

## HENRY CONDENSATION UNDER HIGH PRESSURE.

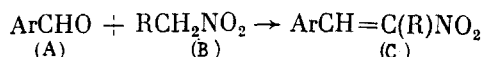
2. EFFECT OF AROMATIC ALDEHYDE TYPE AND PRESSURE ON THE YIELD OF  $\omega$ -NITROSTYRENES AND SECONDARY PROCESSES

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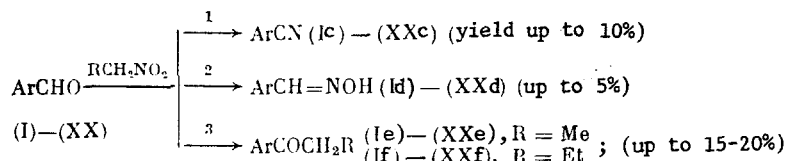
Condensation of aromatic aldehydes (I)-(XX) with  $\text{EtNO}_2$  and  $n\text{-PrNO}_2$  in  $\text{AcOH}$  in the presence of  $\text{AcONH}_4$  or  $i\text{-BuNH}_2$  gives primarily  $\omega$ -nitrostyrenes (Ia, b)-(XXa, b) and small quantities of nitriles (Ic)-(XXc), oximes (Id)-(XXd), and ketones (Ie, f)-(XXe, f). The yields of (Ia, b)-(XXa, b) at  $P = 1$  atm are higher for acceptor substituents on the aromatic ring whereas at  $P = 10$  kbar, they are higher for donor substituents. High pressures suppress the formation of (Ic-f)-(XXc-f) and the Z-isomers of (Ia, b)-(XXa, b). The high pressure technique is especially useful in the preparation of donor-substituted (Ia, b)-(XXa, b) which are intermediates in the synthesis of the psychotropic  $\beta$ -phenylethylamines.

Condensation of aromatic aldehydes (A) with nitroalkanes (B) (the Henry reaction) is widely used in the preparation of  $\omega$ -nitrostyrenes (C) which are fungicides and key intermediates in the synthesis of psychotropic amines and have an extensive bibliography devoted to them [1].



Until now, however, effort in these syntheses has been restricted to a search for the optimal conditions for actual pairs of (A) and (B), and the influence of the nature of the aldehyde (A) and the physicochemical conditions on the yield of (C) and the side reactions have not been studied at all.

For the present study, we selected the aldehydes (I)-(XX) which give the nitroolefins (Ia, b)-(XXa, b) as the main products on condensation with  $\text{EtNO}_2$  and  $\text{PrNO}_2$  (Table 1). It has, however, been established, by chromatography-mass spectrometry analysis of the reaction mixtures, that the Henry reaction always proceeds ambiguously with the formation of secondary products the quantity and type of which vary with the donor-acceptor characteristics of the aldehyde and to a lesser extent with the catalyst type ( $\text{AcONH}_4$ ,  $i\text{-BuNH}_2$ ) (Table 2). The main types of secondary product are set out in the scheme below (routes 1, 2, 3):



Nitriles and oximes (Ic, d)-(XXc, d) are detected in the products of the reaction of aldehydes with different electronic characteristics (donor and acceptor) whereas the yield of ketones (Ie, f)-(XXe, f) increases for acceptor and falls (as far as 0%) for donor substituents ( $\text{AcONH}_4$  catalyst); with  $i\text{-BuNH}_2$  (Ie, f)-(XXe, f) are not formed at all. From an examination of literature results we have established that oximes and ketones are a class of compounds which have not been detected previously in the products of a Henry reaction. The formation of the former is most probably connected with the partial conversion of  $\text{EtNO}_2$  and

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TABLE 1. Yields of ArCH=C(R)NO<sub>2</sub> (I)-(XX), R = Me (a); R = Et (b)

ArCHO	Ar	Yield of ArCH=C(CH <sub>3</sub> )NO <sub>2</sub> (a), % (residual ArCHO, %)*				Yield of ArCH=C(C <sub>2</sub> H <sub>5</sub> )NO <sub>2</sub> (b), % (residual ArCHO, %)*				Diff. between cols. 2 & 1
		AcONH <sub>2</sub>		i-BuNH <sub>2</sub>		AcONH <sub>2</sub>		i-BuNH <sub>2</sub>		
		P=1 atm	P=10 kbar	P=1 atm	P=10 kbar	P=1 atm	P=10 kbar	P=1 atm	P=10 kbar	
(I)	4-Me <sub>2</sub> NC <sub>6</sub> H <sub>4</sub>	26(30)	78(6)	22(42)	80(12)	12(46)	54(22)	8(56)	42(52)	+52
(II)	4-Et <sub>2</sub> NC <sub>6</sub> H <sub>4</sub>	30(26)	80(4)	30(36)	74(10)	16(56)	48(24)	10(70)	36(56)	+50
(III)	4-FC <sub>6</sub> H <sub>4</sub>	50(16)	78(4)	44(14)	74(12)	-	-	-	-	+28
(IV)	3,4,5-(MeO) <sub>3</sub> C <sub>6</sub> H <sub>2</sub>	-	-	-	-	24(50)	56(14)	-	-	-
(V)	4-Methoxy-1-naphthyl	-	-	-	-	26(48)	46(42)	-	-	-
(VI)	C <sub>6</sub> H <sub>5</sub>	56(16)	76(0)	58(22)	52(0)	-	-	-	-	+20
(VII)	4-MeOC <sub>6</sub> H <sub>4</sub>	52(22)	68(0)	50(34)	80(0)	34(50)	58(12)	32(58)	68(10)	+16
(VIII)	3,4-(MeO) <sub>2</sub> C <sub>6</sub> H <sub>3</sub>	44(20)	60(0)	44(26)	58(0)	30(52)	60(10)	40(54)	64(16)	+16
(IX)	2,5-(MeO) <sub>2</sub> -4-MeC <sub>6</sub> H <sub>2</sub>	62(14)	78(0)	62(12)	82(0)	48(20)	74(8)	40(34)	62(22)	+16
(X)	2-MeOC <sub>6</sub> H <sub>4</sub>	54(2)	62(2)	58(8)	62(4)	38(16)	42(2)	52(26)	52(12)	+8
(XI)	2-Furyl	58(0)	62(0)	56(0)	70(0)	50(0)	54(0)	48(0)	78(0)	+4
(XII)	4-ClC <sub>6</sub> H <sub>4</sub>	62(10)	64(6)	64(12)	60(16)	-	-	-	-	+2
(XIII)	4-IC <sub>6</sub> H <sub>4</sub>	56(14)	58(10)	62(6)	62(20)	-	-	-	-	+2
(XIV)	3-MeOC <sub>6</sub> H <sub>4</sub>	76(12)	76(6)	76(28)	76(18)	-	-	-	-	0
(XV)	4-BrC <sub>6</sub> H <sub>4</sub>	58(10)	54(2)	58(32)	64(4)	42(30)	24(8)	46(20)	68(6)	-4
(XVI)	3-O <sub>2</sub> N-4-ClC <sub>6</sub> H <sub>3</sub>	56(0)	48(30)	-	-	-	-	-	-	-8
(XVII)	3-O <sub>2</sub> NC <sub>6</sub> H <sub>4</sub>	62(0)	48(0)	66(0)	26(44)	44(26)	38(10)	52(20)	44(35)	-14
(XVIII)	4-O <sub>2</sub> NC <sub>6</sub> H <sub>4</sub>	58(0)	32(18)	60(4)	38(22)	44(20)	10(42)	60(18)	56(12)	-26
(XIX)	3-Pyridyl †	44(4)	6(26)	50(6)	12(34)	-	-	-	-	-38
(XX)	4-Pyridyl ‡	0	0	0	0	0	0	0	0	-

\*Yield determined from GLC of reaction mixture as average of two independent experiments (discrepancy <6%).

†Dash indicates no reaction.

‡Mixtures resinified; traces of (XXa, b) identified only by chromatography-mass spectrometry.

TABLE 2. Mass Spectra of Compounds (I)-(XXf)\*

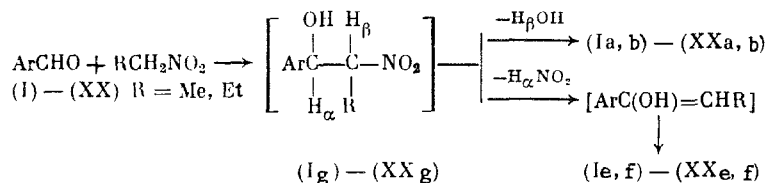
Compound	M <sup>+</sup> , m/z (rel. intensity, %)
(I)	149(M <sup>+</sup> 65), 148(100), 132(9), 105(4), 104(6), 77(12), 51(5), 42(6).
(Ia)	177(M <sup>+</sup> 34), 163(9), 162(100), 134(35), 132(9), 106(10), 105(6), 77(12), 76(5), 51(6), 29(10).
(Ic)	146(M <sup>+</sup> 52), 145(100), 143(6), 130(8), 129(13), 102(12), 75(3), 42(4).
(Ie)	206(M <sup>+</sup> 50), 159(100), 158(60), 148(16), 145(29), 144(46), 115(35).
(III)	124(M <sup>+</sup> 71), 123(100), 96(9), 95(85), 75(31), 69(5), 51(4), 50(8).
(IIIa)	181(M <sup>+</sup> 21), 164(2), 153(2), 135(12), 134(37), 133(100), 123(26), 115(52), 109(43), 108(8), 107(16), 103(17), 84(8), 83(15), 51(3), 39(12).
(IIIc)	121(M <sup>+</sup> 100), 94(29), 75(3), 50(3).
(III d)	139(M <sup>+</sup> 100), 122(6), 121(18), 112(15), 107(5), 96(71), 95(65), 94(31), 84(11), 75(29), 74(5), 27(18).
(IV)	196(M <sup>+</sup> 100), 195(16), 181(49), 125(54), 110(59), 95(54), 93(38), 81(15), 79(20), 77(21), 67(20), 66(21), 65(26), 51(25), 50(18), 39(34), 38(17).
(IVb)	267(M <sup>+</sup> 100), 236(5), 221(11), 220(31), 206(10), 205(28), 191(15), 190(23), 175(28), 163(16), 162(16), 153(16), 147(28), 120(29), 119(22), 115(36), 104(21), 103(39), 92(25), 91(87), 90(22), 89(31), 79(2), 77(68), 75(26), 65(33), 63(21), 53(18), 51(22), 39(26).
(V)	186(M <sup>+</sup> 74), 185(100), 157(15), 143(11), 142(10), 127(18), 126(11), 115(75), 114(56), 113(28), 89(15), 88(15), 87(14), 74(13), 63(19), 62(12).
(Vb)	257(M <sup>+</sup> 84), 226(20), 211(20), 210(100), 196(15), 195(60), 194(11), 182(11), 181(30), 180(15), 179(33), 178(14), 173(12), 167(24), 166(14), 165(58), 160(13), 159(15), 158(22), 153(27), 152(66), 151(24), 150(11), 139(53), 128(11), 127(12), 126(11), 115(34), 114(12), 89(14), 76(11).
(Vc)	183(M <sup>+</sup> 89), 168(17), 140(100), 113(24), 87(9), 63(22), 40(11).
(VI)	106(M <sup>+</sup> 91), 105(98), 78(21), 77(100), 76(11), 74(14), 52(15), 51(64), 50(45), 39(11), 38(11), 37(7), 29(24).
(VIa)	163(M <sup>+</sup> 12), 146(8), 135(4), 117(13), 116(27), 115(100), 105(31), 91(40).
(E, Z)	89(13), 79(7), 77(12), 66(12), 65(18), 63(17), 57(10), 51(21), 50(12), 39(26), 30(26), 27(10).
(VIc)	103(M <sup>+</sup> 100), 77(7), 76(35), 75(12), 51(17), 50(22), 39(8), 38(7).
(VI d)	121(M <sup>+</sup> 100), 120(27), 105(21), 104(15), 103(20), 94(35), 93(10), 89(11), 78(72), 77(87), 76(34), 75(16), 74(15), 66(36), 65(22), 64(10), 63(17), 62(11), 52(14), 51(79), 50(51), 39(23), 38(17).
(VIe)	134(M <sup>+</sup> 19), 105(100), 77(61), 51(28), 50(12), 39(4).
(VII)	136(M <sup>+</sup> 52), 135(100), 107(25), 92(53), 78(12), 77(72), 76(17), 74(15), 65(32), 64(30), 63(41), 62(16), 51(23), 50(24), 39(27), 38(14).
(VIIb)	207(M <sup>+</sup> 15), 161(9), 160(52), 159(15), 146(27), 145(52), 144(15), 135(22), 131(34), 130(16), 129(22), 128(21), 127(16), 124(13), 121(83), 118(19), 117(51), 116(29), 115(91), 108(20), 107(15), 105(13), 103(61), 102(40), 101(11), 96(21), 92(16), 91(100), 90(20), 89(42), 78(22), 77(60), 76(20), 75(14), 65(23), 64(13), 63(33), 62(10), 53(12), 51(27), 50(11), 39(19).
(IX)	180(M <sup>+</sup> 82%), 179(19), 165(40), 163(10), 137(48), 134(43), 123(13), 121(13), 120(17), 109(62), 105(16), 94(27), 93(24), 91(33), 79(34), 78(36), 77(100), 66(44), 65(55), 63(23), 53(43), 52(21), 51(37), 50(19), 39(40).
(IXb)	251(M <sup>+</sup> 100), 220(4), 205(8), 204(58), 190(25), 189(49), 175(54), 174(25), 161(15), 160(20), 159(15), 137(16), 135(25), 132(19), 131(27), 129(19), 128(22), 117(20), 116(21), 115(64), 105(41), 103(34), 102(17), 96(24), 91(65), 89(23), 79(24), 78(23), 77(66), 65(25), 63(16), 53(17), 51(20).
(IXc)	177(M <sup>+</sup> 66%), 162(100), 134(15), 93(11), 79(15), 77(34), 76(29), 75(11), 66(19), 65(29), 64(18), 63(18), 51(21), 39(27).
(X)	136(M <sup>+</sup> 100), 135(55), 121(11), 119(27), 118(38), 107(11), 105(14), 104(26), 94(9), 93(11), 92(25), 91(23), 90(31), 79(26), 78(26), 77(68), 76(52), 65(26), 64(15), 63(23), 51(20), 50(17), 39(21).
(Xa)	193(M <sup>+</sup> 44), 147(13), 146(25), 145(11), 135(22), 132(38), 131(100), 119(14), 115(28), 105(18), 104(14), 103(32), 102(13), 91(76), 89(12), 79(10), 78(17), 77(38), 76(15), 63(13), 51(15), 39(10).
(Xb)	207(M <sup>+</sup> 62), 161(29), 160(38), 146(25), 145(50), 131(81), 129(13), 128(19), 127(13), 121(58), 119(15), 118(16), 117(26), 116(16), 115(58), 107(15), 105(18), 103(18), 102(13), 96(12), 92(12), 91(100), 90(21), 89(19), 78(11), 77(42), 76(13), 65(16), 63(16), 51(18), 39(16).
(Xc)	133(M <sup>+</sup> 88), 132(40), 105(40), 104(100), 103(37), 90(44), 78(10), 77(9), 76(13), 75(10), 64(14), 63(29), 39(12).
(Xd)	151(M <sup>+</sup> 35), 119(91), 92(16), 91(88), 90(18), 78(11), 77(30).
(Xf)	178(M <sup>+</sup> 6), 136(5), 135(100), 92(9), 79(3), 77(28), 51(2), 39(1).
(XI)	96(M <sup>+</sup> 100), 95(99), 67(5), 42(8), 40(14), 39(92), 38(46), 37(27), 36(10), 29(46).
(XIb)	167(M <sup>+</sup> 31), 150(5), 109(11), 91(64), 83(100), 78(21), 77(56), 65(30), 63(16), 55(31), 53(21), 52(15), 51(32), 41(17), 30(26), 29(25), 27(28).
(XI f)	138(M <sup>+</sup> 15), 123(7), 110(45), 95(100), 68(4), 67(55(3), 53(5), 51(3), 43(6), 42(5), 41(11), 39(37), 38(11), 29(6).
(XIV)	136(M <sup>+</sup> 65), 135(100), 107(47), 92(36), 78(14), 77(79), 76(21), 74(11), 65(47), 64(36), 63(53), 62(11), 51(23), 50(22), 39(31).
(XIVa)	193(M <sup>+</sup> 31)+, 146(25), 135(23), 134(12), 132(18), 131(40), 117(11), 116(21), 115(98), 108(16), 107(16), 106(16), 105(26), 104(56), 103(100), 102(52), 96(19), 92(22), 91(92), 89(26), 81(12), 79(21), 78(60), 77(90), 76(26), 75(15), 74(14), 65(24), 64(21), 63(46), 62(17), 51(35), 50(20), 39(25).
(XV)	184(M <sup>+</sup> 57), 185(84), 186(46), 183(100), 157(41), 156(12), 155(51), 77(23), 76(34), 75(35), 74(32), 73(14), 51(20), 50(56), 29(8).

TABLE 2 (continued)

Compound	M <sup>+</sup> , m/z (rel. intensity, %)
(NVa)	241(M <sup>+</sup> 21), 243(18), 196(15), 194(19), 134(11), 132(30), 131(16), 116(55), 115(100), 114(19), 113(10), 89(15), 63(14), 57(14), 50(12), 39(12), 30(12).
(NVb)	255(M <sup>+</sup> 12), 257(12), 210(10), 208(10), 171(13), 169(12), 148(16), 146(34), 131(27), 130(65), 129(100), 128(59), 127(25), 120(15), 115(65), 114(17), 102(14), 101(12), 89(14), 77(11), 75(15), 64(10), 63(19), 51(14), 50(13), 27(14).
(NVc)	181(M <sup>+</sup> 80), 183(72), 102(100), 76(15), 75(35), 74(12), 51(16), 50(25).
(NVd)	199(M <sup>+</sup> 69), 201(69), 181(18), 158(56), 157(53), 156(66), 155(49), 102(64), 93(21), 92(38), 76(81), 75(100), 74(52), 65(40), 63(25), 51(35), 50(72).
(NVia)	242(M <sup>+</sup> 13), 244(3), 197(8), 195(28), 151(10), 149(34), 116(8), 115(100), 114(37), 113(19), 89(14), 75(12), 63(23).
(NVic)	182(M <sup>+</sup> 43), 184(10), 136(35), 124(27), 100(100), 75(18), 74(10), 73(10), 50(13), 30(58).
(NVId)	200(M <sup>+</sup> 24), 183(4), 110(6), 101(6), 100(15), 99(17), 75(25), 74(15), 73(16), 63(13).
(NVII)	151(M <sup>+</sup> 80), 150(79), 148(22), 105(42), 104(17), 102(33), 77(80), 76(42), 75(37), 74(30), 65(12), 51(100), 46(12), 39(15), 38(14), 30(34), 29(26).
(NVIIb) (E, Z)	222(M <sup>+</sup> 12), 176(19), 146(27), 145(16), 136(20), 131(49), 130(61), 129(88), 128(100), 127(61), 117(17), 116(16), 115(100), 114(13), 108(13), 104(13), 103(15), 102(25), 91(18), 90(16), 89(42), 77(38), 76(16), 75(27), 65(23), 64(24), 63(38), 52(15), 51(45), 50(23), 40(15), 39(38), 38(17), 30(44), 27(56).
(NVIIId)	166(M <sup>+</sup> 66), 150(14), 149(31), 139(15), 120(13), 119(43), 104(12), 103(39), 102(31), 92(14), 91(22), 89(12), 77(31), 76(73), 75(71), 74(39), 65(100), 64(26), 63(30), 62(20), 53(22), 51(43), 50(80), 46(27), 39(66), 38(23), 30(51).
(NVIIIf)	193(M <sup>+</sup> 3), 176(16), 165(35), 150(100), 104(44), 77(11), 76(45), 75(16), 51(9), 43(19), 41(16), 39(12), 27(27).
(NVIII)	151(M <sup>+</sup> 100), 150(99), 149(30), 105(22), 104(20), 92(12), 77(60), 76(26), 75(14), 74(18), 65(15), 51(65), 50(50), 39(12), 30(23).
(NVIIIa) (E, Z)	208(M <sup>+</sup> 12), 161(19), 134(9), 132(17), 131(17), 116(31), 115(100), 103(9), 89(13), 63(12), 51(7), 50(9), 39(9), 30(18).
(NVIIIb) (E, Z)	222(M <sup>+</sup> 24), 175(30), 148(13), 146(26), 145(11), 131(28), 130(55), 129(100), 128(86), 127(55), 115(95), 102(15), 91(11), 89(19), 78(14), 77(23), 76(12), 75(12), 63(23), 51(23), 50(16), 39(21), 30(33), 29(16).
(NVIIIc)	148 (M <sup>+</sup> 63), 147(9), 102(100), 90(24), 76(15), 74(17), 64(6), 63(8), 62(7), 51(26), 50(40), 38(9), 30(49), 26(25).
(NVIIIId)	166(M <sup>+</sup> 100), 165(18), 136(22), 103(18), 102(23), 92(14), 81(14), 77(14), 76(38), 75(37), 74(19), 65(51), 64(17), 63(24), 51(18), 50(53), 39(32), 30(39).
(NVIIIe)	179(M <sup>+</sup> 13), 151(9), 150(100), 149(12), 104(27), 103(7), 92(19), 76(28), 51(3), 50(16), 29(12).
(NINe)	164(M <sup>+</sup> 29), 118(17), 117(100), 116(18), 107(4), 106(16), 51(20), 50(13), 39(28).
(XXc)	104(M <sup>+</sup> 100), 77(43), 76(25), 75(9), 51(14), 50(21), 26(10).
(XXf)	149(M <sup>+</sup> 32), 148(8), 132(3), 121(26), 107(6), 106(100), 79(12), 78(70), 52(6), 51(41), 50(19), 43(18), 41(13), 39(11), 27(15).

\*Compounds whose mass spectra are not quoted were identified from their molecular ion.

n-PrNO<sub>2</sub> in AcOH into NH<sub>2</sub>OH (the Nef reaction) which gives, with the aldehydes (I)-(XX), oximes (Id)-(XXd), the latter being dehydrated to nitriles (Ic)-(XXc). The ketones (Ie, f)-(XXe, f) are probably obtained by concurrent splitting off of HNO<sub>2</sub> (in addition to H<sub>2</sub>O) from the intermediate "aldol" - nitroalcohols (Ig)-(XXg) followed by ketonization



[this scheme is supported by the separation of nitrogen oxides which is sometimes observed together with the increase in yields of (Ie, f)-(XXe, f) for an acceptor which can be explained by an increase in the acidity of H<sub>α</sub> and its more facile splitting off under the influence of a base (AcONH<sub>4</sub>)].

We have shown previously [2] that high pressures have a considerable effect on the yield of nitrostyrenes in the Henry reaction. Hence we have compared the manner in which the yields

TABLE 3. PMR Spectra ( $\delta$ , ppm) and Melting Points of Nitrostyrenes (Ia, b)-(XIXa)

Nitrostyrene	Mp, °C	CH=C(CH <sub>3</sub> )NO <sub>2</sub>	CH=C(CH <sub>2</sub> CH <sub>3</sub> )NO <sub>2</sub>	CH=C(CH <sub>2</sub> CH <sub>2</sub> NO <sub>2</sub> )	CH=C(CH <sub>2</sub> CH <sub>2</sub> NO <sub>2</sub> )	CH=C	Aromatic H	Aromatic substituents	Instrument frequency MHz
(Ia)	118-119	2.51 s (3H)	1.30 t (3H)	—	2.94 q (2H)	8.10 s (1H)	6.72 d (2H), 7.42 d (2H)	3.08 s (6H, NMe <sub>2</sub> )	250
(Ib)	90-91.5	—	—	—	—	8.05 s (1H)	6.73 d (2H), 7.41 d (2H)	3.07 s (6H, NMe <sub>2</sub> )	250
(IIa)	63.5-65	2.51 s (3H)	—	—	—	8.10 s (1H)	6.70 d (2H), 7.41 d (2H)	1.21 t (6H, CH <sub>3</sub> CH <sub>2</sub> ), 3.42 q (4H, CH <sub>2</sub> )	250
(IIb)	Oil	—	1.15-1.32 m (9H, all CH <sub>3</sub> )	—	2.94 q (2H)	8.04 s (1H)	6.70 d (2H), 7.40 d (2H)	3.43 q (4H, NCH <sub>2</sub> )	250
(IIIa)	65-67	2.44 s (3H)	1.31 t (3H)	—	2.91 q (2H)	8.05 s (1H)	7.1-7.5 m (4H)	—	250
(IVb)	74.5-76	—	1.28 t (3H)	—	2.83 q (2H)	7.98 s (1H)	6.67 s (2H)	3.91 m (9H, OCH <sub>3</sub> )	250
(Vb)	83-84	—	—	—	—	8.57 s (1H)	6.88 d, 7.42 d (2H), 7.50-7.65 m (2H), 7.85-7.92 m (1H), 8.31-8.39 m (1H)	4.08 s (3H, OCH <sub>3</sub> )	250
(VIa)	63-64.5	2.48 s (3H)	—	—	—	8.11 s (1H)	7.46 m (5H)	—	90
(VIIa)	43-44.5	2.49 s (3H)	—	—	—	8.09 s (1H)	6.98 d (2H), 7.43 d (2H)	3.88 s (3H, OCH <sub>3</sub> )	90
(VIIb)	54-56	—	1.29 t (3H)	—	2.90 q (2H)	8.01 s (1H)	6.98 d (2H), 7.42 d (2H)	3.87 s (3H, OCH <sub>3</sub> )	250
(VIIIa)	71-72.5	2.42 s (3H)	—	—	—	7.99 s (1H)	6.8-7.1 m (3H)	3.80-3.95 m (6H, OCH <sub>3</sub> )	90
(VIIIb)	77.5-79	—	1.31 t (3H)	—	2.92 q (2H)	8.02 s (1H)	6.92-7.12 m (3H)	3.93 s (3H, OCH <sub>3</sub> )	250
(IXa)	89-90	2.42 s (3H)	—	—	—	8.29 s (1H)	6.77 m (2H)	2.28 s (3H, CH <sub>3</sub> ), 3.81 s (3H, OCH <sub>3</sub> ), 3.83 s (3H, OCH <sub>3</sub> )	250
(IXb)	121-122	—	1.30 t (3H)	—	2.86 q (2H)	8.25 s (1H)	6.78 m (2H)	2.28 s (3H, CH <sub>3</sub> ), 3.81 s (3H, OCH <sub>3</sub> ), 3.83 s (3H, OCH <sub>3</sub> )	250
(Xa)	89	2.40 s (3H)	—	—	—	8.29 s (1H)	6.9-7.5 m (4H)	—	250
(Xb)	45-46	—	1.27 t (3H)	—	2.82 q (2H)	8.22 s (1H)	6.9-7.5 m (4H)	3.90 s (3H, OCH <sub>3</sub> )	250
(XIa)	78-49	2.57 s (3H)	—	—	—	7.82 s (1H)	6.57 m (1H), 6.81 m (1H), 6.58 m (1H), 6.81 m (1H), 7.63 m (1H)	3.89 s (3H, OCH <sub>3</sub> )	90
(XIb)	Oil	—	1.22 t (3H)	—	3.06 q (2H)	7.78 s (1H)	7.63 m (1H)	—	250
(XIIa)	87.5-88	2.45 s (3H)	—	—	—	8.03 s (1H)	7.35-7.47 m (4H)	—	250
(XIIIa)	126-128	2.43 s (3H)	—	—	—	8.00 s (1H)	7.17 d (2H), 7.81 d (2H)	—	250
(XIVa)	43-44	2.48 s (3H)	—	—	—	8.06 s (1H)	6.93-7.42 m (4H)	—	250
(XVa)	93-95	2.43 s (3H)	—	—	—	7.98 s (1H)	7.28 d (2H), 7.57 d (2H)	—	90
(XVb)	74-75	—	1.26 t (3H)	—	2.82 q (2H)	7.90 s (1H)	7.25 d (2H), 7.57 d (2H)	3.87 s (3H, OCH <sub>3</sub> )	90
(XVIa)	99.5-100.5	2.47 s (3H)	—	—	—	8.02 s (1H)	7.50-7.95 m (3H)	—	250
(XVIIa)	53-55.5	2.47 s (3H)	—	—	—	8.09 s (1H)	7.65-7.80 m (2H), 8.24-8.32 m (2H)	—	250
(XVIIb)	77-81 †	—	1.29 t (3H)	—	2.83 q (2H)	8.00 s (1H)	7.65-7.80 m (2H), 8.23-8.30 m (2H)	—	250
(XVIIIa)	113.5-114	2.45 s (3H)	—	—	—	8.08 s (1H)	7.61 d (2H), 8.30 d (2H)	—	250
(XVIIIb)	93-102 †, ‡	—	1.26 t (3H)	—	2.81 q (2H)	7.99 s (1H)	7.58 d (2H), 8.27 d (2H)	—	250
(XIXa)	66-68	2.47 s (3H)	—	—	—	8.04 s (1H)	7.41 m (1H), 7.76 m (1H), 8.60-8.70 m (2H)	—	250

\*From MeOH.

†Mixture of Z and E isomers (&lt;10% Z). Substructure of E isomer shown.

‡Aryl hydrogens of Z isomer: 7.38 d (2H), 8.12 d (2H).

of (Ia-f)-(XXa-f) vary with the structure of (I)-(XX) both under the conditions traditionally described in the literature [3] (heating the reactants in AcOH in the presence of AcONH<sub>4</sub>) and also under high pressure under the conditions optimized in [2]. Columns 1, 3, 5, and 7 of Table 1 show the yields of (Ia, b)-(XXa, b) obtained at atmospheric pressure, and columns 2, 4, 6, and 8 at 10 kbar. At atmospheric pressure the yields of (Ia, b)-(XXa, b) are generally higher for aldehydes with strong acceptor substituents on the ring [for example, (XVII) and (XVIII)] and are significantly reduced in the case of donor groups (I) and (II), this tendency being more clearly expressed for (Ib)-(XXb). At 10 kbar, on the other hand, the yields of (Ia, b)-(XXa, b) for donor aldehydes increases considerably while the yields from acceptor are lower, and for the latter, even altering the temperature and the reaction time invariably leads to results worse than at P = 1 atm. The difference between donors and acceptors is even more prominent when one compares not the absolute values of the yields of (Ia, b)-(XXa, b) but their differences, that is whether the yield of nitrostyrene is increased or decreased at 10 kbar in comparison with P = 1 atm and by how much (Table 1, column 9). It turns out that if (I)-(XX) are arranged in decreasing order of this difference their electronic characteristics vary in almost exactly the same way: from the strong donors (I) and (II) to the strong acceptors (XVII)-(XIX) [compound (XX) is not in the series since it gives only traces (<1%) of nitroolefins (XXa, b) under either condition and ketones (XXe, f) are formed exclusively as a result of the strong acceptor properties of the 4-pyridyl group].

High pressure has an effect on the yield not only of (Ia, b)-(XXa, b) but also of (Ic-f)-(XXc-f): In all cases the formation of (Ic-f)-(XXc-f) is almost completely suppressed, resin formation is absent, and isolation of pure (Ia, b)-(XXa, b) is facilitated.

In the literature, the accepted view is that the Henry condensation gives exclusively E-nitrostyrene [1]. Our data are, however, contrary to this conclusion. Sometimes, on heating the reaction mixtures to boiling, a mixture of Z and E isomers is formed, with a preponderance of the latter (the fraction of the Z form does not exceed 10%, see Table 2). However, at 10 kbar the reactions proceed stereospecifically and the Z isomers are not formed at all.

The relationships discovered in the present work make clear the indisputable advantages of the high pressure technique in comparison with traditional methods in the synthesis of  $\omega$ -nitrostyrenes with donor substituents on the ring. It is known that donor-substituted (alkoxy and alkoxyalkyl) nitrostyrenes are of special interest as half-way products in the preparation of the most active and interesting psychotropic  $\beta$ -phenylethylamines. In particular, the improved methods for the synthesis of (VIa), (VIIa), and (IXa, b) which we have put forward makes the corresponding amines, which are used as biologically active and pharmaceutical compounds [4], more accessible.

#### EXPERIMENTAL

Melting points were determined on a Koffler heated stage. PMR spectra were run on a Bruker WM-250 and Jeol-90 FQ spectrometers in CDCl<sub>3</sub> with HMDS internal standard. Chemical shifts are quoted on the  $\delta$  scale from TMS ( $\delta$  HMDS = 0.055 ppm) (Table 3). Qualitative analyses of reaction mixtures were carried out on a Finnigan MAT INCOS-50 quadrupole chromatograph-mass spectrometer with ionization by electron bombardment 70 eV, capillary column 0.25 mm  $\times$  30 m coated with 0.25  $\mu$  polydimethylsiloxane. Quantitative analyses were carried out on a Biochrom 1M gas-liquid chromatograph having a 2 mm  $\times$  3 m glass column with Chromaton N-AW DMCS 0.16-0.20 mm coated with 5% XE-60. Calibration was carried out with pure samples of (I)-(XX) and (Ia, b)-(XIXa) using normal C<sub>14</sub>, C<sub>16</sub>, and C<sub>20</sub> hydrocarbons as reference standards. The accuracy of the analyses was  $\pm 1\%$ . All the E isomers of (Ia, b)-(XIXa) were isolated from the mixtures and characterized by their melting points, and mass and PMR spectra. The Z isomers (Ia, b)-(XIXa), nitriles (Ic)-(XXc), oximes (Id)-(XXd), and ketones (Ie, f)-(XXe, f) were characterized only from the mass spectra of the reaction mixtures (Table 2).

General Method for the Henry Condensation. A. At Atmospheric Pressure. A mixture of 5 g freshly distilled or recrystallized aldehyde (I)-(XX), 5 ml EtNO<sub>2</sub> (or n-PrNO<sub>2</sub>), 2 g AcONH<sub>4</sub> (or 1.9 g i-BuNH<sub>2</sub>), and 20 ml AcOH was heated at bp for 2 h [3], cooled, poured into water, extracted with CHCl<sub>3</sub>, the extract washed with water, dried over Na<sub>2</sub>SO<sub>4</sub> and evaporated. The residue was dissolved in a small quantity of MeOH and cooled to -70°C. If crystallization began, (Ia, b)-(XXa, b) were filtered off, washed with cold (-70°C) MeOH, and dried. If (Ia, b)-(XXa, b) did not separate, the reaction mixture was transferred to a

column ( $l = 10-20$  cm,  $d = 1-2$  cm) packed with  $100 \times 250 \mu$  silica gel and eluted with hexane, benzene, or a mixture of benzene and ether. The yellow nitroolefins (Ia, b)-(XIXa) were collected in the first fraction which was evaporated and the residue crystallized with addition of methanol [except (IIb) and (XIIb)]. For each of the compounds (I)-(XX) the condensation was carried out twice according to the method described. Samples of the reaction mixture were analyzed by chromatography-mass spectrometry and by GLC. The yields of (Ia, b)-(XXa, b) (Table 1) were determined from the results of GLC analysis of the reaction mixtures and the divergence between two determinations (from two independent experiments) did not exceed 6% (in Table 1 the average values are quoted for the yields of (Ia, b)-(XXa, b) and the residual aldehydes (I)-(XX)).

B. At 10 kbar. The ratio of the reagents was the same. Portions of the mixture were placed in Teflon ampuls of 1-1.5 ml volume and heated for 3 h at  $50^\circ\text{C}$  and 10 kbar. Analysis was carried out as described above.

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#### INFLUENCE OF THE NATURE OF THE BASE ELECTROLYTE ON THE REGIOSELECTIVITY OF THE CATHODIC HYDRODIMER- IZATION OF 1-ACETYLNAPHTHALENE IN AN APROTIC MEDIUM

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The electrolysis of 1-acetylnaphthalene at a controlled potential [DMF,  $\text{Ba} \cdot (\text{ClO}_4)_2$ ] leads to the formation of 5-acetyl-1,2,4,5-tetrahydro-2-methyl-2-(1-naphthyl)-1,4-methano-3-benzoxepine (yield of 60%); this is explained by the stabilization of the dimeric dianion of the "head-tail" type by the  $\text{Ba}^{2+}$  cations. The formation of 2,3-dimethyl-2,3-di-(1-naphthyl)-butane-2,3-diol is observed with the acylotropic rearrangement of the intermediate anion, leading to 2-acetylnaphthalene, in the presence of lithium cations.

In one of the recent works dedicated to the electrochemical hydrodimerization of aromatic acetyl derivatives in an aprotic medium [1], it is confirmed that the main products of the dimerization of the corresponding anion radicals (ARs) are dimers of the "head-head" type (pinacones). However, according to recent presentations [2], the regioselectivity of the dimerization of the ARs is determined by the distribution of the electron density on their outer molecular orbitals, which far from always favors the dimerization at the carbonyl group. Therefore, as an example, the electroreduction (ER) of aromatic carbonyl derivatives under conditions permitting disregard of specific interaction with the components of the medium results either in the formation of a low yield of the corresponding pinacones [3] or in the situation where they are not found at all [4]. At the same time, the dimers of the "tail-tail" type, which should be one of the main products of the reaction under consideration according to the theory of [5], are actually isolated in a high yield on the ER of anthracene derivatives in nonaqueous media [4, 6]. The dianions formed by the dimeriza-

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