were removed from the mixture, quenched with methanol, and analyzed by vpc to determine the extent of reaction. The reaction material was then cooled and decomposed with 3 ml of methanol. Analysis was made on this material by vpc or on the hydrogenated products obtained over a 10% palladium/charcoal catalyst.

Reaction Products.—The liquid, cyclized reaction products that were isolated from the general reactions described above were separated from one another by means of preparative vpc. When separation of product from starting material was impossible because of identical relative retention times, *e.g.*, **3** and **9** or **4** and **11** (Table II), the reaction mixture was first hydrogenated and separations were then performed. All products were shown to be of greater than 95% purity by vpc. The products were identified by means of nmr and ir spectral analyses. It is possible to assign the direction of cyclization in the case of the tricyclic products **5–8** by examination of the pyridine ring protons. Compounds **5** and **7** show three different protons at δ 8.20–8.26, 7.26–7.39, and 6.90–6.96 ppm corresponding to the α, γ, and β protons, thus indicating that cyclization occurred in the α position. Similarly, with compounds **6** and **8**, the presence of two α protons a δ 8.20–8.26 ppm and one β proton at δ 6.93–7.00 ppm denotes that cyclization occurred in the γ position. For compounds **5–8** no methyl groups were present, only methylene and methine protons were present as indicated by a broad band at δ 1.00–2.34 ppm that correctly integrated for the proposed number of protons. Compounds **9–12** all had spectra similar to one another. The stereochemistry was determined from nmr by examining the chemical shift fo the methyl group and by coupling constants. Integration again was consistent with the proposed structures. No unsaturation was found by nmr or ir in any of the compounds **5–12**. Refractive indices also indicate cyclic compounds (see Table II).

Analyses.[17]—The nmr spectra of the pure samples in carbon tetrachloride were taken with a Varian T-60 spectrophotometer using tetramethylsilane as an internal standard. The microanalysis was done by M-H-W Laboratories, Garden City, Mich. Vapor phase chromatographic analyses and separations were performed on an F & M Model 720 dual-column instrument equipped with a thermal conductivity detector and using helium as a carrier gas. The separation of products for identification was accomplished with a 6 ft × $^3/_8$ in. column packed with Versamid 900 on Gas-Pack WAB.

Registry No. —**1**, 29883-73-6; **2**, 29883-74-7; **3**, 22241-43-6; **4**, 29883-76-9; **5**, 29883-77-0; **6**, 29883-78-1; **7**, 29883-79-2; **8**, 29905-80-5; **9**, 29864-45-7; **10**, 29864-46-8; **11**, 29864-47-9; **12**, 29868-59-5.

(17) The inclusion of elemental analyses for all the new compounds, suggested by the reviewers, would have been desirable in order to confirm their purity, although the nmr spectra and vpc indicate that all the isolated compounds were of at least 95% purity.

Base-Catalyzed Reactions. XLII.[1] Reactions of *N*-Methyl-2-pyrrolidinone and *N*-Methyl-2-piperidone with Olefins and Diolefins in the Presence of Potassium *tert*-Butoxide as Catalyst

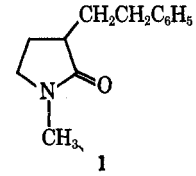
HERMAN PINES,* S. V. KANNAN, AND JARMILA SIMONIK

Ipatieff High Pressure and Catalytic Laboratory, Department of Chemistry, Northwestern University, Evanston, Illinois 60201

Received November 10, 1970

N-Methyl-2-pyrrolidinone (NM-2-Py) and *N*-methyl-2-piperidone (NM-2-Pi), the so-called "aprotic" dipolar solvents, were found to undergo reactions involving protons in the 3 position of their rings, with styrenes and conjugated diolefins. In the reactions studied, NM-2-Py was found to react only half as fast as NM-2-Pi. Also, the reaction of NM-2-Py was found to proceed faster in dimethyl sulfoxide than in hexamethylphosphoramide. Under the same conditions *N*-methylcaprolactam failed to react. A mechanism consistent with the results is proposed.

The reactions of olefins and diolefins with alkylaromatics and alkylpyridines was the subject of intensive research in this laboratory.[2] The experiments were made using sodium and potassium as catalysts. It has been recently observed that with the alkyl heterocyclic compounds the addition to conjugated hydrocarbons can also occur using potassium *tert*-butoxide as catalyst.[3] As an extension of this study the reaction of 3-ethylpyridine with styrene in the "aprotic" solvent *N*-methyl-2-pyrrolidinone (NM-2-Py) and in the presence of potassium *tert*-butoxide was investigated, and it was found that the "solvent" preferentially reacted with the olefins to form mono- and diadducts. The nmr spectrum of the monoadduct **1** conforms with the structure shown.



1

Among widely used dipolar aprotic solvents, only dimethyl sulfoxide (DMSO) has been reported to undergo reactions with olefins,[4] dienes,[5] aldehydes,[6] ketones,[6] and esters[7] in the presence of bases like alkali metal amides, hydrides, and alkoxides through its carbanion. This seems to be the first time that the addition reaction of NM-2-Py to an olefinic double bond is reported. This study was extended to the homologs, namely to *N*-methyl-2-piperidone (NM-2-Pi) and *N*-methylcaprolactam (NMC).

Results and Discussion

The results of the reactions of various olefins with NM-2-Py and NM-2-Pi in the presence of a potassium *tert*-butoxide catalyst are presented in Table I. These reactions are straightforward and occur without opening of the rings of the lactams. The structures of the compounds were assigned on the basis of nmr and ir. The addition of lactams in their 3 position to the olefins

(1) For paper XLI of the series, see H. Pines, S. V. Kanna, and W.M. Stalick, *J. Org. Chem.*, 2308 (1971).

(2) (a) H. Pines and L. A. Schapp, *Advan. Catal.*, **12**, 117 (1960); (b) H. Pines and N. C. Sih, *J. Org. Chem.*, **30**, 280 (1965).

(3) H. Pines and W. M. Stalick, *Tetrahedron Lett.*, **34**, 3723 (1965).

(4) M. Feldman, S. Danishefsky, and R. Levine, *J. Org. Chem.*, **31**, 4322 (1966).

(5) P. A. Argabright, J. E. Hofmann, and S. Schriesheim, *ibid.*, **30**, 3233 (1965).

(6) E. J. Corey and M. Chaykovski, *J. Amer. Chem. Soc.*, **84**, 866 (1962).

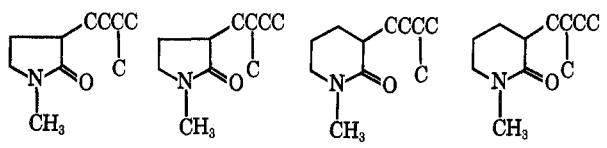
(7) G. A. Russell, E. Sabourin, and G. J. Mikol, *J. Org. Chem.*, **31**, 2854 (1966).

TABLE I

REACTION OF *N*-METHYL-2-PYRROLIDINONE AND *N*-METHYL-2-PIPERIDONE WITH OLEFINS[a]

Expt no.	Olefin (mol)	Solvent[b]	Reaction time hr	Conversion, %[c]	Wt % of product[d] Adducts Mono-[e]	Di-[e]
		N-Methyl-2-pyrrolidinone				
1	$C_6H_5CH=CH_2$ (0.01)		24	100	72 (1)	28 (2)[f]
2	$C_6H_5CH=CH_2$ (0.005)		24	100	100 (1)	
3	$C_6H_5C(CH_3)=CH_2$ (0.01)		24	47	100 (3)	
4	$C_6H_5C(CH_3)=CH_2$ (0.01)	DMSO	24	100	100 (3)	
5	$(CH_3)_3SiCH=CH_2$ (0.025)		24		No reaction	
6	$(CH_3)_3SiCH=CH_2$ (0.025)	DMSO	24	100[g]	67 (4)	33 (5)
7	$(CH_3)_3SiCH=CH_2$ (0.025)	HMPA	24		No reaction	
8	$CH_2=CHCH=CH_2$[h]		15	82[i] (6)	18[i] (7)	
9	$CH_2=CHC(CH_3)=CH_2$ (0.025)	DMSO	3	14[g]	100[i] (8, 9)	
10	$CH_2=CHC(CH_3)=CH_2$ (0.025)	DMSO	6	21[g]	60[i] (8, 9)	40
11	$CH_2=CHC(CH_3)=CH_2$ (0.025)	DMSO	24	100	30[i] (8, 9)	70
		N-Methyl-2-piperidone				
12	$C_6H_5CH=CH_2$ (0.005)		24	100	100 (10)	
13	$C_6H_5C(CH_3)=CH_2$ (0.005)	DMSO	24	100	100 (11)	
14	$(CH_3)_3SiCH=CH_2$ (0.005)	DMSO	24	100[g]	64 (12)	36 (13)
15	$CH_2=CHC(CH_3)=CH_2$		19	100[g]	62 (14a, 14b)[j]	

[a] 0.02 mol of the reactant and 0.005 *M* of catalyst were used, except in expt 1 and 2 where 0.01 *M* of the former and 0.02 *M* of the latter were used. The reactions were made at room temperature. [b] DMSO, dimethyl sulfoxide; HMPA, hexamethylphosphoramide. [c] Based on olefin. [d] Based on vpc peak areas, uncorrected for thermal conductivities. [e] The numbers in parentheses refer to the compound numbers that are used in this paper. [f] Mp (of the diadduct) 103°, after recrystallization from *n*-heptane. [g] Based on lactam. [h] Quantity not known. [i] After hydrogenation the product consisted of 85% tail addition (8) and 15% head addition (9). [j] After hydrogenation the product consisted of 85% tail addition (14a) and 15% head addition (14b).

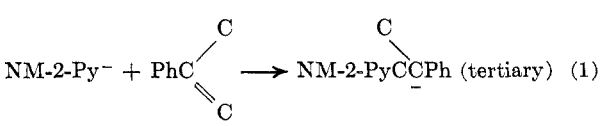


8 9 14a 14b

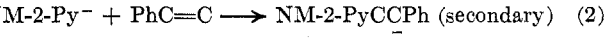
is to be expected since hydrogens in this position are activated to proton abstraction by the neighboring carbonyl group. The resulting carbanion can attack the olefin to generate another resonance-stabilized carbanion which can transmetalate with the parent lactam to form the monoadduct. The reaction sequence using styrene as the olefin is shown in Scheme I.

Efforts to make NMC react with any of the olefins in the presence of potassium *tert*-butoxide were unsuccessful.

Styrenes.—Even in the absence of a solvent, styrene reacts with NM-2-Py to form both mono- (1) and diaddition (2) products. At low concentrations, it forms only the monoadduct **10** with NM-2-Pi. The reaction of NM-2-Py with α-methylstyrene (αMS) is slower and this can be ascribed to the greater stability of a secondary over a tertiary anion formed in the addition reactions (eq 1 and 2).



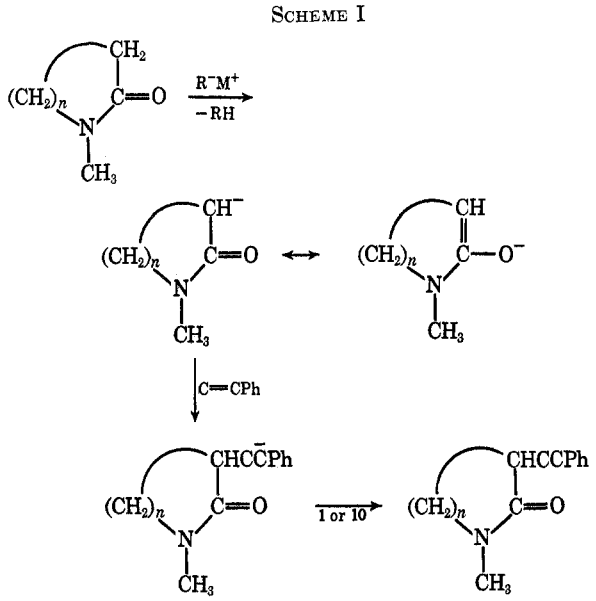
$$\text{NM-2-Py}^- + \text{PhC}(=\text{C})\text{C} \longrightarrow \text{NM-2-PyCCPh (tertiary)} \quad (1)$$



$$\text{NM-2-Py}^- + \text{PhC}{\equiv}\text{C} \longrightarrow \text{NM-2-PyCCPh (secondary)} \quad (2)$$

The direction of addition to the styrenes is to generate a carbanion resonance stabilized by the phenyl group, which is consistent with previous observations.[8-10]

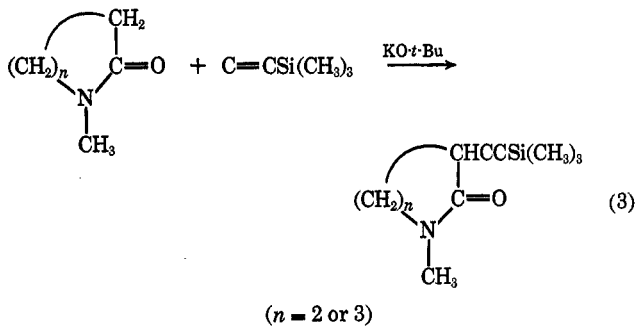
SCHEME I



1, $n = 2$
2, $n = 3$

Trimethylvinylsilane.—Both NM-2-Py and NM-2-Pi add to trimethylvinylsilane in such a manner as to produce a carbanion adjacent to the silicon atom as shown in eq 3. This occurs in preference to the addition which will generate a primary carbanion showing that the silicon atom is exerting a stabilizing effect on the carbanion, thus favoring its formation.[11]

(8) H. Pines and N. E. Sartoris, *J. Org. Chem.*, **34**, 2113 (1969).
(9) J. Shabtai and N. Pines, *ibid.*, **26**, 4225 (1961).
(10) J. Shabtai, E. M. Lewicki, and H. Pines, *ibid.*, **27**, 2618 (1962).
(11) (a) D. J. Cram, "Fundamentals of Carbanion Chemistry," Academic Press, New York, N. Y., 1965, p 71 ff; (b) B. Stipanović and H. Pines, *Chem. Commun.*, 1361 (1969).



(3)

(n = 2 or 3)

Butadiene.—This diolefin on reaction with NM-2-Py can be expected to form both cis and trans monoadducts, which it does (see Experimental Section). The relative ratios of the two could not be determined with accuracy from the ir spectrum. Diadduct is also formed in this reaction.

Isoprene.—The reaction of isoprene with NM-2-Py and NM-2-Pi results in the formation of a mixture of tail- and head-addition isomers, compounds **8**, **14a** and **9**, **14b**, respectively. In the monoaddition product, the tail-addition product (~85%) predominates over the head-addition (~15%) product in both reactions. This can be attributed to the greater stability of the intermediate tail-addition anions as discussed previously in the case of reactions of isoprene with δ-alkylpyridines[12,13] and with alkylbenzenes.[2b]

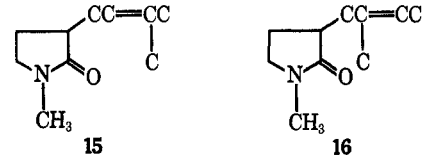
Relative Reactivities of NM-2-Py and NM-2-Pi.—In an effort to determine whether NM-2-Py or NM-2-Pi reacted faster with olefins in the presence of potassium *tert*-butoxide, they were allowed to compete for a small amount of styrene or α-methylstyrene. In both reactions, NM-2-Pi was found to react about twice as fast as NM-2-Py. In the case of styrene, NM-2-Py had a half-life of 52 min compared to 23 min for NM-2-Pi.

In a competitive reaction made at 25° using styrene and an equimolal solution of *N*-methyl-2-piperidone and *N*-methyl-2-pyrrolidinone, it was found that the monoadduct from NM-2-Pi predominated over that from NM-2-Py by 1.8 times. In a similar experiment with α-methylstyrene, it was found that NM-2-Pi formed 1.9 times more product than did NM-2-Py.

The above results are in contrast to the relative rates of base-catalyzed bromination of cyclopentanone and cyclohexanone in which the five-membered ring brominates almost ten times as fast as the six-membered ring.[14] Similarly, in the ionization of cyclopentanone and cyclohexanone as shown by the relative rates of hydrogen–deuterium exchange, the five-membered ring is about seven times as reactive as the six-membered one.[15]

Reaction of NM-2-Py with Olefins in DMSO and in HMPA.—Studies on the influence of solvents on the reaction of alkylpyridines with olefins have been conducted in this laboratory.[16] The results indicated that in addition to increasing the polarity of the medium, dimethyl sulfoxide (DMSO) is involved in the reaction in some other manner, probably by donating a proton in the transmetalation step. This would account for the larger reaction rates observed in DMSO compared to hexamethylphosphoramide (HMPA) contrary to earlier reports where HMPA has been observed to bring about faster reactions.[17] In the present study, DMSO was found to enhance the rates of the addition of NM-2-Py or NM-2-Pi to olefins. Further, the reaction of NM-2-Py with α-methylstyrene was found to have a half-life of 6 hr in HMPA but only 3.3 hr in DMSO.

Effect of Unsaturation on the Relative Reactivities of 3-Substituted NM-2-Py.—It was previously observed that the presence of a side-chain double bond increases the rate of alkenylation of substituted pyridines.[12,13] It was therefore of interest to determine whether a similar effect exists in the reactions of NM-2-Py. To accomplish it a mixture of monoadducts of isoprene with NM-2-Py (85% of **15** and 15% of **16**) and the mixture of their hydrogenated derivatives (**8** and **9**, Table I, footnote *i*) were alkenylated with isoprene under the same experimental conditions.



15 **16**

Their half-lives were found to be 149 min for the mixture of **15** and **16** and 324 min for the mixture of the saturated compounds **8** and **9**. These results demonstrate clearly that the presence of a double bond in the side chain increases the rate of alkenylation of lactams, and this can be ascribed to a complexation of the olefinic bond with the catalyst as discussed previously.[13,16]

Experimental Section

Reagents.—*N*-Methyl-2-pyrrolidinone, *N*-methyl-2-piperidone, styrene, α-methyl- and β-methylstyrene, trimethylvinylsilane, isoprene (all from Aldrich), DMSO (Matheson Coleman and Bell), and HMPA (Fischer) were all distilled and stored over Linde 13A molecular sieves and distilled again before use. *N*-Methylcaprolactam was prepared by the method of Benson and Cairns[18] from ε-caprolactam in 72% yield. Potassium *tert*-butoxide (K & K Laboratories) was sublimed just before use.

General Reaction Procedure.—In a 50-ml reaction bottle, potassium *tert*-butoxide was dissolved in the solution of lactam and isopropylcyclohexane, used as an internal standard, by vigorous shaking. *N*-Methyl-2-pyrrolidinone dissolved the catalyst easily forming a dark brown solution; *N*-methyl-2-piperidone dissolved less readily forming a dark green solution. The dissolution of the potassium *tert*-butoxide in *N*-methylcaprolactam was very slow, ultimately resulting in a pale yellow liquid. The bottle was sealed with a self-sealing neoprene stopper. All these operations were carried out in a drybox. The reaction bottle was then removed to the laboratory or placed in a thermostated constant temperature bath, the olefin injected from a syringe through the neoprene septum, and the reaction allowed to proceed for the desired period of time. Samples were withdrawn at intervals, quenched with methanol, and analyzed by vpc. At the end of the experiment the product was quenched with methanol and analyzed by vpc. For separation of products by preparative vpc, the solution was combined with ethyl acetate and washed with water and the ethyl acetate was removed by distillation.

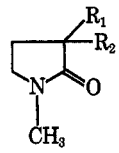
In the experiments where a solvent was used, the catalyst was dissolved in the solvent, the lactam and internal standard were added to it, and the reaction was conducted the usual way.[16]

For successful and reproducible results it is imperative to use

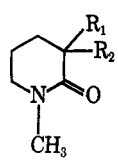
(12) W. M. Stalick and H. Pines, *J. Org. Chem.*, **35**, 415 (1970).
(13) W. M. Stalick and H. Pines, *ibid.*, **35**, 422 (1970).
(14) A. Schriesheim, R. J. Muller, and C. A. Rowe, Jr., *J. Amer. Chem. Soc.*, **84**, 3164 (1962).
(15) H. Schechter, M. J. Collis, R. Dessy, Y. Okuzumi, and A. Chen, *ibid.*, **84**, 2905 (1962).
(16) H. Pines, W. M. Stalick, T. G. Holford, J. Golab, H. Lazar, and J. Simonik, *J. Org. Chem.*, **36**, 2299 (1971).
(17) N. Normant, *Angew. Chem., Int. Ed. Engl.*, **6**, 1046 (1967).
(18) R. E. Benson and T. L. Cairns, *J. Amer. Chem. Soc.*, **70**, 2115 (1948).

TABLE II

NMR SPECTRA OF THE PRODUCTS



Compd no.	R_1	R_2	Group (no. of protons)	Multiplicity	δ, ppm
1	-H	$-CH_2CH_2C_6H_5$ (a) (b)	a (2), b (2)	Broad band of peaks	1.40–2.30
2	$-CH_2CH_2C_6H_5$ (a) (b)	$-CH_2CH_2C_6H_5$ (a) (b) (a) (b)	a (4), b (4)	Multiplet	1.86
3	-H	$-CH_2\underset{\displaystyle CH_3\ (c)}{\underset{\vert}{C}}HC_6H_5$	a (2), b (1)	Broad band of peaks	1.60–2.40
			c (3)	Doublet	1.20
4	-H	$CH_2CH_2Si(CH_3)_3$ (a) (b) (c)	a (2)	Multiplet	1.56
			b (2)	Multiplet	0.53
			c (9)	Singlet	0
5	$CH_2CH_2Si(CH_3)_3$ (a) (b) (c)	$CH_2CH_2Si(CH_3)_3$ (a) (b) (c)	a (4)	Multiplet	1.36
			b (4)	Multiplet	0.40
			c (18)	Singlet	0
6	-H	$-CH_2CH_2CH_2CH_3$ (a) (a) (a) (b)	a (6)	Broad band of peaks	1.30
			b (3)	Triplet	0.92
7	$-CH_2CH_2CH_2CH_3$ (a) (a) (a) (b)	$-CH_2CH_2CH_2CH_3$ (a) (a) (a) (b)	a (12)	Broad band	1.26
			b (6)	Triplet	0.90



10	-H	$-CH_2CH_2C_6H_5$ (a) (b) (a) (b)	a (2), b (2)	Broad band of peaks	1.60–2.60
11	-H	$-CH_2\underset{\displaystyle CH_3\ (c)}{\underset{\vert}{C}}HC_6H_5$	a (2), b (1)	Broad band of peaks	1.60–2.30
			c (3)	Doublet	1.18
12	-H	$CH_2CH_2Si(CH_3)_3$ (a) (b) (c)	a (2)	Multiplet	1.70
			b (2)	Multiplet	0.43
			c (9)	Singlet	0
13	$CH_2CH_2Si(CH_3)_3$ (a) (b) (c)	$CH_2CH_2Si(CH_3)_3$ (a) (b) (c)	a (4)	Multiplet	1.40
			b (4)	Multiplet	0.36
			c (18)	Singlet	0

freshly sublimed potassium *tert*-butoxide and to keep all the reagents completely dry.

Competitive Reactions of NM-2-Py and NM-2-Pi.—In a 50-ml capacity reaction bottle, 0.005 mol of potassium *tert*-butoxide was dissolved in 0.02 mol each of the lactams and 0.2 ml of isopropylcyclohexane, and the bottle was sealed with a neoprene stopper and placed in a thermostated bath at 25°. Styrene, 0.05 mol, was injected into the bottle. At the end of the reaction (24 hr), the product was quenced with methanol and analyzed by vpc. A similar experiment was made with α-methylstyrene.

Effect of Double Bond on Substitution.—In separate reaction bottles, 0.11 mol of the monoadduct from the reaction of NM-2-Py and isoprene (a mixture of about 85% of tail- and 15% of head-addition products) and their hydrogenated isomers were allowed to react with 0.01 mol of isoprene and 0.005 mol of potassium *tert*-butoxide in 5 ml of DMSO. The reaction was followed by vpc and quenched after 16 hr.

Analytical Procedure.—The products were all analyzed on a 5 ft × 0.25 in. column of 20% silicone oil DC 550 on Gas-Pack WAB (60–80 mesh), temperature programmed from 100–220°.

Identification of Products.—The products obtained in the described reactions are reported for the first time. They were all purified by separation by preparative vpc on an 8 ft × 0.25 in. column of 10% Versamid 900 on 60–80 mesh Gas-Pack WAB. These samples were then identified by nmr (Table II) and ir.[19]

Both NM-2-Py and NM-2-Pi have characteristic nmr spectra. The protons on the carbon adjacent to nitrogen in this ring appear at a lower field, δ 3.38 ppm in NM-2-Py and δ 3.32 ppm in NM-2-Pi, compared to the other protons. Substitution of these two protons would be reflected in the nmr spectra of the product. In all of the products obtained in these reactions these two protons were found to be present. The only other protons that could resonably be expected to be affected by the base catalyst are the ones adjacent to the carbonyl group. These do not possess a distinct chemical shift in nmr. In all the nmr spectra of the products, the basic spectrum of NM-2-Py and NM-2-Pi were intact. Also, the characteristic carbonyl frequency for both lactams (at 1676 cm^{-1}) was not displaced in the products. These two facts demonstrate that the ring is not opened during the reactions. It was thus concluded that in the reaction the 3

(19) The inclusion of elemental analyses for all the new compounds, suggested by the reviewers, would have been desirable in order to confirm their purity, although the nmr spectra and vpc, however, indicate that all the isolated compounds were of at least 95% purity.

position of the rings is involved and compounds **1**, **2**, and **3** were identified by their relatively simple nmr spectra.

The direction of addition in **4**, **5**, **12**, and **13** was decided by the absence of terminal methyl group protons in their nmr spectra, which would have been present had the addition taken place in the opposite direction.

The monoaddition product of the reaction of butadiene with NM-2-Py showed the presence of both cis (675 cm^{-1}) and trans (966 cm^{-1}) double bonds. It was also identified by the nmr spectrum of its hydrogenated analog **6**. The diadduct of the reaction was also identified in the same fashion. The monoaddition products from the reaction of isoprene with NM-2-Py and NM-2-Pi were found by vpc and nmr to be a mixture of both head- and tail-addition products in an approximate ratio of 15:85. The assignment of the structures are based on an earlier report.[12] They were confirmed by hydrogenating the double bonds and studying the nmr of the saturated analogs.

Acknowledgment.—The authors wish to thank Dr. B. Stipanovič for active participation in the discovery of the described reactions.

Registry No.—**1**, 21053-47-4; **2**, 21053-48-5; **3**, 29883-83-8; **4**, 29883-84-9; **5**, 29883-85-0; **6**, 29883-86-1; **7**, 29883-87-2; **8**, 29883-88-3, **9**, 29883-89-4; **10**, 29969-85-5; **11**, 29883-90-7; **12**, 29883-91-8; **13**, 29969-86-6; **14**, 29883-92-9; **15**, 29883-93-0; NM-2-Py, 875-20-4; NM-2-Pi, 931-20-4.

Stereospecific Syntheses of the Seven Dimethylcycloheptanes[1a]

JAMES B. HENDRICKSON* AND ROBERT K. BOECKMAN, JR.[1b]

Department of Chemistry, Brandeis University, Waltham, Massachusetts 02154

Received October 7, 1970

Unequivocal stereospecific syntheses of the seven possible dimethylcycloheptanes are reported. Separate preparation of the two (inseparable) 1,4 isomers to assure isomer purity involved synthetic problems of special interest.

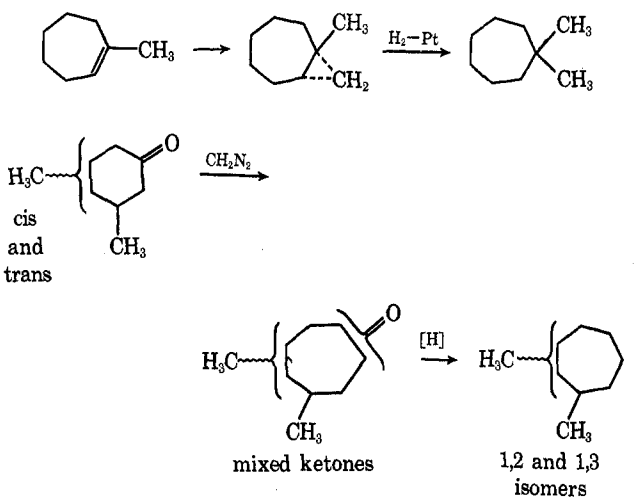
In order to apply experimental tests to the theoretical predictions about the conformational behavior of seven-membered rings,[2,3] we required stereochemically pure samples of the seven possible dimethylcycloheptanes. Inasmuch as the likelihood of reasonable separation of cis and trans isomers was remote, we were obliged to synthesize each one separately by an unambiguously stereospecific route. The four 1,2 and 1,3 isomers could be prepared by diazomethane ring expansion of the appropriate dimethylcyclohexanones, which were known. In order to eliminate the possibility of epimerization, none of the dimethylcyclohexanones were acceptable with methyl α to the ketone. For this reason the 1,4-dimethylcycloheptanes required other syntheses, and these presented an interesting problem in unequivocal stereospecificity. The *cis*-4,4-dimethylcycloheptane was created by cleaving a 1,4 bridge across a cycloheptane ring (Scheme II). The trans 1,4 isomer was created by initial synthesis of an authenticated 1,4-cis derivative followed by SN2 displacement of one substituent by a methyl anion (Scheme III).

While our work was in progress, a report appeared on the preparation of the dimethylcycloheptanes by diazomethane ring expansion.[4] We felt, however, that their preparations did not satisfy our needs for purity and unambiguous stereochemistry. The 1,2 isomers were separated chromatographically, but their relative stereochemistry was not independently assigned. The 1,4 isomers, inseparable chromatographically, may have involved epimerization in the ring expansion. Since their physical properties for the 1,4 isomers are completely identical,[4] only different chemical routes can guarantee their purity.

Our routes to the 1,1, 1,2, and 1,3 isomers are shown in Scheme I. The cyclopropane route to the *gem*-dimethyl compound is briefer than ring expansion.[5] The commercial *cis*- and *trans*-3,4-dimethylcyclohexanones were purified and confirmed first as to identity by Clemmensen reduction and vpc comparison with authentic samples of the two 1,2-dimethylcyclohexanes. The *cis*- and *trans*-1,2-dimethylcycloheptanes produced from them (Scheme I) were identical in vpc retention time with the two components (4:1 = cis:trans) of the mixture formed on hydrogenation of 1,2-dimethylcycloheptenes. The latter was a mixture of three isomeric olefins produced by the action of methyllithium on 2-

SCHEME I

PREPARATION OF THE FIVE 1,1-, 1,2-, AND 1,3-DIMETHYLCYCLOHEPTANES



(1) (a) Financial Assistance from the National Institutes of Health (Grant No. GM-10714) is gratefully acknowledged; (b) taken from the doctoral thesis of R. K. B., National Institutes of Health Predoctoral Fellow, 1969–1970.

(2) J. B. Hendrickson, *J. Amer. Chem. Soc.*, **89**, 7036, 7043, 7047 (1967).

(3) The results of these experiments are being prepared for publication.

(4) G. Mann, M. Mühlstädt, R. Müller, E. Kesn, and W. Hadeball, *Tetrahedron*, **24**, 6941 (1968).

(5) C. W. Woodworth, V. Buss, and P. v. R. Schleyer, *Chem. Commun.*, 569 (1968).