# STRUCTURAL STUDIES BY NUCLEAR MAGNETIC RESONANCE—XII

## CONFORMATIONS AND CONFIGURATIONS OF N-METHYLPHENYLHYDRAZONES

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Abstract—Conformations and configurations were assigned to several aldehyde and ketone N-methylphenylhydrazones from analysis of their 60-Mc NMR spectra. Whereas ketone N-methylphenylhydrazones show detectable configurational isomerism about the C----N double bond, aldehyde N-methylphenylhydrazones exist solely as the *syn* isomers. This observation is rationalized in terms of conformational isomerism about the N---N single bond.

Interpretation of the spin-spin coupling constants of aldehyde N-methylphenylhydrazones in terms of rotamers I and II, whereby a single bond eclipses the double bond, leads to the following results: For  $\alpha$ -monosubstituted derivatives when R is Me, Et, i-Pr, or Ph,  $\Delta F_{340}^{\circ}$  for I  $\rightarrow$  II is +60, +300, +600 and +700 cal/mole, respectively. When R is *t*-Bu  $\Delta F_{540}^{\circ}$  is +2,500 cal/mole. For  $\alpha,\alpha$ -disubstituted derivatives when R is Me, Et or i-Pr,  $\Delta F_{540}^{\circ}$  for I  $\rightarrow$  II is +100, +350 and +700 cal/mole, respectively. For cyclohexanecarboxaldehyde N-methylphenylhydrazone  $\Delta F_{540}^{\circ}$  for I  $\rightarrow$  II is +50 cal/mole.

Some stereospecific spin-spin coupling constants between protons separated by five and six bonds are listed and compared with analogous couplings.

THE relative stabilities of I and II were evaluated when Z is methoxy<sup>3</sup> and compared to those of aliphatic aldehydes.<sup>3</sup> We have extended our NMR studies to N-methyl-



phenylhydrazones, Z = N-methylanilino, as part of a program designed to probe further into the nature of the factors influencing rotamer stability and configurational isomerism about C=N double bonds.

#### RESULTS

The chemical shifts, whose accuracy is  $\pm 0.03$  ppm, and the syn|anti ratios of representative N-methylphenylhydrazones are summarized in Table 1. The notation

<sup>&</sup>lt;sup>1</sup> Fellow of the Alfred P. Sloan Foundation.

<sup>&</sup>lt;sup>8</sup>G. J. Karabatsos and N. Hsi, Tetrahedron 23, 1079 (1967).

<sup>&</sup>lt;sup>8</sup> G. J. Karabatsos and N. Hsi, J. Amer. Chem. Soc. 87, 2864 (1965).

R, R, C=NN(Me)Ph         H, R,         H, C(H,         H, C(H,													
H         H         CCI         368         682           H         H         CCI         368         737         737           H         Me         C(I, 3, 30)         731         737         737           H         Me         C(I, 3, 31)         738         737         737           H         Me         C(I, 3, 31)         738         735         737           H         Ei         C(I, 3, 318         758         822         725           H         Ei         C(I, 3, 348         758         832         675         725           H         Neopentyl         C(I, 3, 348         778         892         725         725           H         Neopentyl         C(I, 3, 348         778         738         637         882         675         726           H         Neopentyl         C(I, 3, 348         778         892         726         726           H         Neopentyl         C(I, 3, 348         778         892         726           H         Neopentyl         C(I, 3, 348         778         892         726           Me         Neopentyl         C(I, 3, 358         631         737<	RIRIC RI	=NN(Me)Ph R1	Solvent*	H, cis	H <sub>a</sub> (CH) trans	H <sub>a</sub> (CH <sub>1</sub> ) trans	))"H	CH.)	))¢H <sup>-</sup> ( ;;	CH <sub>a</sub> )	NCH.	% syn <sup>b</sup>  anti	$\Delta F_{\mathbf{m}}^{\circ}(\mathbf{Kcal/mole})$ (syn $\rightarrow ant$ )
H       H       C,H,       (33)       737         H       Me       Nast       341       795       717       717         H       Me       CtL,       311       795       675       717         H       Me       CtL,       310       755       675       725         H       Ne       CtL,       306       755       675       725         H       Neopentyl       CtL,       314       753       675       725         H       Neopentyl       CtL,       314       776       814       822       675       725         H       Neopentyl       CtL,       314       778       812       723       723         H       Neopentyl       CtL,       314       778       823       636       723         H       H       Neopentyl       CtL,       314       7718       813       723       732         H       H       Neopentyl       CtL,       314       7718       823       636       723         H       H       Ne       Natt       CtL,       313       813       723       723         Me       Me <th>H</th> <td>Н</td> <td>ccı</td> <td>3.68</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>6-82</td> <td></td> <td></td>	H	Н	ccı	3.68							6-82		
H         Me         Near         (400)           H         Me         Cd, 314         7.35         8.14         7.35         6.75         17           H         Me         Cd, 316         7.55         8.14         7.35         6.75         17           H         E         Cd, 316         7.55         8.14         7.35         6.75         17           H         Noppentyl         Neat         7.48         7.68         7.22         17.22         17.22           H         Noppentyl         Cd, 3.06         7.78         7.78         8.92         7.22         17.20           H         Noppentyl         Cd, 3.06         7.78         7.78         8.92         7.22         17.20           H         Benzyl         Cd, 3.06         7.78         7.78         7.73         17.30           H         H         Noppentyl         Cd, 3.36         6.34         6.54         17.30         17.30           H         H         Noppentyl         Cd, 3.36         8.33         8.13         7.32         17.30           H         H         Noppentyl         Cd, 3.36         6.34         6.37         7.32         17.30	н	н	C,H,	<b>3-90</b>							7-37		
H         Me         Neat         341 $921$ $717$ $11$ H         Me         C(L_1         311 $795$ $675$ $17$ $11$ H         Me         C(L_1         306 $7.55$ $814$ $882$ $675$ $12$ H         E.         C(L_1         306 $7.53$ $814$ $7.22$ $120$ H         Neopentyl         C(L_1         3.38 $7.78$ $814$ $7.20$ $120$ H         Neopentyl         C(L_1         3.58 $6.34$ $7.78$ $8.92$ $7.30$ H         Benzyl         C(L_1         3.58 $6.34$ $7.78$ $8.85$ $6.82$ H         Benzyl         C(L_1         3.58 $6.34$ $7.79$ $7.20$ $7.72$ H         Benzyl         C(L_1         3.58 $6.34$ $7.72$ $7.22$ H         Benzyl         C(L_1         3.58 $6.37$ $8.73$ $7.90$ $7.72$ Me         Me         No				(4 9 4)									
H         Me         CC(L         3-11         7-95         673         H           H         E         CC(L         3-48         7-55         8-14         7-25         7-25           H         E         CC(L         3-48         7-55         8-14         7-25         7-20           H         Neopentyl         Neat         3-48         7-78         8-92         7-20         17-3           H         Noopentyl         CC(L         3-34         -7-78         8-92         7-20         17-3           H         Noopentyl         CC(L         3-34         -7-78         8-92         7-20         17-3           H         Noopentyl         CC(L         3-34         -7-78         8-92         7-30         17-3           H         Benzyl         CC(L         3-34         -7-78         8-37         8-93         7-37           Me         Me         Noopentyl         CC(L         3-34         7-78         8-93         7-37           Me         Me         No         Second         8-13         8-13         8-93         7-13           Me         Me         Me         Me         No         9-25 <th>H</th> <td>Mc</td> <td>Ncat</td> <td>3.41</td> <td></td> <td></td> <td></td> <td>8·21</td> <td></td> <td></td> <td>7.17</td> <td>100/0</td> <td></td>	H	Mc	Ncat	3.41				8·21			7.17	100/0	
H         Me         C,H,         3-48         7-25         11           H         E         C,C,         3-06         7-55         8-14         7-25         11           H         E         C,C,         3-06         7-55         8-14         7-25         11           H         Noopennyl         C,H,         3-48         7-76         8-92         7-22         11           H         Noopennyl         C,H,         3-48         7-78         8-92         7-20         11           H         Noopennyl         C,H,         3-48         7-78         8-92         7-30         17           H         Noopennyl         C,L,         3-30         6-34         7-78         8-93         7-30         17           H         H         Encyl         C,L,         3-37         6-34         7-30         7-30         17           H         H-Pr         C,C,L,         3-37         6-31         7-31         8-92         7-32         19           Me         Me         Nat         Nat         Nat         8-13         8-13         8-92         7-32         10           Me         Me         Nat	H	Mc	ไว้ว	3-11				7-95			6-75	100/0	
H         Ei         CCl, 306         755         882         675         11           H         Ei         CCl, 314         768         768         720         173           H         Noopennyl         CLL, 314         778         720         173           H         Noopennyl         CL, 314         778         720         173           H         Noopennyl         CL, 314         778         730         682         730           H         Noopennyl         CL, 313         778         778         733         733           H         Benzyl         CCL, 313         637         637         739         682         730           H         H         Noopennyl         CLL, 313         733         813         737         737           Me         Me         Net         CCL, 313         813         813         772         705           Me         Me         Net         Net         737         893         703         703           Me         Me         CCL, 313         713         813         873         703         703           Me         Me         Net         Noopennyl	H	Mc	C.H.	3.48				8·14			7-25	100/0	
H         Ei         C,H,         3-38         7-68         8-92         7-22         11           H         Neopentyl         Neat         3-48         7-78         7-30         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-30         1-34         7-31         1-36         1-37         1-36         1-37         1-36         1-37         1-36         1-37 <th>H</th> <td>ŭ</td> <td>้บิว</td> <td>3.06</td> <td></td> <td>7-55</td> <td></td> <td></td> <td></td> <td>8·82</td> <td>6-75</td> <td>100/0</td> <td></td>	H	ŭ	้บิว	3.06		7-55				8·82	6-75	100/0	
H         Neopenryl         Near         348         786         720         1           H         Neopenryl         CCI         334         -778         684         1           H         Neopenryl         CCI         334         -778         673         1           H         Neopenryl         CCI         334         778         730         684         1           H         Benzyl         CCI         355         637         537         537         537         1           H         Benzyl         CCI         3-35         6-34         672         1         737         1           H         H         Senzyl         CCI         3-37         5-37         5-37         5-37         1	н	Ē	C,H,	3-38		7.68				8·92	7-22	100/0	
H       Neopentyl       CCI,       3.34       -7.78       7.30       6.84       1         H       Neopentyl       C,H       3.48       7.78       7.30       6.82       1         H       Neopentyl       C,H       3.34       7.78       7.78       7.30       6.82       1         H       Benzyl       C,CI,       3.37       6.37       6.37       7.30       6.82       1         H       H       Penzyl       C,CI,       3.37       6.37       6.37       7.30       17         Me       Me       Neat       C,CI,       3.37       6.37       8.13       8.13       7.22       17         Me       Me       Neat       8.13       8.13       8.93       7.05       7.17         Me       Me       Neopentyl       C,L,       7.11       8.07       7.05       7.16         Me       Noopentyl       C,L,       7.35       8.13       7.97       8.99       7.05         Me       Noopentyl       C,L,       7.71       8.07       7.02       7.16       7.10         Me       Noopentyl       C,H,       7.87       8.97       8.97       7.00	H	Neopentyl	Ncat	3.48		7.86					7-20	100/0	
H         Noopenityl         CH         3-48         7-78         7-30         H           H         Benzyl         CCI         3-30         6-34         6-34         6-82         173         7-37         7-37         7-37         173         174	H	Neopentyl	cci,	3-34		-7.78					6-84	100/0	
H         Benzyl         CCI         3.20         6.34         6.37         7.37         6.82         11           H         Benzyl         CCI         3.35         6.37         6.37         7.37         11         6.82         7.37         11         11         7.37         11         11         7.37         11         11         8.83         6.86         11         7.32         11         11         8.92         7.32         11         11         11         11         8.92         7.32         11         11         7.22         11	H	Neopentyl	C,H,	3.48		7.78					7-30	100/0	
H         Benzyl         C,H         3-55         6-37         7-37         11           H         i-Pr         CC(L         3-37         6-37         8-85         6-86         11           H         i-Pr         CC(L         3-37         8-13         8-13         8-92         7-32         11           Me         Me         Ne         Ne         Ne         S-93         8-13         7-97         7-05           Me         Me         C(L         3-58         8-13         7-97         8-92         7-32         11           Me         Me         C(L         7-56         8-13         7-97         7-05         7-05           Me         Et         C(L         7-11         8-13         7-93         8-92         7-16           Me         Noopentyl         C(L         7-11         8-07         7-93         8-17         7-16           Me         Noopentyl         C(L         7-13         8-13         7-93         7-16           Me         Noopentyl         C(L         7-35         8-17         7-93         7-16           Me         Propentyl         C(L         7-35         8-17	H	Benzyl	cci	3-20		6.34					6·82	100/0	
H       i-Pr       CCI,       3-37       8-85       6-86       19         H       i-Pr       C,H,       3-58       8-35       8-92       7-32       19         Me       Me       Me       Neat       8-35       8-33       8-13       7-22       7-32       17         Me       Me       CCL,       3-58       8-13       8-13       7-97       7-05         Me       Me       CCL,       7-64       8-13       7-93       8-92       7-17         Me       Et       CCL,       7-64       8-13       7-93       8-92       7-16         Me       Noopentyl       C,CL,       7-71       8-07       9-27       8-93       7-16         Me       Noopentyl       C,CL,       7-71       8-07       70       7-16         Me       Noopentyl       C,H,       7-73       8-17       9-27       8-93       7-16         Me       Benzyl       Neat       7-73       8-17       9-27       8-93       7-16         Me       Benzyl       Neat       7-35       8-17       8-17       9-25       8-93       7-16         Me       H       7-18	H	Benzyl	C.H.	3.55		6.37					7-37	0/001	
H         i-Pr         C,H <sub>4</sub> 3-58         8-33         8-13         8-13         7-32         19           Me         Me         Me         C,H <sub>4</sub> 3-58         8-13         8-13         8-13         7-37         7-05           Me         Me         C,Cl <sub>4</sub> Neat         8-42         8-33         8-13         7-93         8-93         7-17         7-05           Me         Ei         C,Cl <sub>4</sub> 7-11         8-13         7-93         8-93         7-03         7-17           Me         Ei         C,Cl <sub>4</sub> 7-11         8-07         7-93         8-13         9-27         8-93         7-16           Me         Noopentyl         C,Cl <sub>4</sub> 7-11         8-07         7-93         8-17         9-27         8-93         7-16           Me         Noopentyl         C,Cl <sub>4</sub> 7-35         8-17         8-17         8-13         9-27         8-93         7-16           Me         Noopentyl         C,Cl <sub>4</sub> 7-35         8-17         8-17         9-27         8-93         7-16           Me         Noopentyl         C,Cl <sub>4</sub> 7-35         8-17         8-17         9-27	H	, Pr	cci	3-37						8.85	6.86	100/0	
Me         T22         T22           Me         Me         CCL4         Near         CCL4         8-15         7-97         7-05         7-17           Me         Et         CCL4         7-64         8-13         7-93         8-99         8-80         7-02           Me         Et         CCL4         7-71         8-07         7-93         8-99         8-80         7-02           Me         Neopentyl         CCL4         7-71         8-07         7-87         8-95         7-16         7-17           Me         Neopentyl         CCL4         7-71         8-07         7-87         8-99         8-80         7-02           Me         Neopentyl         CCL4         7-31         8-17         8-00         9-02*         9-15*         7-10           Me         i-Pr         CCL4         7-35         8-17         8-17         8-17         7-15           Me         i-Pr         CCL4         7-35         8-17         8-17         9-25         8-13         7-15           Me	Η	-Pr	C.H.	3.58						8-92	7-32	0/001	
Mc         Me         Me         CCL         8:15         7:97         7:05           Me         Et         CCL         8:13         7:93         8:99         8:80         7:02           Me         Et         CCL         7:13         8:42         8:13         9:27         8:95         7:16           Me         Et         CCL         7:71         8:07         7:87         8:95         7:16         7:02           Me         Neopentyl         CCL         7:71         8:07         7:87         8:95         7:16         7:10           Me         Neopentyl         CCL         7:71         8:07         7:87         8:95         7:16         7:10           Me         Neopentyl         CCL         7:71         8:07         7:87         8:95         7:16           Me         Neopentyl         CCL         7:33         8:17         8:00         9:02*         9:13*         7:10           Me         i-Pr         CCL         7:35         8:17         8:07         9:25         8:93         7:13           Me         i-Pr         CCL         7:35         8:17         8:00         9:02         9:13* <th< td=""><th>Mc</th><td>Mc</td><td>Neat</td><td></td><td></td><td></td><td>8-33</td><td>8·13</td><td></td><td></td><td>7-22</td><td></td><td></td></th<>	Mc	Mc	Neat				8-33	8·13			7-22		
Me         Me         Me         C, Ha         8-42         8-20         7-17           Me         Et         CCla         7-64         8-13         7-93         8-99         8-80         7-02           Me         Et         CCla         7-71         8-07         7-81         8-13         9-27         8-95         7-16         702           Me         Neopentyl         CCla         7-71         8-07         7-87         8-95         7-16         702           Me         Neopentyl         CCla         7-71         8-07         7-87         8-90         8-00         7-02           Me         Neopentyl         CCla         7-35         8-37         8-17         8-00         9-02*         9-15*         7-10           Me         I+Pr         CCla         7-35         8-17         8-00         9-02*         9-15*         7-10           Me         I+Pr         CCla         7-35         8-17         8-17         8-17         7-10           Me         I+Pr         CCla         7-35         8-17         8-17         9-25         8-93         7-15           Me         I+Bu         CCla         7-35	Mc	Me	ขึ้				8·15	7.97			7-05		
Me         Et         CCI,         7-64         8-13         7-93         8-99         8-80         702           Me         Et         C,H,         7-85         8-13         9-27         8-95         7-16         702           Me         Noopentyl         C,L,         7-71         8-07         7-87         8-95         9-03*         7-00           Me         Noopentyl         C,L,         7-71         8-07         7-87         8-90         9-03*         7-10           Me         Noopentyl         C,L,         7-82         8-27         8-00         9-02*         9-15*         7-10           Me         Benzyl         Neat         6-45         8-17         8-00         9-02*         9-15*         7-10           Me         i-Pr         C,L,         7-35         8-17         8-17         9-25         8-17         7-10           Me         i-Pr         C,L,         7-35         8-17         8-17         9-25         8-93         7-15           Me         i-Bu         C,L,         7-35         8-17         8-30         7-35         8-37         7-15           Me         Bu         C,L,         7-35	Mc	Mc	C.H.				8.42	8·20			7.17		
Me         Et         C <sub>4</sub> H         7.85         8:38         8:13         9:27         8:95         7:16           Me         Noopentyl         CCL         7.71         8:07         7:87         8:95         9:03         7:00           Me         Noopentyl         CCL         7.71         8:07         7:87         8:95         9:03         7:00           Me         Noopentyl         CCL         7.72         8:27         8:00         9:02         9:15         7:10           Me         Benzyl         Neat         6:45         8:37         8:17         8:00         9:02         7:10           Me         i-Pr         CCL4         7:35         8:17         8:00         9:00         8:27         7:10           Me         i-Pr         CCL4         7:35         8:17         8:00         9:00         8:93         7:15           Me         i-Bu         CCL4         7:35         8:17         8:27         8:37         7:15           Me         i-Bu         CCL4         7:35         8:17         9:28         7:39           Me         t-Bu         CCL4         7:35         8:17         9:23         8:87	Me	Ē	ี้ยี			7-64	8·13	7-93	8 8	8·80	7·02	86/14	+1·2
Me         Noopentyl         CCl         7-71         8-07         7-87         8-95 <sup>4</sup> 9-03 <sup>4</sup> 7-00           Me         Neopentyl         C,Ha         7-82         8-27         8-00         9-02 <sup>4</sup> 9-15 <sup>4</sup> 7-16           Me         Benzyl         Neat         6-45         8-37         8-17         9-02 <sup>4</sup> 9-15 <sup>4</sup> 7-16           Me         Benzyl         Neat         6-45         8-37         8-17         9-02 <sup>4</sup> 9-15 <sup>4</sup> 7-16           Me         i-Pr         CCl <sub>4</sub> 7-35         8-17         8-00         9-00         8-82         7-02           Me         i-Pr         CCl <sub>4</sub> 7-35         8-17         8-17         9-25         8-37         7-15           Me         t-Bu         CCl <sub>4</sub> 7-52         8-37         8-17         9-25         8-37         7-15           Me         t-Bu         CCl <sub>4</sub> 7-52         8-15         8-17         9-25         8-37         7-15           Me         t-Bu         CCl <sub>4</sub> 7-52         8-15         8-37         8-37         7-15           Me         Ph         CCl <sub>4</sub> <td< td=""><th>Me</th><td>ŭ</td><td>C.H.</td><td></td><td></td><td>7.85</td><td>8.38</td><td>8·13</td><td>9-27</td><td>8-95</td><td>7.16</td><td>86/14</td><td>+1·2</td></td<>	Me	ŭ	C.H.			7.85	8.38	8·13	9-27	8-95	7.16	86/14	+1·2
Me         Noopentyl         C <sub>4</sub> H         7:82         8:27         8:00         9:02"         9:15"         7:15           Me         Benzyl         Neat         6:45         8:37         8:17         7:00         7:10         7:10           Me         Penzyl         Neat         6:45         8:37         8:17         9:00         9:02"         9:16'         7:10         7           Me         i-Pr         CCL4         7:35         8:17         8:00         9:00         8:82         7:02           Me         i-Pr         CCL4         7:52         8:37         8:17         9:25         8:93         7:15           Me         t-Bu         CCL4         7:52         8:15         8:17         9:25         8:87         7:20         11           Me         Ph         CCL4         7:52         8:15         8:17         9:25         8:87         7:20         11           Me         Ph         CCL4         7:52         8:15         8:37         8:17         9:25         8:87         7:20         11           Me         Ph         CCL4         8:93         7:64         8:32         6:82         10	Me	Neopentyl	CC			7-71	8-07	7-87	8-954	9-034	7-00	93/7	+1.7
Me         Benzyl         Neat         6-45         8-37         8-17         7-10         7           Me         i-Pr         CCl4         7.35         (6-88)*         8-17         8-00         9-00         8-82         7-02           Me         i-Pr         CCl4         7.35         8-17         8-00         9-00         8-82         7-02           Me         i-Pr         Ccl4         7-52         8-37         8-17         9-25         8-93         7-15           Me         t-Bu         CCl4         7-52         8-15         8-17         9-25         8-93         7-15           Me         t-Bu         CCl4         7-52         8-15         8-17         9-25         8-80         7-02           Me         Ph         CCl4         7-52         8-15         8-17         9-26         19           Me         Ph         CCl4         7-52         8-15         8-32         7-02         11           Me         Ph         CCl4         7-52         8-15         7-64         6-82         11           Me         Ph         CCl4         8-30         7-64         6-82         1 <t< td=""><th>Жc</th><td>Neopentyl</td><td>CH,</td><td></td><td></td><td>7.82</td><td>8.27</td><td>8 8</td><td>9-024</td><td>9-154</td><td>7-15</td><td>93/7</td><td>+1-7</td></t<>	Жc	Neopentyl	CH,			7.82	8.27	8 8	9-024	9-154	7-15	93/7	+1-7
Mc         i-Pr         CCl <sub>4</sub> 7.35         (6.88)*         (7.16)*         (7.16)*           Mc         i-Pr         CCl <sub>4</sub> 7.35         8.17         8.00         9.00         8.82         7.02           Mc         i-Pr         C, H <sub>4</sub> 7.52         8.37         8.17         9.25         8.93         7.15           Mc         t-Bu         CCl <sub>4</sub> 7.52         8.15         8.17         9.25         8.93         7.15           Me         t-Bu         CCl <sub>4</sub> 7.52         8.15         8.17         9.25         8.93         7.08         10           Me         Ph         CCl <sub>4</sub> 7.52         8.15         8.87         7.20         11           Mc         Ph         CCl <sub>4</sub> 7.64         8.32         1.652         1           Mc         Ph         CCl <sub>4</sub> 7.64         8.32         1.02         1           Mc         Ph         CCl <sub>4</sub> 7.50         1         1         1         1           Mc         Ph         CCl <sub>4</sub> 7.04         8.32         1         6.82         1           Mc         Ph         CCl <sub>4</sub>	Mc	Benzyl	Ncat			6.45	8·37	8.17			7.10	80/20	+ 0-93
Mc         i-Pr         CCl <sub>4</sub> 7.35         8-17         8-00         9-00         8-82         7-02           Mc         i-Pr         C <sub>4</sub> H <sub>4</sub> 7.52         8-37         8-17         9-25         8-93         7-15           Mc         t-Bu         CCL <sub>4</sub> 7-52         8-37         8-17         9-25         8-93         7-15           Mc         t-Bu         CCL <sub>4</sub> 7-52         8-15         8-17         9-25         8-93         7-15           Me         t-Bu         CCL <sub>4</sub> 7-52         8-15         8-17         9-25         8-80         7-08         10           Mc         Ph         CCL <sub>4</sub> 7-52         8-12         7-20         11           Mc         Ph         CCL <sub>4</sub> 7-64         8-32         6-82         1           About 10% (v/v) concentrations. * Syn is the isomer having R <sub>1</sub> cir to N-methylamilino group. * Resonance of theresonance of the cir-CH <sub>4</sub> groups of the other compounds listed could not be catablished.						(6-88)*					(1-16)		
Me     i-Pr     C <sub>4</sub> H <sub>4</sub> 7.52     8.37     8.17     9.25     8.93     7.15       Me     t-Bu     CCL <sub>4</sub> 7.52     8.15     8.17     9.25     8.93     7.15       Me     t-Bu     CCL <sub>4</sub> 7.52     8.15     8.17     9.25     8.80     7.08     10       Me     t-Bu     CCL <sub>4</sub> 8.32     8.32     8.87     7.20     11       Me     Ph     CCL <sub>4</sub> 7.64     6.82     1       • About 10% (v/v) concentrations. • Syn is the isomer having R <sub>1</sub> cir to N-methylamilino group. • Resonance of trans     6.82     1       • Resonance of cir-CH <sub>4</sub> . The resonance of the cir-CH <sub>4</sub> groups of the other compounds listed could not be established.	Mc	Ŀ Ŀ	ไวว		7-35		8.17	8-00	86	8-82	7-02	94/6	+1.8
Me     t-Bu     CCl <sub>4</sub> 8·15     8·80     7·08     1       Me     t-Bu     C,H <sub>4</sub> 8·32     8·87     7·20     1       Me     Ph     CCl <sub>4</sub> 8·32     8·87     7·20     1       Me     Ph     CCl <sub>4</sub> 8·32     8·87     7·20     1       Me     Ph     CCl <sub>4</sub> 8·32     8·87     7·20     1       • About 10% (v/v) concentrations. • Syn is the isomer having R <sub>1</sub> cir to N-methylamilino group. • Resonance of trans     • Resonance of the cir-CH <sub>6</sub> groups of the other compounds listed could not be established.	Mc	i-Pr	C,H,		7-52		8-37	8·17	9-25	8-93	7-15	94/6	+1.8
Me       t-Bu       C <sub>4</sub> 8.32       8.87       7.20       10         Mc       Ph       CCl <sub>4</sub> 7.64       6.82       11         • About 10% (v/v) concentrations. • Syn is the isomer having R <sub>1</sub> cir to N-methylamilino group. • Resonance of trans       • Resonance of the cir-CH <sub>4</sub> groups of the other compounds listed could not be established.	Mc	t-Bu	้บ้ว				8·15			8:80 8	7-08	100/0	
Me Ph CCI <sub>4</sub> 6-82 1/ • About 10% (v/v) concentrations. • Syn is the isomer having R <sub>1</sub> cis to N-methylamilino group. • Resonance of trans Resonance of cir-CHa. The resonance of the cir-CHa groups of the other compounds listed could not be established.	Me	t-Bu	C,H,				8-32			8·87	7.20	100/0	
• About 10% (v/v) concentrations. • Syn is the isomer having R <sub>1</sub> cis to N-methylamilino group. • Resonance of trans Resonance of cis-CHa. The resonance of the cis-CHa groups of the other compounds listed could not be established.	Mc	£	CCI				7.64				6·82	100/0	
• Reconsider of cively concentrations. Symils the resoluted having Ar the to twinter partial group. Account of the transition of the other compounds listed could not be established.		100/ /1/10			maai ada a	- having	N ci io	aludame	nilino aec	. D.	Ponence of	Proventi 6	aconstra of theread
	POA -	ut 10% (V/V) ( ve of circ(H.	Concentrations The recorder		is the isome	T DUNNED T		mpounds	listed o	oup. The	be establish	thed. 'Reso	nance of NCH. clift
	VCMM					orn to solno		mmodim					

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used to distinguish the various protons is shown in III, each proton being referred to as cis or trans



with respect to the N-methylanilino group. Assignment of peaks to syn and anti isomers is based on previously presented arguments.<sup>4</sup> The syn|anti ratios were determined by integration of peak areas and are accurate to  $\pm 5\%$ .

The absence of detectable configurational isomerism, even after heating or acid treatment, about the C==N double bond of all aldehyde N-methylphenylhydrazones is the most notable feature of the data. We have assigned the *syn* configuration to these isomers for reasons that will be discussed later.

Figures 1 and 2 show the effect of dilution on the chemical shifts of representative N-methylphenylhydrazones. Whereas dilution with benzene shifts the N-methyl proton resonance of acetaldehyde and other aldehyde N-methylphenylhydrazones upfield, it shifts the corresponding resonance of acetone and other ketone N-methylphenylhydrazones downfield.

The UV spectra in Table 2 show additional differences between aldehyde and ketone N-methylphenylhydrazones. Whereas the maximum absorption of the aldehyde derivatives occurs about 278 m $\mu$ , that of the ketone derivatives occurs lower and is similar to those of 1-methyl-1-phenylhydrazine and N,N-dimethylaniline.

In Table 3 we have summarized the spin-spin coupling constants between various nuclei, whose notation appears in IV and V.



The proton-<sup>13</sup>C coupling constants,  $J_{1-1^{10}C}$ , whose accuracy is  $\pm 2 \text{ c/s}$ , were determined from natural abundance spectra and are typical couplings involving sp<sup>3</sup>-hybridized carbon atoms. In accord with previously reported<sup>8</sup> J<sub>HH</sub> values of CH<sub>3</sub>=N-systems J<sub>11</sub> is unusually large.<sup>6</sup>

Another difference between aldehyde and ketone N-methylphenylhydrazones is manifested in  $J_{23}$ . The former have finite  $J_{23}$  values, whose trend is opposite to that of  $J_{12}$ , the latter zero. The  $J_{12}$ , with accuracy of  $\pm 0.05$  c/s, is the coupling pertinent to the problem of rotational isomerism about the single bonds joining the sp<sup>2</sup> to the sp<sup>3</sup> hybridized carbon atoms. In Table 4 we have summarized the effect of temperature on a few of these constants. Their overall correspondence to the analogous couplings of aldehydes<sup>3</sup> and syn, but not anti, isomers of oxime O-methyl ethers<sup>2</sup> is one indication

<sup>8</sup> B. L. Shapiro, S. J. Ebersole, G. J. Karabatsos, F. M. Vane and S. L. Manatt, J. Amer. Chem. Soc. 85, 4041 (1963).

<sup>4</sup> G. J. Karabatsos, R. A. Taller and F. M. Vane, J. Amer. Chem. Soc. 85, 2326 (1963).

<sup>\*</sup> For an explanation see J. A. Pople and A. A. Bothner-By, J. Chem. Phys. 42, 1339 (1965).



that we have correctly assigned the *syn* configuration to the aldehyde N-methylphenylhydrazone isomers.

#### DISCUSSION

Rotational isomerism. Making the reasonable assumption<sup>3.3</sup> that I and II are the stable rotamers of aldehyde N-methylphenylhydrazones, the relative populations of VI and VII are related to  $J_{obs.}$  by Eq. (1), where p is the fractional population of VI, (l-p) that of VII,  $J_t$  is the *trans* coupling, and  $J_g$  is

$$\mathbf{J}_{obs} = \mathbf{p}(\mathbf{J}_t + \mathbf{J}_g)/2 + (1 - \mathbf{p})\mathbf{J}_g \tag{1}$$

$$\mathbf{J}_{obs} = \mathbf{p}\mathbf{J}_{t} + (1 - \mathbf{p})\mathbf{J}_{g}$$
<sup>(2)</sup>



					Pia	itcau <sup>4</sup>
R,R,C	-NN(Me)Ph	Solvent	$\lambda_{max}(m\mu)$	$\varepsilon  imes 10^4$	Amax	e × 10 <sup>2</sup>
R <sub>1</sub>	R,					
н	Мс	95% EtOH	278	1.84		
н	Mc	cyclohex.	277	1.31		
н	Et	95% EtOH	278	1.84		
н	Et	cyclohex.	277	1.40		
н	n-Pr	95% EtOH	279	2.23		
н	3-Pentyl	95% EtOH	279	2.21		
Mc	Me	95% EtOH	250	0.95	~288	~3.0
Me	Mc	cyclohex.	249	0.59	~280	~1.0
Me	Et	95% EtOH	250	1.03	~277	~3.5
Mc	Et	cyclohex.	250	0.45		
PhN(M	e)NH	95% EtOH	247	1.0		
PhN(M	c),	95% EtOH	251	1-5		

TABLE	2.	UV	SPECTRA	OF	N-METHYLPHENYLHYDRAZONES
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• In addition to the main peak at 250 m $\mu$  the ketone derivatives show this broad and flat shoulder.

R <sub>1</sub> R	C=NN(CH <sub>2</sub> )C <sub>4</sub> H <sub>6</sub>	J <sub>11</sub> ,	Jis	J <sub>18</sub>	J <sub>1/1</sub>	J	J <sub>1'3</sub>	J <sub>113</sub> c
R <sub>1</sub>	R <sub>s</sub>							
н	н	12.0		0.80*	<0.4.,			
н	Me		5.06	0.77		0.40		162
н	Et		4.76	0.76		~0.4		154
н	n-Pr		5.10	0.66		~04		157
Н	i-Bu		5-33	0.70		0.3		156
н	Neopentyl		5-98	0.76		<0.5		
н	Benzyl		5-40	0.79		0-3		
н	i-Pr		4.60	0.80		0-3		156
н	sec-Bu		5-24	0.71		~0·2		153
н	3-Pentyl		5-91	0-67		<01		155
н	CH(Et)(CH <sub>1</sub> ),Me		5.97	0.70		<01		
н	CH(CHMe_)		6.39	0-71		<01		
н	$\square$		4-48	0.72		<0.5		158
Me	Me					0¢	0	
Mc	Et					0	0	
Mc	Neopentyl					0	0	
Me	i-Pr					0	0	
Me	t-Bu						0	
Et	Et					0	0	

TABLE 3. SPIN-SPIN COUPLING CONSTANTS (C/S) OF NEAT N-METHYLPHENYLHYDRAZONES

• Values from 10% CCl<sub>4</sub> sol. • Estimated from the half-width, about 1.8 c/s, of H(1'). • All values reported as zero are estimated from the half-widths of the appropriate H(2), H(2') and H(3). These half-widths are about 0.5 c/s, as compared with a 0.4 c/s half-width of the TMS signal.

R <sub>1</sub> R <sub>2</sub> CH <sub>2</sub> CH	r=NN(Me)Ph		J <sub>E_x</sub> i	r,(c/s)•	
R1	R,	0°	36°	65°	95°
н	н	5.06	<b>5·0</b> 6	5-10	5.08
н	Me	4.78	4.76	4.71	
н	t-Bu		5.98	5-90	5.60
Et	Et		5-91	5.83	5-60
$\langle$	$\supset$		4-41		4.43

TABLE 4. EFFECT OF TEMPERATURE ON  $J_{E_{\alpha}E_{1}}(J_{1s})$  of some N-methylphenylhydrazones

• These values, accurate to  $\pm 0.05$  c/s, are from neat solns.

the gauche. Equation (2) relates the populations of VIII and IX to  $J_{obs}$ , where p is



the fractional population of VIII and (1 - p) that of IX. The free energy differences for VI<sub>a</sub>  $\rightarrow$  VII and VIII  $\rightarrow$  IX<sub>a</sub> are expressed by Eqs. (3) and (4), respectively.

$$\Delta \mathbf{F}^{\bullet}_{\mathbf{VI}_{\mathbf{a}} \rightarrow \mathbf{VII}} = -\mathbf{RT} \ln \left( \mathbf{J}_{\mathbf{t}} + \mathbf{J}_{\mathbf{g}} - 2\mathbf{J}_{\mathbf{obs}} \right) / (\mathbf{J}_{\mathbf{obs}} - \mathbf{J}_{\mathbf{g}})$$
(3)

 $\Delta \mathbf{F}^*_{\text{VIII} \rightarrow 1 \mathbf{X}_s} = -\mathbf{R} \mathbf{T} \ln \frac{1}{2} (\mathbf{J}_t - \mathbf{J}_{\text{obs.}}) / (\mathbf{J}_{\text{obs.}} - \mathbf{J}_{\text{f}})$ (4)

The  $J_i$  and  $J_g$  needed for calculation of p and  $\Delta F^\circ$  can be calculated from Eqs. (5) and (6), by assuming that

$$J_{obs.}$$
 (acetaldehyde deriv.) =  $\frac{1}{3}(J_t + 2J_g)$  (5)

$$J_{obs.}$$
 (t-butylacetaldehyde deriv.) =  $\frac{1}{2}(J_t + J_s)$  (6)

t-butylacetaldehyde N-methylphenylhydrazone exists exclusively in VI. In view of our previous results<sup>3.3</sup> such an assumption is reasonable. As mentioned,<sup>3.3</sup> however, an error would be introduced in p and  $\Delta F^{\circ}$ , because of the incorrect assumption that J<sub>t</sub> and J<sub>g</sub> are independent of the  $\alpha$ -carbon substituents. This error can be diminished by applying a 0.4 c/s correction for each alkyl or aryl  $\alpha$ -substituent, i.e. by increasing J<sub>obs</sub>. of each monosubstituted derivative by 0.4 c/s and of each disubstituted by 0.8 c/s.<sup>7</sup> We have thus calculated J<sub>t</sub> = 10.3 c/s, J<sub>g</sub> = 2.4 c/s, and the p and  $\Delta F^{\circ}$  values reported in Table 5. For reasons previously discussed<sup>2.3</sup> the  $\Delta F^{\circ}$  values are probably reliable to  $\pm 30\%$ .

Since  $\Delta H^{\circ}$  and  $\Delta F_{36}^{\circ}$  values between I and II are comparable in magnitude,<sup>2.3</sup> it is interesting to compare now the relative stabilities of I and II as a function of Z. Although any firm conclusions at this stage will be premature and must await further experimentation, apparently increase in the electronegativity of Z decreases the ratio

<sup>&</sup>lt;sup>\*</sup> The correctness of our choice of 0.4 c/s is supported further by the temperature variation of J<sub>obs</sub>, of propionaldehyde and cyclopropanecarboxaldehyde N-methylphenylhydrazones (Table 4).

		N(Mc)Ph N at 36° H	
R₁R₅CH	CH—NN(Me)Ph	ж / <sup>-</sup> н	$\Delta F_{se}^{\circ} \text{ for } VI_{e} \rightarrow VII$ (cal/mole)
R <sub>1</sub>	R,		
н	Me	69	+60
Н	Et	78	+ 300
н	i-Pr	84	+ 600
н	Ph	86	+700
н	t-Bu	99*	+2,500*
			$\Delta F_{ab}$ ° for VIII $\rightarrow IX_{ab}$
Mc	Mc	38	+100
Et	Et	46	+ 350
i-Pr	i-Pr	59	+700
		35	+ 50

TABLE 5. ROTAMER POPULATIONS AND  $\Delta F^{\circ}$  values of n-methylphenylhydrazones

Values at 65°.

II |I. For example, whereas  $\Delta F_{36}^{\circ}$  for I  $\rightarrow$  II of propionaldehyde oxime O-methyl ether is about +300 cal/mole, the corresponding value of propionaldehyde N-methyl-phenylhydrazone is only +60 cal/mole.

Conformations of the N-methylanilino group. The absence of detectable configurational isomerism about the C—N double bond of the aldehyde, but not of the ketone, N-methylphenylhydrazones may be rationalized in terms of rotational isomerism about the N—N single bond. For example, whereas in isomer X the unshared electron pair orbital on the anilino nitrogen is parallel to and overlaps with the  $\pi$ -orbitals



of the C=N double bond, in isomer XI, as a result of nonbonded repulsions between R and N-methylanilino, it would be orthogonal to the  $\pi$ -orbitals. The ensuing loss of resonance stabilization in IX might therefore be responsible for the presence of

only X isomers. In contrast to the aldehyde N-methylphenylhydrazone isomers, both isomers of the ketone N-methylphenylhydrazones would suffer loss of overlap (XII and XIII), and their relative stabilities would therefore be primarily a function of the nonbonded interactions between  $R_1$ ,  $R_2$  and N-methylanilino. The correctness of this explanation is supported by the following:

(a) UV Spectra. Conformations XII and XIII require that the ultraviolet spectra of ketone N-methylhydrazones be similar to those of N,N-disubstituted anilines. Indeed, their 250 m $\mu$  maximum absorption is similar to the 247 m $\mu$  absorption of 1-methyl-1-phenylhydrazine and to the 251 m $\mu$  absorption of N,N-dimethylaniline. In contrast, the  $\lambda_{max}$  of X should be bathochromically shifted, as is the case, on account of conjugation between the carbon-nitrogen double bond and the N-anilino group.

(b) Solvent effects on chemical shifts. Orientation of benzene by interaction with the C=N double bond (XIV) is a common and important feature of compounds having C==N double bonds. In the present case, judging by the larger upfield shift



of the trans- $\alpha$ -methyl over the cis- $\alpha$ -methyl protons (Fig. 1) on dilution with benzene, the benzene is probably closer to  $R_1$  than  $R_1$ .

If our assumptions on the conformations of the N-methylanilino groups are correct, then, on the basis of XV and XVI, the N-methyl protons of the aldehyde N-methylhydrazones should be shifted upfield on dilution with benzene, whereas the corresponding protons of the ketone N-methylphenylhydrazones should be shifted downfield. The results (Fig. 2) cogently support this argument.



Long range couplings. Like all long range spin-spin couplings<sup>8</sup> the five bond,  $J_{13}$  and  $J_{1'8}$ , and six bond,  $J_{28}$  and  $J_{23'}$ , couplings observed in the present work are stereospecific. As might have been anticipated, the stereochemical dependence of the five bond coupling (XVII) is similar to that of the analogous four bond (XVIII).<sup>9</sup>

\* For a review on long range coupling see S. Sternhell, Revs. Pure Appl. Chem. 14, 15 (1964).

<sup>\*</sup> G. J. Karabatsos, B. L. Shapiro, F. M. Vane, J. S. Fleming and J. S. Ratka, J. Amer. Chem. Soc. 85, 2784 (1963).



The stereospecificity of the six bond coupling,  $J_{23}$ , is borne out by its decrease on increase of the populations of VI and VIII. Disregarding the sign of the coupling,  $J_{B-CH_{2}}$  is therefore greater than  $J_{A-CH_{2}}$  (XIX). A similar trend was observed<sup>10</sup> with



the four bond coupling (XX) involving A, B and C. The further dependence of  $J_{33}$  on the conformation of the N-methylanilino group is summarized under XXI.



#### **EXPERIMENTAL**

Preparation of N-methylphenylhydrazones. To 0.05 mole 1-methyl-1-phenylhydrazine in 10 mt water, after addition of sufficient glacial AcOH to dissolve the hydrazine, was added dropwise 0.05 moles of the appropriate aldehyde or ketone. After stirring the mixture for 30 min at room temp, the organic layer was separated, dried over  $K_sCO_s$ , and fractionated under reduced press. All products were oils. Di-t-butylacetaldehyde did not form the corresponding N-methylphenyl-hydrazone even under reflux conditions.

NMR spectra were determined at 60-Mc on a Model A-60 spectrometer (Varian Associates, Palo Alto, Calif.). Undegassed sol were used with TMS as internal reference.

UV spectra were taken at 25° with a Beckman D.B. spectrophotometer.

Acknowledgment—We thank the United States Atomic Energy Commission for financial support, Grant COO-1189-17.

<sup>10</sup> A. A. Bothner-By, C. Naar-Colin and H. Günther, J. Amer. Chem. Soc. 84, 2748 (1962).

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