]^{+\cdot}$
—	—	163(5)	167(45)	135(4)	—	$[M-C_2H_5(C_2H_4D)]^+$
190(5)	193(3)	162(9)		134(1)	106(2)	$[M-2CH_3]^{+\cdot}$
189(1)	192(2)	161(3)	166(16)	133(2)	105(1)	$[M-2CH_3-H]^+$
179(13)	182(11)	151(2)	154(8)	—	—	$[M-C_3H_5]^+$
178(100)	181(100)	150(4)	153(16)	—	—	$[M-C_3H_6]^{+\cdot}$
177(2)	180(54)	149(15)	152(10)	—	—	$[M-C_3H_7]^+$
—	—	—	—	121(5)	—	$[M-C_2H_4-CH_3]^+$
163(15)	166(14)	—	—	—	—	$[M-Bu^t]^+$
—	—	135(19)	139(21)	—	—	$[M-Pr^i-Me]^+$
149(24)	152(22)	—	—	—	—	$[M-Bu^t-Me]^+$
137(10)	140(5)	123(17)	126(13)	109(36)	95(12)	$[M-RCN]^{+\cdot}$, **13** ⇌ **14**
136(7)	139(7)	122(10)	125(10)	108(10)	94(14)	$[M-RCN-H]^+$
122(52)	125(50)	108(86)	112(58)	94(93)	80(8)	$[M-RCN-Me]^+$
107(19)	110(11)	93(10)	97(13)	79(11)	65(1)	$[M-RCN-2Me]^{+\cdot}$
95(16)	97(16)	—	—	—	—	?
91(7)	94(7)	91(14)	94(13)	91(5)	91(2)	?
81(40)	84(42)	81(100)	84(100)	81(100)		[3-Me-pyrrole]$^{+\cdot}$
57(63)	57(43)	—	—	—	—	$[Bu^t]^+$
53(7)	56(8)	53(13)	56(12)	53(14)	53(2)	$[M-2RCN]^{+\cdot}$, **16**
84(6)	—	70(9)	71(22)	56(4)	—	$[RCNH]^+$, $[RCND]^+$

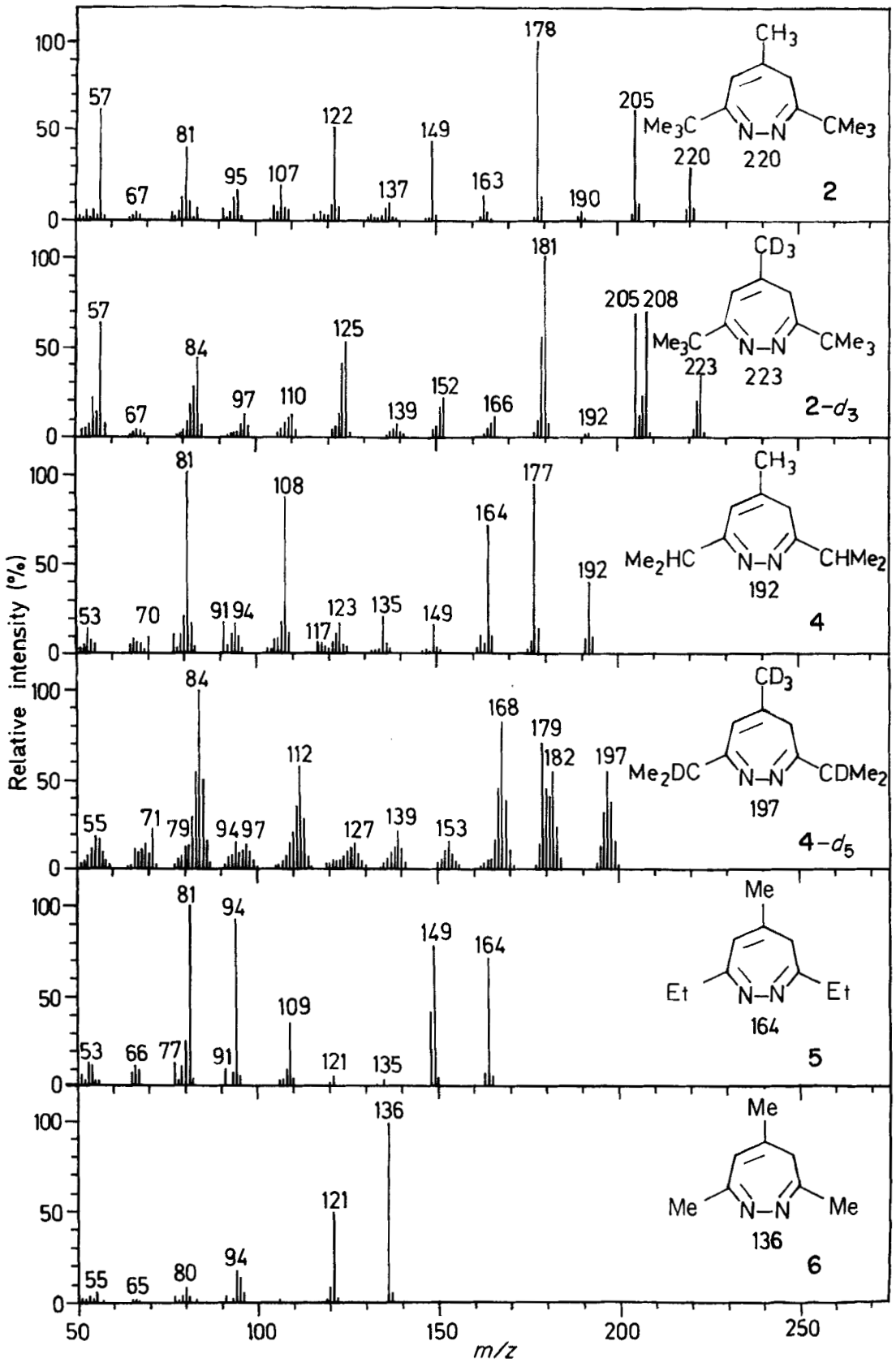
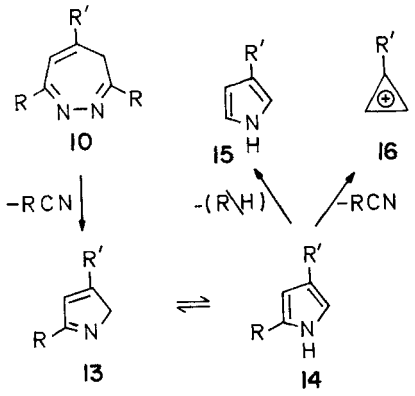


Figure 1. 70 eV EI mass spectra of 3,5,7-trialkyl-4*H*-1,2-diazepines.



probably resulting in a cyclopropenium system **16**. Confirmations of this mode of fragmentation are: (i) it appears with moderate intensity in all four compounds (**2**, **4**, **5** and **6**), and was also observed in triaryl diazepines (**1**); (ii) it appears in combination with the above alkyl fragmentations; (iii) the pyrrole fragment remaining after loss of RCN and R (the other side-chain) is found as an intense peak at $m/z = 81$ in all four non-deuteriated compounds and at $m/z = 84$ in the deuteriated congeners; (iv) the protonated/deuterionated nitrilium ions $[RCNH]^+/[RCND]^+$ appear with moderate intensities.

For more complete fragmentation schemes the two previous references should be consulted.[1,2]

High resolution EI mass spectrum of 3,5,7-triphenyl-4*H*-1,2-diazepine

Table 3 presents the high resolution data for compound **1** with Ar = Ph. The $[M-28]^{+\cdot}$ peak has an m/z value corresponding to loss of N_2, in agreement with the previous assignments based on metastable peaks.[1]

Table 3. High resolution EI mass spectrum of 3,5,7-triphenyl-4*H*-1,2-diazepine (1, Ar = Ph)

Peak obs.	Intensity (%)	Formula	Deviation (mu)[a]	Assignment
324.1532	1.48	$^{13}C_2C_{21}H_{18}N_2$	+0.5	$[M]^{+\cdot}(^{13}C_2)$
323.1489	12.35	$^{13}CC_{22}H_{18}N_2$	+1.4	$[M]^{+\cdot}(^{13}C)$
322.1455	49.95	$C_{23}H_{18}N_2$	+1.5	$[M]^{+\cdot}$
321.1378	10.45	$C_{23}H_{17}N_2$	+1.3	$[M-H]^+$
307.1340	2.11	$C_{23}H_{17}N$	+2.1	$[M-NH]^{+\cdot}$
294.1414	5.81	$C_{23}H_{18}$	−0.5	$[M-N_2]^{+\cdot}$
220.1064	19.43	$C_{16}H_{14}N$	+6.2	$[M-PhCN+H]^+$
219.1047	100.00	$C_{16}H_{13}N$	+0.1	$[M-PhCN]^{+\cdot}$
218.0951	18.90	$C_{16}H_{12}N$	+1.9	$[M-PhCN-H]^+$
217.0912	8.13	$C_{16}H_{11}N$	−2.0	$[M-PhCN-2H]^{+\cdot}$
191.0852	9.61	$C_{15}H_{11}$	+0.9	$[C_3HPh_2]^+$ [a]
117.0581	12.35	C_8H_7N	−0.3	$[C_2H_2NPh]^{+\cdot}$
116.0601	10.24	C_9H_8	+2.5	$[C_3H_2Ph]^{+\cdot}$, [b,c] **16**, (R' = Ph)
115.0547	34.95	C_9H_7	+0.1	$[C_7H_6{-}C{\equiv}CH]^{+\cdot}$ [d]

[a] The deviation (in milli-atomic mass units) represents the difference between observed and calculated values.
[b] Postulated cyclopropenium ion structure.
[c] $[M-2\,PhCN]^{+\cdot}$.
[d] Postulated tropylium ion structure.

EXPERIMENTAL

A DuPont DP-102 EI mass spectrometer coupled with a gas chromatograph equipped with a capillary column was used.

Substituted 4*H*-1,2-diazepines were obtained by treating with hydrazine hydrate either (1) the methanolic solution of the corresponding substituted pyrylium salts or (2) the ethereal solution of the unstable pyrylium pseudo-bases obtained on shaking ice-cool mixtures of water, ethyl ether, pyrylium salt and sodium hydrogen carbonate, and rapidly separating the upper layer.

Procedure (1) affords in good yield compounds **1**, **2** and **4**; if a deuteriated pyrylium salt is used as starting material their deuteriated counterparts can also be obtained.

3,7-Diisopropyl-5-methyl-4*H*-1,2-diazepine (4) was obtained in 90% yield as a pale-yellow liquid with b.p. 110 °C/1.5 Torr.

IR (CCl_4): 3030 w, 2975 vs, 2940 s, 2878 ms, 1635 ms, 1605 m, 1470 s, 1446 s, 1388 ms, 1370 m, 1304 m, 1290 w, 1082 w cm^{-1}.

^1H NMR (C_6D_6): $\delta = 1.17$ (6H, d, Me_2CH, $J = 7$ Hz), 1.27 (6H, d, $\underline{Me}_2CH$, $J = 7$ Hz), 1.40 (1H, d, CH_2, $J = 12$ Hz), 1.80 (3H, d, Me, $J = 1.5$ Hz), 1.93 (1H, d, CH_2, $J = 12$ Hz), 2.55 (1H, septet, $C\underline{H}Me_2$, $J = 7$ Hz), 2.65 (1H, septet, $C\underline{H}Me_2$, $J = 7$ Hz), 5.62 (1H, q, —CH=, $J = 1.5$ Hz).

Procedure (2) was used for compounds **5** and **6** which could not be prepared by procedure (1). The yields were low (approximately 5%); the reactions afforded mixtures which were successfully resolved by gas chromatography. Attempts to produce useful EI mass spectra of deuteriated counterparts of **5** and **6** failed because of partial dedeuteriation of the pyrylium salts in alkaline solution when preparing pseudo-bases.

Incidentally, GCMS detected the pyrazoline derivative **12**, R = Pr^i, R' = Me, i.e. 3-isopropyl-5-methyl-(3-methylbutan-2-one-1-yl)-Δ^2-pyrazoline, obtained in 0.2% yield.

Deuteriations of pyrylium salts were carried out by isotope exchange in D_2O;[3–5] conversions of pyrylium salts or their pseudo-bases into diazepines were performed as described.[1,2,6–8] The initial pyrylium salts were prepared by diacylation of alkenes.[9–12]

Small amounts of the 1*H*-1,2-diazepinic tautomers were detected by ^1H NMR spectroscopy in the 4*H*-1,2-diazepines, in agreement with literature data.[13]

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