[CONTRIBUTION FROM THE FRICK CHEMICAL LABORATORY, PRINCETON UNIVERSITY]

THE INTERCONVERSION AND BECKMANN REARRANGEMENT OF SOME α,β-UNSATURATED CYCLIC OXIMES[1]

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This paper describes the synthesis, interconversion of geometric isomers, and Beckmann rearrangement of some α,β-unsaturated cyclic oximes. The Beckmann rearrangement of this type of oxime has not been reported in the literature and it was thought that it would be of interest to determine how this grouping would affect the rearrangement.

Both geometric isomers of isophorone oxime, 3-methyl-5-phenylcyclohexen-2-one-1 oxime, and cyclohexen-2-one-1 oxime were prepared. Only one isomer of *d*-carvone oxime could be prepared. Both isomers of the first two of the above oximes are formed when the corresponding ketones are reacted with hydroxylamine under neutral conditions. These geometric isomers give almost identical ultraviolet absorption spectra. The ultraviolet spectra of these α,β-unsaturated oximes show maxima in the expected region, *i.e.*, 236.0 ± 6.5 mμ.

In all cases where two geometric isomers were obtained, the lower-melting isomer was converted into the higher on being heated under reflux with 20% sodium hydroxide or on being heated with concentrated sulfuric acid. The higher-melting isomer, on the other hand, was converted into the lower on being heated under reflux with 10 or 20% sulfuric acid.

Both isomers of isophorone oxime (R_1, R_2 = Me) and 3-methyl-5-phenylcyclohexen-2-one-1 (R_1 = Ph, R_2 = H) were subjected to the Beckmann rearrangement using phosphorus pentachloride. The ultraviolet absorption spectra of the lactams obtained from the rearrangement of the higher-melting isomers showed maxima at about 240 mμ indicating that they contained an α-β double bond while the lactams obtained from the lower-melting isomers showed no maxima in this region. The other lactams did, however, show maxima at a much shorter wavelength. This absorption could be explained, perhaps, as due to the resonance of the double bond with the unpaired electrons on the adjacent nitrogen. This indicates that the original higher-melting, base- and concentrated sulfuric acid-stable oximes in both cases have the configuration with the hydroxyl group *syn* to the double bond and that the lower-melting, acid-stable, oximes have the *anti* configuration. The infrared absorption spectra is also in accord with this conclusion. The double bond band at 6.1–6.15 μ is much more prominent in the spectra of the lactams obtained from the lower-melting isomers than it is in the spectra of the other lactams. This type of intensification of a

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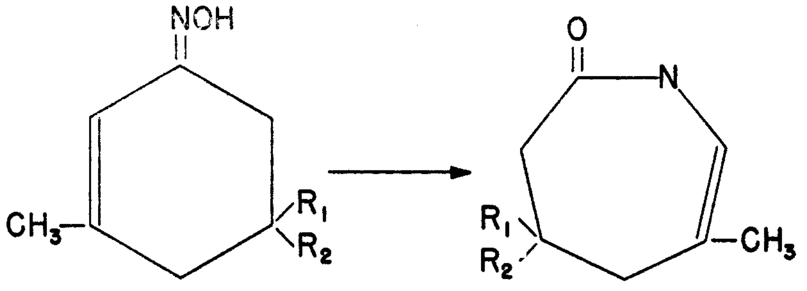
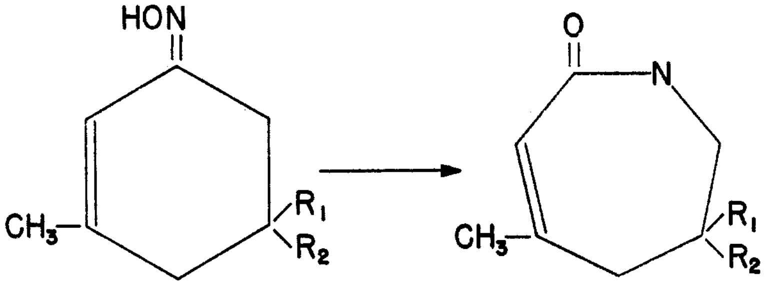
carbon-carbon double bond band is observed when there is an adjacent nitrogen atom which can enter strongly into the same mode of vibration.





d-Carvone oxime was also rearranged. A lactam was obtained that contained chlorine. It was considered probable that the elements of hydrogen chloride had added across one of the double bonds during the rearrangement. Since the ultraviolet spectra of this lactam showed neither of the two types of maxima shown by the other lactams, it was concluded that the addition had occurred across the double bond α-β to the original oxime group.

EXPERIMENTAL

Benzine for recrystallization had b.p. 60–70°. All melting points are corrected and boiling points are uncorrected.

Isophorone oximes. Isophorone in ethanol was mixed with a concentrated aqueous hydroxylamine hydrochloride solution (50% excess) and cooled in an ice-bath. When the mixture was cold, a concentrated solution of potassium hydroxide was added slowly with shaking until the mixture was neutral to litmus. Enough ethanol was then added so that the two layers were miscible and the reaction mixture was allowed to stand at room temperature for eight days. Salt was then added and the reaction mixture was extracted with ether. The ether was evaporated at room temperature and the white crystalline residue was recrystallized from dilute methanol. A 96% yield was obtained after recrystallization. This was a mixture of two isomeric oximes which was easily separated by recrystallizing a few times from dilute methanol. A 31% yield of the higher-melting and a 55% yield of the lower-melting oxime was obtained. The oximes were then recrystallized from benzine to give white crystals, m.p. 101.8–102.4° and m.p. 78.2–78.5°. The higher-melting isomer has not been reported before. The lower-melting isomer is much more soluble than is the higher. The ultraviolet absorption spectra of these isomers are almost identical. Both show maxima at 232 mμ in *n*-heptane, 236.5 mμ in alcohol, and 241 mμ in distilled water. For the higher-melting isomer, ε 18,000 while for the lower-melting isomer ε 16,700 in alcohol.

Anal. Calc'd for $C_9H_{15}NO$: C, 70.54; H, 9.87.

Found for higher-melting isomer: C, 70.42; H, 9.90.
Found for lower-melting isomer: C, 70.50; H, 9.76.

3-Methyl-5-phenylcyclohexen-2-one-1 oximes. A 60% yield of the above ketone, b.p. 160–164° at 5 mm., n_D^{20} 1.5663, was obtained from the condensation of benzaldehyde and ethyl acetoacetate according to the method of Horning, Denekas, and Field (1). This ketone was reacted with hydroxylamine under neutral conditions to give a 59% yield of a mixture of the two isomeric oximes. The oximes were fractionally crystallized from dilute methanol and then recrystallized from benzine to give white crystals, m.p. 154.3–155.1° and m.p. 120.2–121.2°. The lower-melting isomer is much more soluble than is the higher. The ultraviolet absorption spectra of these isomers show maxima at 233 mμ in *n*-heptane, 210.5 mμ and 238.5 mμ in alcohol, and 241.5 mμ in distilled water. For the higher-melting isomer, $\epsilon_{210.5}$ 13,200 and $\epsilon_{238.5}$ 19,700 while for the lower-melting isomer $\epsilon_{210.5}$ 12,500 and $\epsilon_{238.5}$ 16,400 in alcohol.

Anal. Calc'd for $C_{13}H_{15}NO$: C, 77.58; H, 7.51.
Found for higher-melting isomer: C, 77.54; H, 7.50.
Found for lower-melting isomer: C, 77.49; H, 7.39.

Cyclohexen-2-one-1 oximes. A 20% yield of the above ketone, b.p. 70–79° at 35 mm., was obtained by the oxidation of cyclohexene according to Whitmore and Pedlow (2). This ketone was reacted with hydroxylamine in sodium acetate buffer according to Bartlett and Woods (3) to give a 37% yield of the white oxime crystals, m.p. 97.4–98.3° recrystallized from benzine. The other isomer was not isolated probably because of its considerable solubility in water. This oxime was converted into its lower-melting isomer on being heated on a steam-bath with 20% sulfuric acid. The lower-melting isomer was in the form of white crystals, m.p. 88.1–89.1° recrystallized from benzine. Again the lower-melting isomer was much more soluble than was the higher. The ultraviolet absorption spectra of these isomers show maxima at 227 mμ in *n*-heptane and 229.5 mμ in alcohol. For the higher-melting isomer, ϵ 17,300 while for the lower-melting isomer, ϵ 16,700.

Anal. Calc'd for C_6H_9NO: C, 64.84; H, 8.16.
Found for the higher-melting isomer: C, 64.85; H, 8.15.
Found for the lower-melting isomer: C, 64.84; H, 8.12.

d-Carvone oxime. A 62% yield of *d*-carvone oxime, m.p. 73.1–73.7° recrystallized from dilute methanol, was obtained by reacting *d*-carvone with hydroxylamine hydrochloride according to Harries (4). No other isomer of *d*-carvone oxime could be obtained by treating this isomer with acid or base. The ultraviolet spectra showed a maximum at 232.5 mμ in *n*-heptane and 234 mμ in alcohol. ϵ 16,200 in alcohol.

Anal. Calc'd for $C_{10}H_{15}NO$: C, 72.69; H, 9.15.
Found: C, 72.72; H, 9.14.

Conversion of higher-melting to lower-melting isomers. The higher-melting isomer of isophorone oxime was heated under reflux for three hours with 10% sulfuric acid and the reaction mixture was neutralized with 25% potassium hydroxide and ether extracted. The ether extract was evaporated and the residue recrystallized from benzine to give a 46% yield of the lower-melting isomer of isophorone oxime. A yield of 70% of the lower-melting isomer of 3-methyl-5-phenylcyclohexen-2-one-1 oxime was obtained by heating under reflux the higher-melting isomer with 20% sulfuric acid for 10 minutes and a yield of 45% of the lower-melting isomer of cyclohexen-2-one-1 oxime was obtained by heating the acid solution of the higher-melting isomer of this oxime for 30 minutes on a slow steam-bath.

Conversion of lower-melting to higher-melting isomers. The lower-melting isomer of isophorone oxime was heated under reflux for 2 hours with 20% potassium hydroxide solution and the reaction mixture was neutralized with 20% sulfuric acid and ether extracted. The ether extract was evaporated and the residue was recrystallized from benzine to give a 43% yield of the higher-melting isomer of isophorone oxime. The lower-melting isomer of 3-methyl-5-phenylcyclohexen-2-one-1 oxime gave a 66% yield of the higher-melting isomer when treated in the same manner and the lower-melting isomer of cyclohexen-2-one-1 oxime gave the higher-melting isomer on being heated 30 minutes with 20% sodium hydroxide on a slow steam-bath. The lower-melting isomer of isophorone oxime gave an 80% yield of the higher-melting isomer and the lower-melting isomer of 3-methyl-5-phenylcyclohexen-2-one-1 oxime gave a 33% yield of the higher-melting isomer on being heated a short time with a mixture of 1 part of water to 4 parts of concentrated sulfuric acid.

The Beckmann rearrangement. The lower-melting isomer of isophorone oxime when treated with phosphorus pentachloride in ether gave a lactam, m.p. 108.8–109.1° recrystallized from benzine, in 20% yield. This lactam was very soluble in water and alcohol and its ultraviolet spectra showed a maximum at 218.5 mμ in alcohol and 221.5 mμ in distilled water; ϵ 10,700 in alcohol. The higher-melting isomer of isophorone oxime gave a lactam, m.p. 90.1–90.7° recrystallized from benzine, in 25% yield. This lactam is more soluble in organic solvents than was the above lactam. Its ultraviolet spectra showed a maximum at 230 mμ in *n*-heptane, 237 mμ in alcohol, and 239.5 mμ in distilled water; ϵ 7,320 in alcohol.

Anal. Calc'd for $C_9H_{15}NO$: C, 70.54; H, 9.87.
Found for lactam from low isomer: C, 70.50; H, 9.87.
Found for lactam from high isomer: C, 70.39; H, 9.93.

The lower-melting isomer of 3-methyl-5-phenylcyclohexen-2-one-1 oxime gave a lactam, m.p. 146.0–146.6° recrystallized from benzene-benzine, in 15% yield when treated with phosphorus pentachloride in a mixture of 1 part of benzene to 3 parts of ether. Its ultraviolet spectra showed a maximum at 210.5 mμ in alcohol and 211.5 mμ in distilled water; ϵ 19,000 in alcohol. The higher-melting isomer of 3-methyl-5-phenylcyclohexen-2-one-1 oxime gave a lactam, m.p. 118.3–118.7° recrystallized from benzine, in 25% yield when treated with phosphorus pentachloride in a mixture of 2 parts of benzene to 3 parts of ether. This lactam was more soluble in organic solvents than was the above lactam. Its ultraviolet spectra showed maxima at 204.5 mμ and 241.5 mμ in alcohol and at 244 mμ in distilled water; $\epsilon_{204.5}$ 13,400 and $\epsilon_{241.5}$ 7,250 in alcohol.

Anal. Calc'd for $C_{13}H_{15}NO$: C, 77.58; H, 7.51.
Found for lactam from low isomer: C, 77.43; H, 7.44.
Found for lactam from high isomer: C, 77.48; H, 7.43.

d-Carvone oxime gives a lactam that contains chlorine, m.p. 203.1–203.3°d. recrystallized from benzine, in 12% yield when treated with phosphorus pentachloride in ether. Its ultraviolet spectra showed no maximum although the spectrum down to 204 mμ in alcohol was investigated.

Anal. Calc'd for $C_{10}H_{16}ClNO$: C, 59.57; H, 8.00.
Found: C, 59.47; H, 7.93.

SUMMARY

This work was undertaken in order to determine how an α-β double bond would affect the Beckmann rearrangement of cyclic oximes. Where there is no α substituent, there are two isomeric oximes formed from the ketones under neutral conditions. The results of the rearrangements indicate that the configuration of the oxime with the hydroxyl group *syn* to the double bond is stable in base and in concentrated sulfuric acid while the *anti* configuration of the oxime is stable in more dilute acid. The isomers can be readily interconverted by treating them with either acid or base. When there is an α substituent, only one oxime could be obtained. These oximes could be rearranged with phosphorus pentachloride but not with concentrated sulfuric acid.

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REFERENCES

(1) HORNING, DENEKAS, AND FIELD, *Org. Syntheses*, **27**, 24 (1947).
(2) WHITMORE AND PEDLOW, *J. Amer. Chem. Soc.*, **63**, 758 (1941).
(3) BARTLETT AND WOODS, *J. Amer. Chem. Soc.*, **62**, 2933 (1940).
(4) HARRIES, *Lehrbuch der organischen Chemie von V. Meyer und P. Jacobson*, Bd. II, Tl. I, Von Veit & Co., Leipzig, 1902, p 939.