Journal of Chromatography, 170 (1979) 73–80

CHROM. 11,463

CHROMATOGRAPHY OF BENZOTHIAZOLES

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(Received September 11th, 1978)

SUMMARY

Thin-layer chromatography (TLC) of some 2-alkyl-, 2-aryl- and 2,2′-bis-benzothiazoles has been examined to develop analytical procedures and to determine the influence of substituents. No simple relationship was found for the R_M values of the 2-alkyl derivatives but the R_M values of the 2,2′-bis compounds showed linear behaviour, indicative of mixed partition–adsorption and pure partition separation, respectively. ΔR_M values were calculated for the compounds and shown to be characteristic of structural features.

Gas–liquid chromatographic (GLC) behaviour was studied on SE-30 and Carbowax 20M columns. In this case both 2-alkyl- and 2,2′-bis-benzothiazoles show exponential relationships between retention times and carbon chain length of substituents.

The calculated TLC and GLC relationships can provide a basis for the identification of components of reaction mixtures of benzothiazoles.

INTRODUCTION

Relatively few reports have appeared in the literature on the chromatography of benzothiazoles. Only one restricted study of the chromatographic behaviour of 2-substituted benzothiazoles has appeared incidental to an examination of a wider series of thiazoles and related heterocyclic ring systems[1–3].

The present report is concerned with a more complete series of 2-alkyl-, together with some 2-aryl- and 2,2′-bis-benzothiazoles. Solvent combinations have been studied in thin-layer chromatography (TLC) and two columns, SE-30 and a contrasting polar Carbowax 20M, have been used over a range of temperatures to evaluate gas–liquid chromatographic (GLC) behaviour. These studies have been carried out in order to establish conditions for the separation and identification of the compounds, and also to investigate the influence of structure on chromatographic behaviour.

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EXPERIMENTAL

Materials

2-Alkyl- and 2-aryl-benzothiazoles were synthesized from 2-aminothiophenol and the appropriate carboxylic acid[4]. A modified procedure, employing polyphosphate ester as reaction medium, gave consistent high yields of products after short reaction times[5]. 2,2′-Bisbenzothiazoles were prepared similarly from 2-aminothiophenol and the corresponding dicarboxylic acids. All compounds had satisfactory elemental analysis.

Procedures

TLC on Merck silica gel 60 precoated plates (0.25 mm) was carried out with a series of solvents. Spots were readily located by inspection under ultraviolet light (254 nm), or by exposure of plates to iodine vapour.

GLC on glass columns (90 × 0.5 cm I.D.) was carried out at various temperatures using SE-30 (10%) and Carbowax 20M (10%), applied by the filtration technique, to 100–120 mesh Celite, previously acid washed and treated with hexamethyldisilazane. Nitrogen (30 ml/min) was used as the carrier gas, with a flame-ionization detector.

RESULTS AND DISCUSSION

TLC results for 2-alkyl-, 2-aryl- and 2,2′-bis-benzothiazoles are reported in Table I.

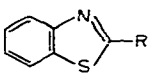
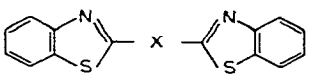
The bunched R_F values obtained at the origin and front with light petroleum and ethyl acetate individually were satisfactorily spread by the four combinations listed.

For the 2-alkyl derivatives R_F values increase as the side chain lengthens but with decreasing increments so that no effective separation is possible for members higher than C_9. The anomalous behaviour of the parent compound, benzothiazole (R = H) is also noted. In contrast R_F values for 2,2′-bis-benzothiazoles decrease with increase in length of the bridge between the two rings.

To investigate further the chromatographic behaviour, R_M values for the compounds were calculated for solvent systems 1 and 3 and are listed in Table I. These values were plotted *vs.* the number of C-atoms in the side chain, for straight chain 2-alkyl derivatives (Fig. 1), where it can be seen that the points do not fit a straight line. Instead a smooth curve can be constructed with a discontinuity for the parent substance. From the theory of partition chromatography it follows that a linear relationship is expected for R_M *vs.* C-number plots for homologous series. This has been verified on numerous occasions for paper chromatography but is less common for TLC where mixed partition and adsorption effects are normally encountered[6]. The observed relationship between R_M and C-number in the present case verifies that they are being separated by mixed adsorption–partition effects. R_M values for the bis compounds were also plotted against C-number of the bridge (Fig. 2) and in this case a straight line relationship holds. This may be taken as an indication that these compounds are being separated by partitioning.

The ΔR_M value, defined as $\Delta R_M = R_M$ (system A) $- R_M$ (system B), should

TABLE I
TLC OF BENZOTHIAZOLES ON SILICA GEL

Compound	($R_F \times 100$) in solvent systems*				R_M** in solvent systems		ΔR_M*** (1–3)
	1	2	3	4	1	3	
R							
H	23	35	49	63	0.525	0.017	0.508
CH_3	21	36	48	59	0.575	0.035	0.540
C_2H_5	29	44	56	64	0.389	−0.104	0.493
C_3H_7	34	48	63	66	0.288	−0.231	0.519
C_4H_9	37	54	66	67	0.231	−0.288	0.519
C_5H_{11}	39	58	69	67	0.194	−0.347	0.541
C_6H_{13}	40	59	70	68	0.176	−0.368	0.544
C_7H_{15}	41	59	71	68	0.158	−0.389	0.547
C_8H_{17}	42	59	71	68	0.140	−0.389	0.529
C_9H_{19}	43	60	73	69	0.122	−0.432	0.544
$CH(CH_3)_2$	36	53	67	65	0.250	−0.308	0.558
$C(CH_3)_3$	45	61	74	67	0.087	−0.454	0.541
C_6H_5	42	54	68	68	0.140	−0.327	0.467
p-Methylphenyl	44	52	66	70	0.105	−0.288	0.393
o-Hydroxyphenyl	46	46	64	65	0.070	−0.250	0.320
Styryl	32	46	65	67	0.327	−0.269	0.596
X							
—	39	40	64	65	0.194	−0.250	0.444
$-(CH_2)-$	34	33	57	63	0.288	−0.122	0.410
$-(CH_2)_2-$	28	28	50	58	0.410	0	0.410
$-(CH_2)_3-$	22	23	43	55	0.550	0.122	0.428
$-(CH_2)_4-$	19	22	39	53	0.630	0.194	0.436

* Solvent systems: light petroleum (b.p. 40–60°)–ethyl acetate in the ratios 1 = 9:1; 2 = 3:1; 3 = 1:1; 4 = 1:3.

** $R_M = \log\left(\frac{1}{R_F} - 1\right)$.

*** ΔR_M = R_M (system 1) − R_M (system 3).

be constant for a homologous series, but will change with the introduction of a substituent[7]. This concept has been tested for the three groups of compounds studied and ΔR_M values are listed in the last column of Table I. The values for the 2-alkyl derivatives are reasonably constant with an average of 0.53. Excellent results were also obtained for the bis compounds with an average value of 0.43. As expected for the aryl derivatives, which have a variety of substituents in the aromatic ring, values of ΔR_M vary considerably. In the benzothiazoles studied, derived ΔR_M values could have potential in aiding structural interpretation of unknowns.

GLC results for 2-alkylbenzothiazoles on the SE-30 and Carbowax columns are summarized in Table II. For the non-polar SE-30 column retention times increase in accord with increasing boiling point. The optimum temperature for separation of the series was 180°. Table II shows that at 120° excellent resolution is obtained with

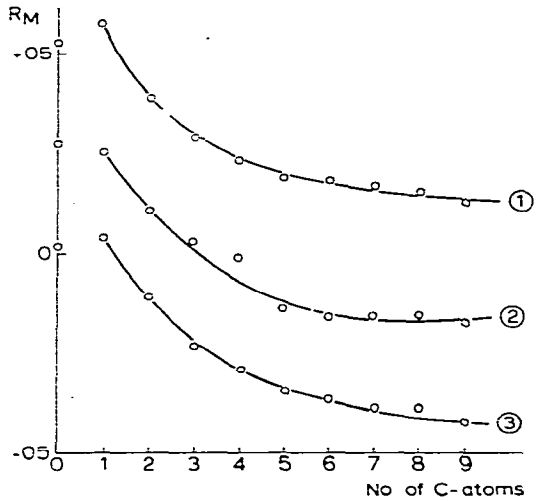


Fig. 1. R_M *vs.* C-number of 2-alkylbenzothiazoles.

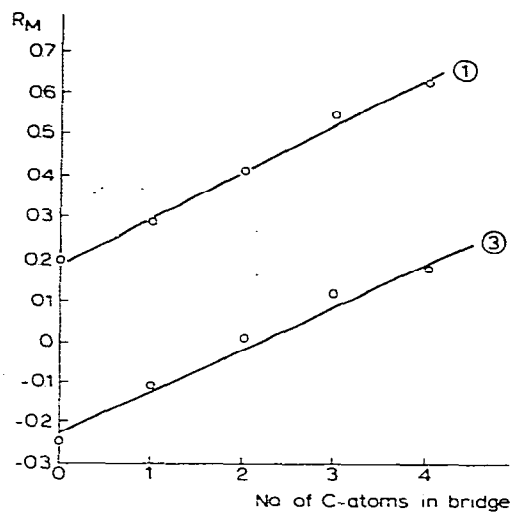


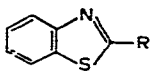
Fig. 2. R_M *vs.* C-atoms in bridge of 2,2'-bis-benzothiazoles.

acceptable retention times for chain lengths up to C_4 after which retention times are unduly increased and the highest members do not emerge. Conversely at the highest temperature employed, 230° separation of long chain derivatives is satisfactory at some sacrifice of resolution of lower members of the series. Separation over the complete series was achieved by temperature programming (Fig. 3). Plots of retention times *vs.* C-number of the series show straight line behaviour as anticipated for a homologous series (Fig. 4).

On the Carbowax column retention times were much longer, indicating a strong attachment of the benzothiazole ring for this phase. Much higher temperatures were necessary and this restricted the range of temperatures available. However data

TABLE II

GLC OF 2-ALKYLBENZOTHIAZOLES



R	Retention times (sec)									
	SE-30 column							Carbowax column		
	120°	140°	160°	180°	200°	220°	230°	200°	215°	240°
-H	111	72	42	30	22	15	12	232	181	106
$-CH_3$	168	102	54	36	25	18	15	212	173	104
$-C_2H_5$	264	132	78	39	33	24	18	256	201	116
$-C_3H_7$	408	222	102	71	47	27	24	319	236	136
$-CH(CH_3)_2$	309	180	93	66	39	27	24	244	197	118
$-C_4H_9$	726	279	165	80	63	42	36	431	314	173
$-C(CH_3)_3$	375	195	96	71	39	30	24	244	185	110
$-C_5H_{11}$	—	498	225	121	75	60	48	594	413	219
$-C_6H_{13}$	—	774	354	175	108	72	60	803	551	276
$-C_7H_{15}$	—	—	582	275	123	96	78	1102	740	354
$-C_8H_{17}$	—	—	—	400	200	132	102	—	970	480
$-C_9H_{19}$	—	—	—	618	288	192	145	—	1339	591

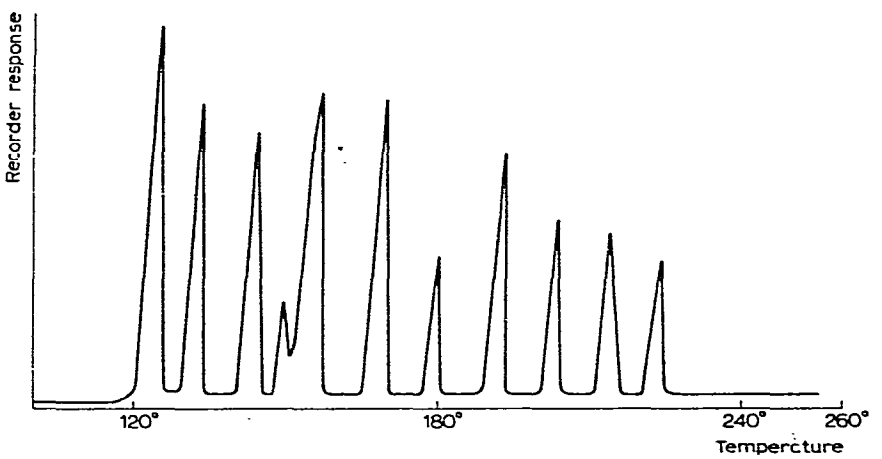


Fig. 3. Separation of 2-alkylbenzothiazoles using temperature-programming conditions. Initial temperature, 120°; heating rate 5°/min; final temperature 260°.

derived from three temperatures indicated that separation was satisfactory. Log retention times *vs.* C-number of side chains gives straight line relationships with in this case significant deviation for the parent compound, benzothiazole (Fig. 5).

Fig. 6 illustrates the relationship between log retention timex on SE-30 *vs.* the same function on Carbowax at the same temperature. A classic linear relationship is obtained for the straight chain 2-alkyl derivativex with deviation for the branched 2-isopropyl- and more significantly for the 2-*tert.*-butyl isomer. The above relationships are sufficiently accurate to be used for identification purposes.

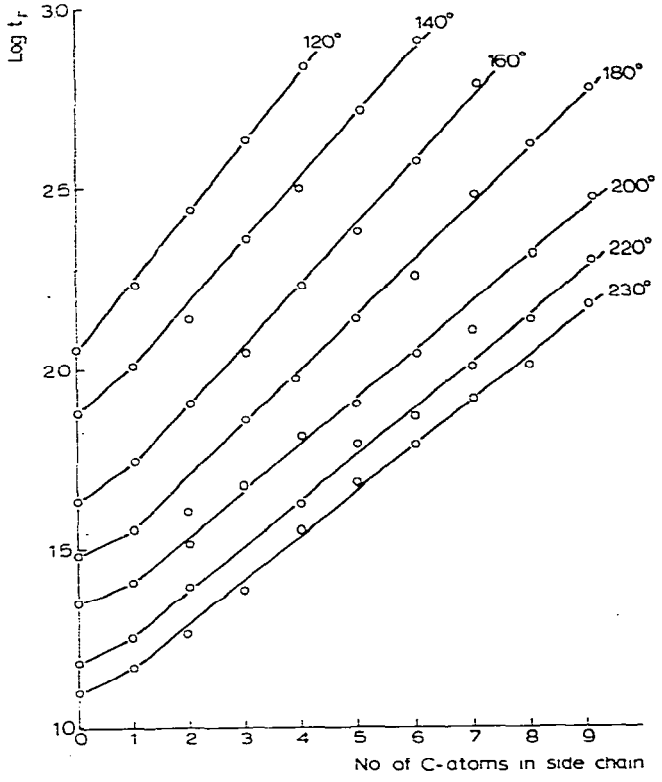


Fig. 4. Log t_R of 2-alkylbenzothiazoles *vs.* C-number (SE-30).

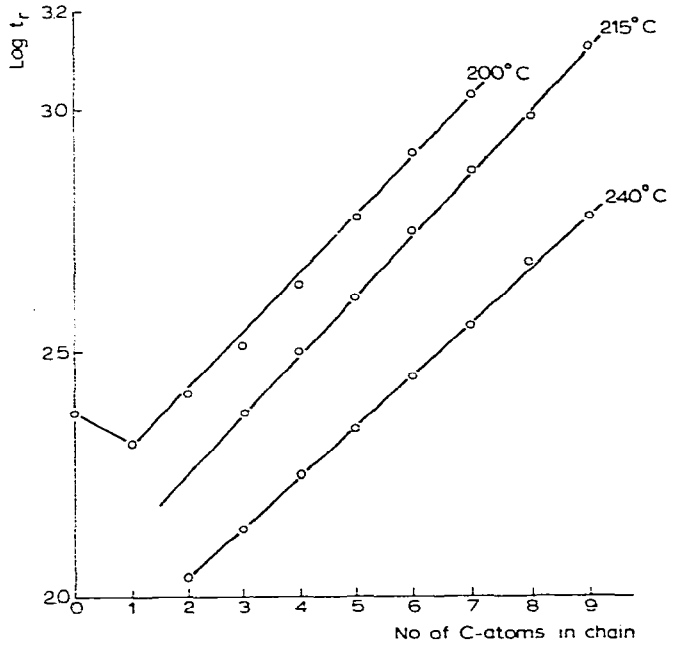


Fig. 5. Log t_R of 2-alkylbenzothiazoles *vs.* C-number (Carbowax).

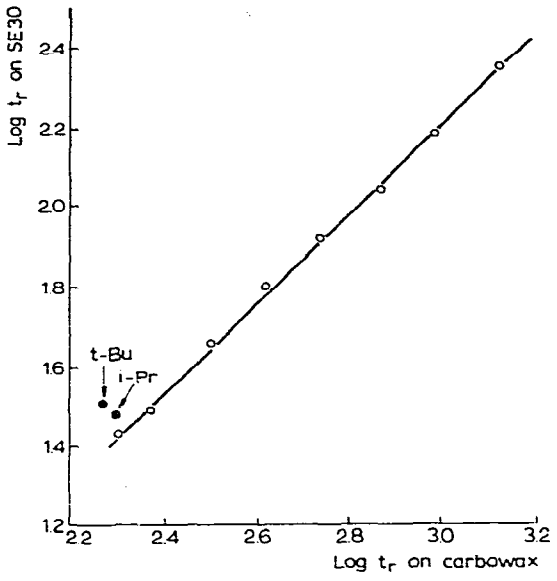
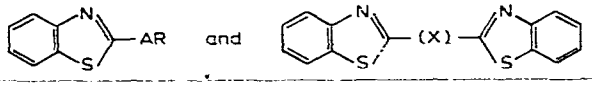
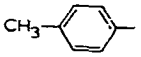
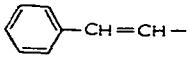


Fig. 6. Log t_R on SE-30 *vs.* log t_R on Carbowax for 2-alkylbenzothiazoles.

TABLE III

GLC RESULTS FOR 2-ARYLBENZOTHIAZOLES AND 2,2′-BIS-BENZOTHIAZOLES ON SE-30



Compound	*Retention times (sec)*			
	220°	*240°*	*260°*	*280°*
Ar				
	150	96	60	42
	222	132	84	54
	252	144	90	60
	290	210	126	78
–(X)–				
$-(CH_2)-$	—	300	148	114
$-(CH_2)_2-$	—	372	200	120
$-(CH_2)_3-$	—	528	324	150
$-(CH_2)_4-$	—	750	500	186

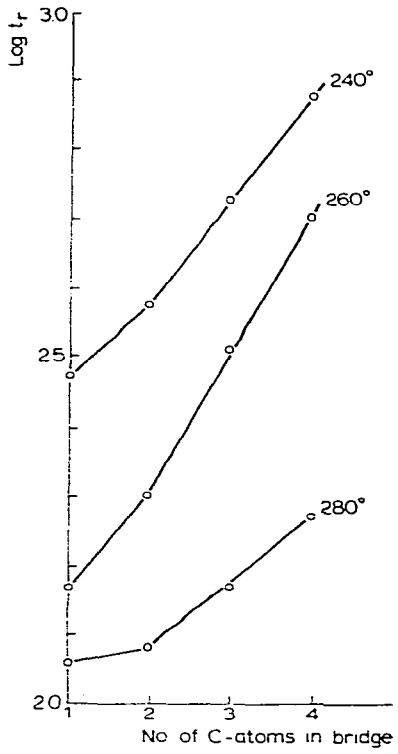


Fig. 7. Log t_R of bis-benzothiazoles *vs.* C-number (SE-30).

2-Arylbenzothiazoles and 2,2′-bis-benzothiazoles were also chromatographed on the SE-30 column (Table III) with satisfactory separation. For the latter group a plot of log retention time *vs.* the number of methylene groups in the bridge gave a straight line with deviation for the first member (Fig. 7). The Carbowax column proved to be unsuitable for these compounds since at the maximum operating temperature (250°), retention times were long and only very broad peaks were obtained.

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