Chiroptical Properties of *N*-(2-Pyrazinoyl)-α-amino-esters, -aziridines, and Related Compounds †

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A series of pyrazinoyl-amino-esters, -amino-alcohols, and -amines, as well as pyrazinoyl- and quinoxaloyl-aziridines, all with the (*S*)-configuration, were synthesized and their spectral data analysed. The c.d. spectra of the aliphatic and aromatic amino-ester derivatives show sign reversal in the medium bands at *ca.* 270 and 240 nm. Comparable c.d. trends were also observed in the corresponding amino-alcohol and amine derivatives. This was rationalized as due to differences in conformational isomerism. Such c.d. behaviour was not observed in the pyrazinoylaziridines nor in the quinoxaloylaziridines, a fact that suggests similar conformational equilibria in each of these two series. These equilibria are associated with rapid nitrogen inversion and rapid rotation around the CO–N bond. Support for these conclusions comes from ^{1}H n.m.r. and chiral shift reagent n.m.r. studies.

SIGN inversion of c.d. curves has recently been observed for the quinoxaline derivatives of aliphatic and aromatic (*S*)-α-amino-acids and -esters.[1] This prompted further investigation of the parent 1,4-diazine (pyrazine) analogues (I) and (II) (Table 1).

were prepared in a similar way. The parent 2-alkyl- and 2-benzyl-aziridines were obtained in 54—75% yield from the respective amino-alcohols by employing the Wenker method.[3,4] Direct pyrazinoylation of (*S*)-amino-ester hydrochlorides, using pyrazinoyl chloride in

TABLE 1

Analytical and physical data for compounds (I)—(III)

Compound	M.p. (°C) (Recryst. solvent) *	$[\alpha]_D$(°)	Formula (Mol. wt.)	Analysis (%) Required (found) C	H	N	Compound	M.p. (°C) (Recryst. solvent) *	Analysis (%) Found C	H	N
(*S*)-(1a)	Oil	+28.6	$C_9H_{11}N_3O_3$ (209.2)	51.7 (51.6	5.3 5.4	20.1 20.0)	(*RS*)-(1a)	Oil	51.9	5.3	19.9
(*S*)-(2c)	50 (P)	+27.1	$C_9H_{13}N_3O$ (179.2)	60.3 (60.1	7.3 7.2	23.5 23.5)	(*RS*)-(2c)	74 (B + P)	60.0	7.1	23.3
(*S*)-(3a)	Oil	+35.7	$C_{11}H_{15}N_3O_3$ (237.3)	55.7 (55.2	6.4 6.4	17.7 17.5)	(*RS*)-(3a)	Oil	55.5	6.5	17.6
(*S*)-(3b)	55 (C + P)	−30.2	$C_{10}H_{15}N_3O_2$ (209.3)	57.4 (57.5	7.2 7.2	20.1 20.1)	(*RS*)-(3b)	51 (C + P)	57.7	7.2	20.1
(*S*)-(4a)	53 (C + P)	+88.8	$C_{14}H_{13}N_3O_3$ (271.3)	62.0 (61.8	4.8 4.8	15.5 15.5)	(*RS*)-(4a)	101 (C + P)			
(*S*)-(4c)	126 (B + P)	+7.3	$C_{13}H_{13}N_3O$ (227.3)	68.7 (68.2	5.8 5.7	18.5 18.7)	(*RS*)-(4c)	143 (B + P)	68.6	5.8	18.5
(*S*)-(5a)	55 (C + P)	+62.9	$C_{15}H_{15}N_3O_3$ (285.3)	63.2 (63.7	5.3 5.3	14.7 14.6)	(*RS*)-(5a)	88 (C + P)			
(*S*)-(5b)	131 (B)	−70.8	$C_{14}H_{15}N_3O_2$ (257.3)	65.3 (65.4	5.9 5.9	16.3 16.4)	(*RS*)-(5b)	135 (B)	65.6	5.8	16.3
(6)	66 (P)		$C_7H_7N_3O$ (149.2)	56.4 (56.3	4.7 4.7	28.2 28.0)					
(*S*)-(7)	36 (P)	+48.2	$C_8H_9N_3O$ (163.2)	58.9 (58.8	5.6 5.6	25.8 25.5)	(*RS*)-(7)	39 (P)	58.8	5.5	25.8
(*S*)-(8)	Oil	+96.7	$C_{10}H_{13}N_3O$ (191.2)	62.8 (62.4	6.9 6.9	22.0 21.6)	(*RS*)-(8)	Oil	62.9	7.0	21.7
(*S*)-(9)	44 (P)	+95.1	$C_{14}H_{13}N_3O$ (239.3)	70.3 (70.0	5.5 5.5	17.6 17.5)	(*RS*)-(9)	53 (P)	70.2	5.5	17.4
(10)	131 (P)		$C_{11}H_9N_3O$ (199.2)	66.3 (66.2	4.6 4.6	21.1 21.1)					
(*S*)-(11)	101 (P)	+10.4	$C_{12}H_{11}N_3O$ (213.2)	67.6 (67.3	5.2 5.1	19.7 19.7)	(*RS*)-(11)	74 (P)	67.2	5.2	19.8
(*S*)-(12)	61 (P)	+48.0	$C_{14}H_{15}N_3O$ (241.3)	69.7 (69.7	6.3 6.2	17.4 17.3)	(*RS*)-(12)	55 (P)	69.9	6.3	17.4
(*S*)-(13)	104 (P)	+34.9	$C_{18}H_{15}N_3O$ (289.3)	74.7 (74.7	5.2 5.3	14.5 14.5)	(*RS*)-(13)	82 (P)	74.4	5.3	14.5

* B = benzene, C = chloroform, P = Light petroleum (b.p. 60—80 °C).

Some of the pyrazinoyl derivatives of (*S*)-amino-alcohols (Ib), (*S*)-amines (Ic), and (*S*)-aziridines (II) were prepared by the reaction of pyrazinoyl chloride with the appropriate amino-compound.[2] The *N*-(2-quinoxaloyl)aziridines (III) (Table 1), used for comparison,

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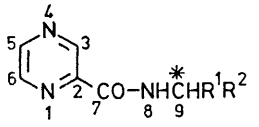
aqueous lithium carbonate,[5] gave a poor yield of (Ia), and considerable hydrolysis of the acid chloride occurred. The pyrazinoyl-(*S*)-amino-esters (Ia) were therefore prepared, in good yields, by direct coupling of pyrazinoic acid with the appropriate amino-ester hydrochloride using diphenylphosphoryl azide as the coupling reagent.[6]

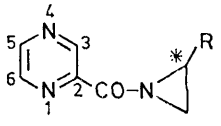
The synthetic routes to compounds (I)—(III) are expected to lead to no racemization. In the present work, this was confirmed by the chiral lanthanide shift reagent (l.s.r.) ^{1}H n.m.r. technique.[7]

The common criterion for optical purity was the 3-H signal of the heteroaromatic ring in (I)—(III), as well as the ester methyl proton signal in (Ia). In addition, particular proton signals for individual cases were also utilized for this purpose.* The signals of these proton probes show splitting for the (*RS*)-compounds in the presence of l.s.r., but in no case do these signals show such splitting in the (*S*)-isomer.

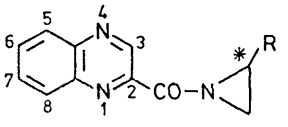


(I)

(1) R^1 = Me
(2) R^1 = Et
(3) R^1 = Pr^i
(4) R^1 = Ph
(5) R^1 = PhCH$_2$
a; R^2 = CO_2Me
b; R^2 = CH_2OH
c; R^2 = Me



(II)



(III)

(6) R = H
(7) R = Me
(8) R = Pr^i
(9) R = PhCH$_2$

(10) R = H
(11) R = Me
(12) R = Pr^i
(13) R = PhCH$_2$

N.M.R. Spectra.—The pyrazinoyl protons in (I) and (II) appear as two doublets at δ 9.20 and 8.60 and a quartet centred at δ 8.46. These signals are assigned to 3-, 6-, and 5-H, respectively. As expected,[8] *para*-coupling was not detected, and *ortho*-coupling ($J_{5,6}$ 2.4 Hz) is larger than *meta*-coupling ($J_{3,5}$ 1.4 Hz).

The n.m.r. spectra of (II) and (III) reflect the stereochemistry of the aziridine ring nitrogen. The parent aziridine ring protons, in each of (6) and (10), give rise to a sharp singlet. This is consistent with rapid nitrogen inversion and rapid rotation around the CO–N bond, and is in agreement with previous reports on *N*-acyl aziridines which indicated high nitrogen inversion rates at ambient temperature.[9] Rotamers were not observed since the CO–N partial double bond character is expected to be very small due to the difficulty of placing a positive charge on the strained aziridine ring nitrogen. Further support for this conclusion may be found from optishift ^{1}H n.m.r. spectral measurements. The 3-H signal in each of (II) and (III) experiences an induced shift (Δδ) much smaller than that observed in the case of the acyclic amide analogues [10] {for instance, δ 2.72 for (7) compared with 5.70 for (2c), both at [tfc]/[substrate] 0.45; also δ 1.72 for (II) compared with 2.63 for (*S*)-*N*-(2-quinoxaloyl)-2-aminobutane at [tfc]/[substrate] 0.40}. This is the expected result of decreased negative charge on the amide oxygen of (7) and (11) which reduces its donor ability. Invertomers and rotamers were also not detected at ambient temperature in the 2-substituted aziridine derivatives (7)—(9) and (11)—(13).

Mass Spectra.—The main fragmentation patterns for the *N*-pyrazinoyl- and *N*-quinoxaloyl-aziridines (II) and (III) are given in SUP 22619. Cleavage of the CO–N bond is the predominant process, in accord with previous observations on *N*-acetyl-[11] and *N*-phenylacetylaziridines.[12] As expected, retro-Chapman [13] rearrangement peaks are also observed, and are produced by the expulsion of HCHO or RCHO from the respective oxazoline ions formed by ring expansion. Amide cleavage also occurs in compounds (I), but is in competition with other fragmentation modes characteristic of the compounds involved. Thus, (4c) gives the iminium ion Ph(CH$_3$)C=NH$_2$ as the base peak, whereas the base peaks in most cases of (Ia and b) are M — CO_2CH_3 and M — CH_2OH, respectively.

U.V. Spectra.—The electronic absorption spectra of the pyrazinoyl derivatives (I) and (II) (Table 2) show, in ethanol and in acetonitrile, three major bands at *ca.* 320 ($n \longrightarrow \pi^*$ transition), 270, and 210 nm ($\pi \longrightarrow \pi^*$ transitions). This assignment conforms to reported u.v. data on pyrazines.[14–16] In iso-octane the 320 nm band is red-shifted and shows fine structure, a behaviour diagnostic of $n \longrightarrow \pi^*$ transitions.

C.D. Spectra.—Among the few reports describing the c.d. spectra of compounds containing the pyrazine chromophore, those of a terpenoid,[15] a steroidal,[15] and some decalinoid [16] pyrazines have recently been presented. We now report c.d. studies on the pyrazinoyl chromophore of the aliphatic and aromatic chiral amino-compounds (I) and (II).

The c.d. spectra of the pyrazinoyl-(*S*)-amino-esters (3a)—(5a) exhibit, in ethanol, Cotton effect bands at *ca.* 325, 270, 240, and 210 nm, besides a shoulder at *ca.* 285 nm (Table 2). These, in general, correspond to u.v. absorption maxima, except for the 240-nm band which coincides with a u.v. minimum, a fact which strongly suggests that the transition is magnetic-dipole allowed, but electric-dipole forbidden in the zero order. The longest and shortest wavelength bands are positive for both aliphatic, (3a), and aromatic, (4a) and (5a), derivatives. However, the c.d. spectra of the aliphatic series differ characteristically from those of the aromatic counterparts in the signs of the medium bands at *ca.* 270 and 240 nm (Eigure). The sign reversal of these two

* Details are available in Supplementary Publication No. SUP 22619 (4 pp.). For details of Supplementary Publications see Notice to Authors No. 7 in *J.C.S. Perkin I*, 1978, Index issue.

TABLE 2

C.d. and u.v. data for the (*S*)-derivatives (I)—(III)

Compound	Solvent *	C.d. $\lambda_{max.}$/nm ($\Delta\varepsilon$)	U.v. $\lambda_{max.}$/nm ($\times 10^{-3}$ ε)
(1a)	E	325 (+0.1), 268 (+1.4), 235 (−1.5), 213 (+0.5)	316 (0.7), 269 (9.4), 210 (11.6)
	A	316 (+0.05), 265 (+1.4), 235 (−1.1), 215 (+0.7)	320 (0.6), 268 (8.3), 208 (10.7)
	O	329 (+0.1), 285 (−0.2), 260 (+0.6), 238 (−0.2), 215 (+1.5)	341—322 † (0.6), 266 (8.7), 208 (10.9)
(2c)	E	325 (−0.2), 276 (+0.6), 253 (−0.2), 230 (+0.1), 210 (−0.7)	320 (0.6), 269 (8.2), 211 (10.2)
	A	327 (−0.1), 275 (+0.8), 230 (+0.5)	322 (0.7), 268 (9.4), 208 (12.0)
	O	345—326 † (−0.1), 291 (+0.2), 276 (+0.6), 232 (+0.3)	342—322 † (0.5), 266 (7.5), 208 (9.7)
(3a)	E	323 (+0.2), 285 (−0.1), 268 (+0.1), 239 (−1.3), 212 (+1.2)	320 (0.6), 270 (8.0), 211 (10.4)
	A	332 (+0.1), 282 (−0.5), 263 (+1.2), 238 (−0.8), 218 (+1.9)	321 (0.6), 268 (8.5), 209 (10.8)
	O	350—325 † (+0.2), 282 (−0.3), 265 (+1.0), 240 (−0.1), 215 (+2.9)	348—321 † (0.6), 267 (7.8), 208 (10.9)
(3b)	E	323 (+0.2), 286 (−0.05), 272 (+0.3), 238 (−0.9)	320 (0.7), 268 (8.6), 210 (10.7)
	A	326 (+0.1), 282 (−0.2), 263 (+0.2), 230 (−0.5)	322 (0.5), 267 (8.1), 209 (10.0)
(4a)	A	325 (+0.2), 280sh (−2.8), 272 (−3.6), 248sh (+1.5), 220 (+17.6)	324 (0.6), 270 (8.6), 207 (17.9)
	E	340 (+0.05), 272 (−4.3), 245sh (+1.8), 220 (+19.8)	322 (0.6), 268 (11.2), 207 (22.7)
	O	321 (+0.1), 272 (−3.8), 247 (+1.6), 221 (+11.5)	343—322 † (0.6), 267 (8.7), 207 (18.7)
(4c)	E	325 (+0.1), 273 (−5.2), 245 (+3.2), 217 (+11.5)	323 (0.6), 270 (8.4), 207 (17.4)
	A	335 (+0.05), 273 (−5.5), 243 (+3.2), 217 (+9.8)	322 (0.6), 268 (8.8), 207 (18.5)
	O	347—328 † (+0.2), 276—268 † (−3.9), 245 (+1.8), 216 (+10.4)	343—321 † (0.5), 266 (7.8), 207 (17.6)
(5a)	E	326 (+0.2), 280sh (−1.4), 274 (−1.7), 252 (+0.8), 215 (+6.9)	322 (0.7), 269 (8.2), 208 (18.5)
	A	330 (+0.1), 273 (−1.6), 250 (+1.5), 215 (+9.6)	312 (0.5), 268 (9.5), 208 (20.3)
	O	342—315 † (+0.1), 273 (−0.8), 248 (+1.5), 214 (+10.3)	342—321 † (0.6), 267 (9.2), 207 (20.4)
(5b)	E	325 (+0.1), 274 (−3.3), 227 (−3.1), 211 (+2.6)	323 (0.9), 269 (8.8), 207 (20.4)
	A	329 (+0.2), 272 (−3.4), 224 (−3.4), 205 (+2.5)	322 (1.0), 268 (9.5), 208 (22.6)
(7)	E	338 (−0.3), 286 (+0.4), 265 (−0.8), 235 (+2.7), 201 (+0.6)	323 (0.7), 269 (9.2), 214 (8.2)
	A	336 (−0.35), 290 (+0.1), 270 (−1.5), 241 (+3.1), 201 (+1.0)	322 (0.6), 270 (10.8), 215 (8.3)
	O	348—334 † (−0.5), 290 (+0.3), 265 (−2.3), 238 (+4.0), 201 (+1.9)	330 (0.5), 268 (9.1), 214 (7.7)
(8)	E	324 (+0.2), 274 (+0.4), 223 (+1.3)	320 (1.1), 268 (7.9), 212 (8.2)
	A	325 (+0.2), 270 (+0.4), 220 (+2.6)	320 (1.0), 268 (7.6), 212 (7.9)
	O	351—336 † (+0.3), 270 (−0.5), 243 (+1.5), 220 (+0.7)	331 (0.6), 267 (8.4), 211 (8.2)
(9)	E	340 (−0.4), 287 (+0.2), 270 (−1.0), 240 (+2.8), 220 (+2.6)	324 (0.8), 268 (9.3), 208 (16.5)
	A	339 (−0.4), 270 (−1.7), 242 (+3.2), 215 (+2.8)	326 (0.9), 268 (8.7), 208 (15.9)
	O	349—340 † (−0.8), 287 (+0.3), 267 (−2.1), 243 (+5.8), 214 (+4.0)	333 (0.6), 267 (9.1), 208 (17.7)
(11)	E	325 (+0.3), 294 (−1.8), 264 (+0.9), 247 (+2.8), 220 (+1.0)	318 (7.0), 245 (35.1), 203 (27.8)
	A	325 (+0.2), 295 (−2.6), 262 (+0.8), 245 (+5.5), 233 (−2.4)	328sh (6.9), 317 (8.0), 243 (41.0), 203 (32.5)
	O	350 (+0.1), 325 (+1.0), 294 (−3.0), 265sh (+1.6), 246 (+7.5), 236 (−3.3), 222 (+0.8)	328 (6.1), 317 (7.2), 305 (6.6), 244 (45.5), 242 (46.3), 203 (35.9)
(12)	E	330 (+0.2), 293 (−0.5), 247 (+3.2), 220 (+2.1)	318 (6.4), 245 (31.9), 203 (25.6)
	A	325 (+0.1), 294 (−0.7), 260sh (+1.9), 247 (+5.4), 223 (+2.2)	328sh (7.1), 316 (8.2), 243 (38.1), 203 (29.0)
	O	328 (+0.2), 295 (−1.6), 260sh (+1.0), 247 (+5.2), 236 (−3.0), 215 (+0.9)	328 (5.7), 317 (6.8), 307 (6.2), 244 (36.2), 241 (37.3), 203 (28.7)
(13)	E	326 (+0.4), 296 (−1.9), 263 (+1.2), 247 (+4.4), 215 (+3.2)	319 (6.7), 245 (33.1), 203 (33.9)
	A	320 (+0.2), 295 (−2.4), 263 (+0.8), 247 (+2.2), 237 (−3.5), 217 (+1.0)	318 (5.7), 244 (32.4), 204 (29.8)
	O	327 (+0.8), 317sh (−0.6), 295 (−3.8), 262 (+2.5) 248 (+6.9), 237 (−6.4), 218 (+2.0)	328 (4.8), 318 (5.6), 245 (35.6) 242 (36.1), 204 (34.0)

* A = acetonitrile; E = ethanol (95%); O = iso-octane. † Fine structure.

bands might be attributed to differences in conformational isomerism in the different series. Arguments along the lines adopted in previous, related work [1,17] apply here also.

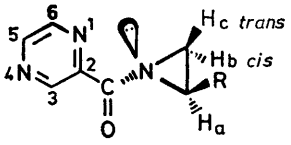
The aliphatic amino-alcohol (3b) exhibits, in organic solvents, c.d. spectra that are similar to those observed for the aliphatic amino-ester analogues (band positions and signs). The c.d. spectra of the 3-phenylpropan-1-ol derivative (5b) also resemble those of the aromatic amino-ester analogues in the respective solvents, except for the appearance of a negative Cotton effect band around 230 nm which, by virtue of its strength, obscures the 240 nm band.

The aromatic amine derivative (4c) has Cotton effect bands that very closely resemble those of the aromatic amino-ester series, while the c.d. spectra of the aliphatic amine counterpart (2c) show sign reversal, when compared with those of (4c) in the solvents studied. This chiroptical behaviour of the aliphatic and aromatic pairs of the amino-alcohol and amine derivatives might be rationalized, by analogy with series (Ia), as due, in either case, to conformational differences.

In the solvents studied, the c.d. spectra of the pyrazinoylaziridines (7)—(9) are similar (band positions and signs). The slight differences that characterize (8) might be caused by the steric influence of the isopropyl substituent. $\Delta\varepsilon$ Values for the bands at *ca.* 210 and 270 nm increase hyperchromically with decreased solvent polarity (Table 2).

It is noteworthy that sign reversal for certain c.d. bands is not observed in the aziridine series. This implies that the aliphatic and aromatic pyrazinoylaziridines most probably have similar conformational equilibria. In the predominant conformer (A), the amide nitrogen of the non-flexible aziridine ring is strongly pyramidal [18] and displays rapid nitrogen inversion, accompanied by rapid rotation around the CO–N bond at ambient temperature. This is reminiscent of the conclusion about the absence of rotamers and invertomers previously derived from the ^{1}H n.m.r.

studies. The pyrazinoyl group in (A) is *trans* to the aziridine ring substituent (R), and this ensures minimal aryl–heteroaryl interaction.



(A)

Furthermore, the c.d. spectra of the aliphatic and aromatic quinoxaloylaziridines (III) are similar in the solvents studied (Table 2). Again, this similarity could be traced back to similar conformational isomerism where a conformation analogous to (A) prevails.

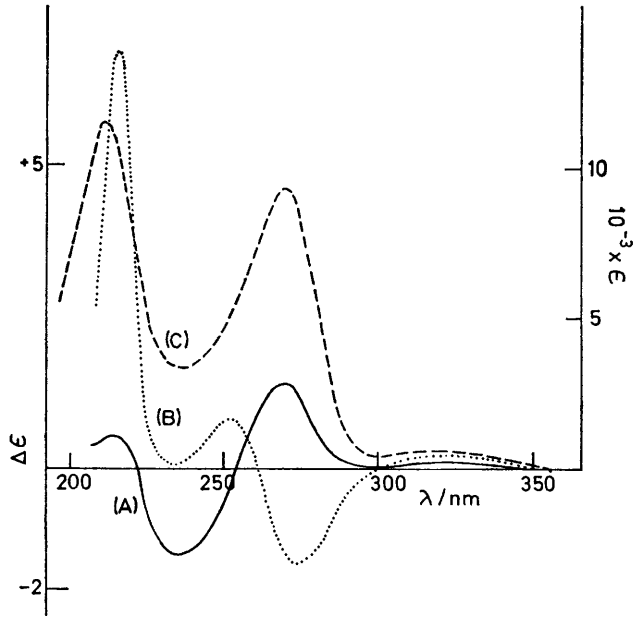


FIGURE C.d. curves of (*S*)-(1a) (A) and (*S*)-(5a) (B) in ethanol. U.v. curve of (5a) (C) in ethanol

EXPERIMENTAL

Chemicals and instruments, required for this study, have been previously reported.[1,7c,17] Optical rotations were measured at 20 ± 1° in chloroform (*c* 1—2) for compounds (I)—(III), and in ethanol (*c* 1.5) for the parent aziridines. N.m.r. spectra were taken for solutions in $CDCl_3$. M.p.s and b.p.s are uncorrected. Analyses were carried out in the laboratory of Drs. F. and E. Pascher (Bonn).

2-*Substituted Aziridines*.—A cold mixture of sulphuric acid (98%, 100 g), and water (100 ml) was added to an amino-alcohol (1.0 mol) in water (60 ml) at 0—5 °C. The mixture was heated to 120 °C and the water was distilled off *in vacuo*. The solid sulphate residue (1.0 mol) was powdered, washed with methanol (for alaninol) or with acetone (for valinol), treated with 6.2N-potassium hydroxide, and distilled. The distillate (300 ml) was cooled and saturated with potassium hydroxide pellets. The organic layer was separated, stored over potassium hydroxide for 24 h in the cold, and fractionally distilled. For 2-benzylaziridine, the crude sulphate residue was treated directly with potassium hydroxide solution, and the mixture was steam distilled. The distillate was collected in ether (100 ml) over potassium hydroxide. The ether layer was separated, dried, and distilled through a short column. (*S*)-2-Methylaziridine had b.p. 65—66 °C at 690 mmHg (lit.,[4] 66—67° at 760 mmHg); $[\alpha]_D$ −12.4° (lit.,[4] −12.8°, *c* 2.27 in ethanol at 25 °C). The (*RS*)-isomer had b.p. 65—66 °C at 690 mmHg (lit.,[4] 66—67 °C at 760 mmHg). (S)-2-*Isopropylaziridine* had b.p. 100—101 °C at 690 mmHg; $[\alpha]_D$ −21.8° (Found: C, 70.4; H, 12.95; N, 16.5. $C_5H_{11}N$ requires C, 70.5; H, 13.0; N, 16.45%). The (*RS*)-isomer had b.p. 100—101 °C at 690 mmHg (lit.,[19] 103—104 °C at 760 mmHg). (S)-2-*Benzylaziridine* had b.p. 73—74 °C at 1.0 mmHg; $[\alpha]_D$ −26.9° (Found: C, 81.1; H, 8.4; N, 10.4. $C_9H_{11}N$ requires C, 81.2; H, 8.3; N, 10.5%). The (*RS*)-isomer had b.p. 73—74 °C (lit.,[20] 68—70 °C at 0.5 mmHg).

N-(2-*Pyrazinoyl*)*amino-esters* (Ia).—To a stirred mixture of pyrazinoic acid (Merck; 0.1 mol) and the appropriate amino-ester hydrochloride (0.11 mol) in dimethylformamide was added diphenylphosphoryl azide (0.11 mol) in dimethylformamide (20 ml) at 0 °C. Triethylamine (0.22 mol) was then added, and stirring was continued for 4 h at 0 °C and overnight at room temperature. The mixture was poured over crushed ice (400 g), and extracted with chloroform. The solvent was removed and the oily residue was purified using t.l.c. The racemates of (4a) and (5a) were obtained by refluxing the respective (*S*)-isomers in triethylamine for 72 h. The (*S*)-derivatives (1a) and (3a) could not, however, be racemized under these conditions. Yields were in the range 75—86%.

N-(2-*Quinoxaloyl*)*aziridines* (III).—To a stirred solution of the aziridine (0.1 mol) and triethylamine (0.11 mol) in benzene (200 ml) was added, dropwise, a solution of 2-quinoxaloyl chloride (0.1 mol) in benzene at 7—12 °C. Stirring was continued for 2 h at ambient temperature. The benzene solution was filtered and the filtrate was washed twice with 1N-potassium hydroxide, then with water, dried (Na_2SO_4), and evaporated. The yellowish residue was crystallized (Norit) from the appropriate solvent. Yields were in the range 68—82%.

N-(2-*Pyrazinoyl*)*aziridines* (II).—These were prepared from the interaction of pyrazinoyl chloride [21] with the parent aziridines as described for (III) above, except that benzene–toluene (4 : 1 v/v) was used at 0 °C, and aqueous sodium hydrogencarbonate was substituted for potassium hydroxide. The crude oily products crystallized rapidly upon pouring over light petroleum. Compounds (*S*)-(7) and (*RS*)-(7) were liquids. Yields were in the range 60—75%.

Compounds (II) are rather unstable at ambient temperature, though they are stable when stored in the cold (neat or under light petroleum). The order of stability is (9) > (8) > (7) > (6).

N-(2-*Pyrazinoyl*)*amines* (Ic).—These were prepared as for (II) above, except that the benzene–toluene filtrate was washed first with 0.25N hydrochloric acid, and then with alkali. Yields were in the range 50—61%.

N-(2-*Pyrazinoyl*)*amino-alcohols* (Ib).—The general pyrazinoylation procedure above was also applied here. A slight excess (*ca.* 10%) of the amino-alcohol was used. Powdered (*S*)-3-phenylpropan-1-ol was suspended in benzene; its pyrazinoyl derivative (5b) precipitated from the reaction mixture together with triethylammonium chloride. The latter was removed by soaking in water. Yields were in the range 58—67%.

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REFERENCES

[1] M. M. El-Abadelah, S. S. Sabri, M. Z. Nazer, and M. F. Za'ater, *Tetrahedron*, 1976, **32**, 2931.
[2] T. A. Foglia, L. M. Gregory, and G. Maerker, *J. Org. Chem.*, 1970, **35**, 3779.
[3] H. Wenker, *J. Amer. Chem. Soc.*, 1935, **57**, 2328.
[4] Y. Minoura, M. Takebayashi, and C. C. Price, *J. Amer. Chem. Soc.*, 1959, **81**, 4689.
[5] J. D. Taylor, U.S.P. 2,864,821/1958 (*Chem. Abs.*, 1959, **53**, 8178c).
[6] T. Shioiri, K. Ninomiya, and S. Yamada, *J. Amer. Chem. Soc.*, 1972, **94**, 6203.
[7] (*a*) R. Von Ammon, and R. D. Fischer, *Angew. Chem. Internat. Edn.*, 1972, **11**, 675; (*b*) B. C. Mayo, *Chem. Soc. Rev.*, 1973, **2**, 49; (*c*) M. M. El-Abadelah, S. S. Sabri, H. D. Tabba', and H. Duddeck, *J. Heterocyclic Chem.*, 1977, **14**, 871 and references therein.
[8] G. S. Marx and P. E. Spoerri, *J. Org. Chem.*, 1972, **37**, 111.
[9] G. R. Boggs and J. T. Gerig, *J. Org. Chem.*, 1968, **34**, 1484; F. A. L. Anet and J. M. Osyany, *J. Amer. Chem. Soc.*, 1967, **89**, 352.
[10] M. M. El-Abadelah, S. S. Sabri, and M. H. Abu Zarga, unpublished data.
[11] R. G. Kostyanovsky, V. G. Plekhanov, Kh. Khafizov, L. M. Zagurskaya, G. K. Kadorkina, and Yu. I. Elnatanov, *Org. Mass Spectrometry*, 1973, **7**, 1113 and references therein.
[12] H. Schwarz and F. Bohlmann, *Tetrahedron Letters*, 1973, 3703.
[13] T. Z. Papoyan, I. I. Tchervin, and R. G. Kostyanovsky, *Izvest. Akad. Nauk S.S.S.R., Otdel Khim. Nauk*, 1968, 1530, 2399.
[14] F. Halverson and R. C. Hirt, *J. Chem. Phys.*, 1951, **19**, 711; K. K. Innes, J. P. Byrne, and I. G. Ross, *J. Mol. Spectroscopy*, 1967, **22**, 125.
[15] H. E. Smith and A. A. Hicks, *Chem. Comm.*, 1970, 1112.
[16] G. Snatzke and E. Hajós, *Heterocycles*, 1976, **5**, 299 and references therein.
[17] S. S. Sabri, M. M. El-Abadelah, and M. F. Za'ater, *J.C.S. Perkin I*, 1977, 1356.
[18] R. P. Shibaeva, L. O. Atovmyan, and R. G. Kostyanovsky, *Doklady Akad. Nauk S.S.S.R.*, 1967, **175**, 586.
[19] C. S. Dewey and R. A. Bafford, *J. Org. Chem.*, 1967, **32**, 3108.
[20] K. Brewster and R. M. Pinder, *J. Medicin. Chem.*, 1972, **15**, 1078.
[21] I. A. Solomons and P. E. Spoerri, *J. Amer. Chem. Soc.*, 1953, **75**, 679.