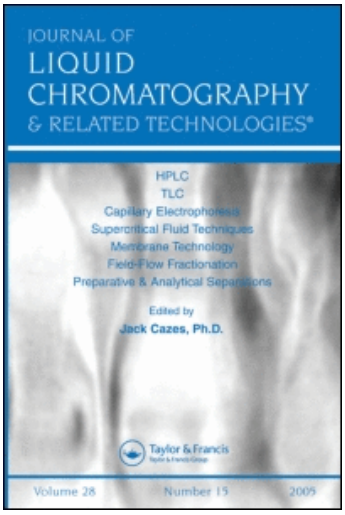

Journal of Liquid Chromatography & Related Technologies
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597273

An Application of Aryl Stationary Phases for Separation of Select Organogermanium Compounds

Mariusz Kluska[a]
[a] Institute of Chemistry, University of Podlasie, Poland

To cite this Article Kluska, Mariusz(2008) 'An Application of Aryl Stationary Phases for Separation of Select Organogermanium Compounds', Journal of Liquid Chromatography & Related Technologies, 31: 2, 210 — 218
To link to this Article: DOI: 10.1080/10826070701738845
URL: http://dx.doi.org/10.1080/10826070701738845

Journal of Liquid Chromatography & Related Technologies®, 31: 210–218, 2008

ISSN 1082-6076 print/1520-572X online
DOI: 10.1080/10826070701738845

An Application of Aryl Stationary Phases for Separation of Select Organogermanium Compounds

Mariusz Kluska

Institute of Chemistry, University of Podlasie, Poland

Abstract: In this paper are reported the results of the continuation of investigations concerning optimization of the chromatographic process of benzylgermanium derivatives. Optimal conditions of separation and determination have been elaborated for di-, tri-, and tetra-benzylhalogeno germanium derivatives using aryl stationary phases. Interaction of a π-π type between a stationary phase and a chromatographed compound exhibited predominance in this process. During determination numerous difficulties were observed. These difficulties were caused, as had been shown in earlier experiments, by column surface modification. Three stationary phases and two mobile phases were taken under consideration. The best selectivity and separation factors $\alpha_1 = 3.50$ and $\alpha_2 = 1.46$ were obtained using the RP Si-PGC column and pure dichloromethane. Slightly worse results were yielded with the naphthyl stationary phase.

Keywords: Aryl stationary phases, Benzylgermanium, π-π Interactions, Surface modification, Chromatography

INTRODUCTION

Benzyl derivatives of germanium are analogues of silicon compounds. Their practical application in the synthesis of extended organic systems has been long confirmed and reported.[1] A chemistry of organogermanium compounds is of exciting progressive interest. Subtle differences of physical chemical properties significantly influence the biological activity

Correspondence: Mariusz Kluska, Institute of Chemistry, University of Podlasie, ul. 3 Maja 54, 08-110, Poland. E-mail: kluskam@ap.siedlce.pl

of germanium compounds, which is higher than the biological activity of their silicon analogue.[2] Among benzyl derivatives of germanium, the most biologically active are benzylgermatranes.[3] Their toxicity is low; they possess anaesthetic and anticonvulsive properties, and they improve memorization ability.[4] Some other germanium compounds, e.g., Ge-132 are used in anticancer therapy.[3]

Germanium derivatives are still considered a group of compounds with insufficiently known properties, but there are great expectations of their possible applications. Determined benzylgermanium derivatives showed an ability of modification of stationary phase surface.[5]

This ability decreases with a number of benzyl groups (it is the lowest in case of tetrabenzylgermanium). Monobenzyl derivatives of germanium are forming the strongest binding with a stationary phase surface. These bindings cannot be broken during the usual elution process. Only when inorganic concentrated acids: sulfuric (VI) or hydrochloric were used, were inorganic germoxanes formed.[5] Therefore, in results presented here, chromatography data of monobenzyl derivatives are omitted. Simultaneously, this information can be a warning against a possibility of modification of stationary phase and therefore, errors made during determination of various compounds by means of this column.

Similarly, the dibenzylgermanium subsistent is bound by the stationary phase surface to such a degree, that breaking of this binding and transformation into dibenzylgermoxanes, requires the use of polar solvents.[5] On the other hand, binding of tribenzylchlorogermanium with the stationary phase surface, because of a sterically spacious group, is slightly weaker. They can be disrupted by the use of aqueous organic solvent, and then germanium is eluted in the form of hexabenzyldigermoxane. However, an application of anhydrous solvent (dichloromethane) enables tribenzylchlorogermanium to pass unchanged through the column. Therefore, for determinations only anhydrous solvent should be used.

In consideration of these difficulties in the determination of the above mentioned compounds (caused mainly by the possibility of modification of stationary phase surface and unsatisfactory exploration of their possible application), the investigation concerning the optimal condition of their separation and determination seems to be rational.

EXPERIMENTAL

Analysis of Benzylgermanium Derivatives by HPLC Using Aryl Stationary Phase

On the basis of an earlier report concerning models of column surface modification[6] (Figure 1), samples of di-, tri-, and tetrabenzylgermanium (Figure 2) were dissolved in dichloromethane (HPLC purity, Fluka AG, Buchs,

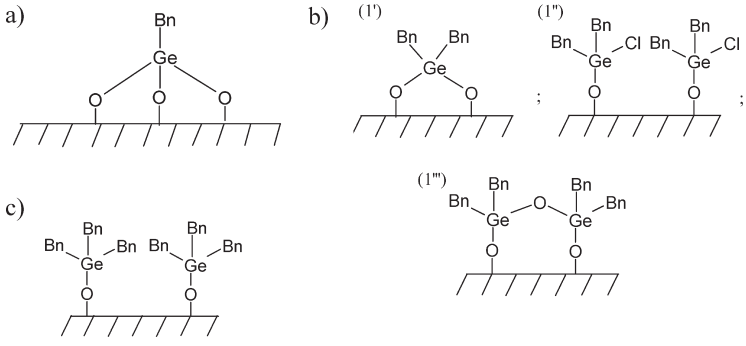

Figure 1. Scheme of structures stationary phase surface modification by a) benzyltrichlorogermanium, b) dibenzyldichlorogermanium, c) tribenzylchlorogermanium (Bn = $PhCH_2$).

Switzerland) obtaining a concentration at about 20 $\mu g \cdot mL^{-1}$ and subjected to HPLC analysis. Analysis was carried out at wavelength 242 nm and temperature 20°C. Three stationary phases were tested: phenylbutyl (RP Si-PB), naphthylpropyl (RP Si-NAF), and hypercarb (RP Si-PGC), (Figures 3–4, Table 1).[7] Dimensions of the steel columns were, respectively, RP Si-PB–125 × 4.6 mm, RP Si-NAF–125 × 4.6 mm, RP Si-PGC–100 × 4.6 mm. Two anhydrous mobile phases were used: dichloromethane and methanol. The organogermanium compounds were prepared by the method described in the literature.[6]

Dibenzyldichlorogermanium

^{1}H NMR, δ (ppm) 3.02 (s, 4H, CH_2Ge), 7.09–7.36 (m, 10H, aromat.). ^{13}C NMR, δ (ppm) 33.92 (-CH_2-), 126.53, 128.82, 129.07, 133.22 ($C_{aromat.}$). MS (EI), m/z (%): 328* (3.46), 182 (1.80), 104 (2.15), 91 (100). UV/Vis ($CHCl_3$): λ_{max} (lgε) = 242 (4.62), 267 (4.57), 288 (4.54).

Tribenzylchlorogermanium

^{1}H NMR, δ (ppm) 2.61 (s, 6H, CH_2Ge) 6.84–7.31 (m, 15H, aromat.). ^{13}C NMR, δ (ppm) 26.73 (-CH_2-), 125.41, 128.59, 128.62, 136.41 ($C_{aromat.}$).

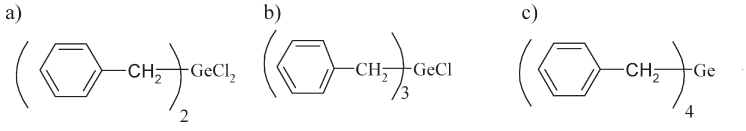

Figure 2. Structures of: a) dibenzyldichlorogermanium, b) tribenzylchlorogermanium, c) tetrabenzylgermanium.

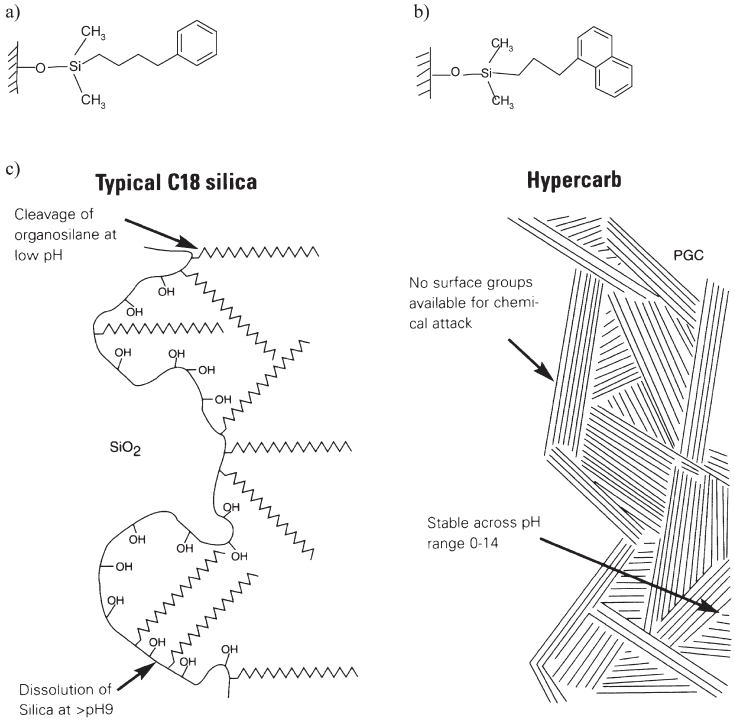

Figure 3. Scheme of chemically bonded stationary phases: a) phenylbutyl (RP Si-PB), b) naphthylpropyl (RP Si-NAF), c) Hypercarb (RP Si-PGC) and typical C_{18} silica.

MS (EI), m/z (%): 382* (2.29), 291 (10.95), 255 (3, 55), 165 (3.11), 109 (1.67), 91 (100). UV/Vis ($CHCl_3$): λ_{max} (lgε) = 242 (4.62), 266 (4.57), 274 (4.56), 290 (4.54).

Tetrabenzylgermanium

^{1}H NMR, δ (ppm) 2.19 (s, 8H, CH_2Ge), 6.85–7.22 (m, 20H, aromat.). ^{13}C NMR, δ (ppm) 21 (-CH_2-), 124, 128, 128.3, 140 ($C_{aromat.}$). UV/Vis ($CHCl_3$): λ_{max} (lgε) = 242 (4.62), 268 (4.55), 290 (4.52). MS (EI), m/z (%): 438* (1.41), 347 (87.16), 267 (2.73), 253 (5.43), 165 (79.71), 151 (8.74), 139 (9.37), 91 (100).

Apparatus

Chromatographic measurements were performed on a liquid chromatograph SPD-6A (Shimadzu, Kyoto, Japan) equipped with a gradient pump LC-6A,

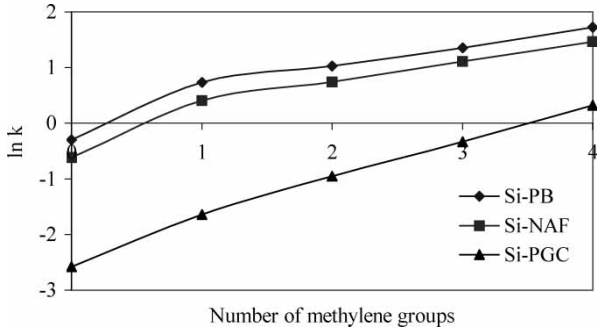

Figure 4. Dependence ln k on the number of carbon atoms in alkyl chain of alkylbenzenes for phenylbutyl, naphthylpropyl, and Hypercarb packings. Chromatographic conditions: mobile phase 75/25 vol.% acetonitryle/water, flow $-0.5\ \text{mL} \cdot \text{min}^{-1}$, wavelength -254 nm, temperature -20°C.

UV detector, a sampling valve Rheodyne (Berkeley, CA, USA), model 7125, with a 20 μL sample loop, and a Shimadzu C-R6A data recorder.

The organogermanium compounds were prepared by the method described in the literature.[6] ^{1}H NMR spectra were recorded on a Bruker-200 in $CDCl_3$, with HMDS as internal standard. MS-spectra were performed with a Shimadzu Mass Spectrometer GC/MS-QP5050, column Phenomenex BPX-5 30 m × 0.25 mm ID × 0.25 μm FT, total flow 52.7 $\text{mL} \cdot \text{min}^{-1}$.

RESULTS AND DISCUSSION

Optimal results obtained during experiments of the chromatographic separation of benzylgermanium derivatives are presented in Table 2. Chromatographic separation and determination of benzyl derivatives (Figure 2), similar to the determination of furylo germanium derivatives, are accompanied by numerous difficulties.[8] These compounds can modify column packing and are hardly eluted, therefore, only anhydrous mobile

Table 1. Characteristics of aryl bonded phase

Phase code	Column dimensions (mm)	Carbon (%)	Manufacturer of column
RP Si-PB	125 × 4.6	14.9	Home made
RP Si-NAF	125 × 4.6	16.1	Home made
RP Si-PGC	100 × 4.6	100	Thermo Electron Corporation (UK)

Table 2. Chosen dependence k for di- (k_1), tri (k_2) and tetra- (k_3) benzyl derivatives of germanium from on type of stationary and mobile phase. Chromatographic conditions: flow −0.3 or 0.1 mL · min^{-1}, wavelength −242 nm, temperature −20°C

Type of stationary phase	Mobile phase/flow (mL · min^{-1})	k_1	k_2	k_3	$\alpha_1 = k_2/k_1$	$\alpha_2 = k_3/k_2$
RP Si-PGC	Dichloromethane/0.3	0.38	1.33	1.94	3.50	1.46
	Dichloromethane/0.1	1.59	3.04	5.87	1.91	1.93
	Methanol/0.3	0.42	1.37	2.04	3.26	1.49
	Methanol/0.1	1.95	4.26	6.78	2.19	1.59
RP Si-NAF	Dichloromethane/0.3	0.86	2.53	6.45	2.94	2.55
	Dichloromethane/0.1	5.51	10.03	17.92	1.82	1.79
	Methanol/0.3	0.92	2.71	7.14	2.95	2.64
	Methanol/0.1	6.13	10.98	19.22	1.79	1.75
RP Si-PB	Dichloromethane/0.3	1.98	4.86	9.91	2.46	2.04
	Dichloromethane/0.1	8.58	17.70	26.38	2.06	1.49
	Methanol/0.3	2.34	5.40	11.75	2.31	2.18
	Methanol/0.1	9.12	18.92	28.31	2.07	1.50

[a]In the Table only optimal data (under 30 min) of chromatographic separation and determination of (di-, tri-, tetra-) benzylgermanium derivatives were placed.

phase can be used. In order to gain satisfactory results, i.e., good separation in relatively short time, aryl stationary phases were applied. These phases are, by most authors, indicated as "dedicated" to determinations of compounds containing π electrons, because during the chromatographic process predominate interactions of π-π type between the stationary phase and chromatographer compounds.[9–11]

Two mobile phases and various flow intensities were tested for selection of optimal process conditions and three stationary phases: phenylbutyl, naphthylpropyl and Hypercarb with graphitized coal. The best separation yielded pure dichloromethane as the mobile phase (Table 2).

When dichloromethane was used as the mobile phase (flow 0.3 mL · min^{-1}) and column RP Si-PGC as the stationary phase, retention time of tetrabenzylgermanium was 6.228 min. On the other hand, as was reported earlier, for the same solvent system and RP Si-C_{18} column, retention time was 48.578 min.[5] Obtained results confirm the reasonableness of a continued investigation concerning the applications of aryl stationary phases. Di- and tribenzylgermanium derivatives were characterized by a shorter retention time, than tetrabenzylgermanium. Decreasing of the dichloromethane flow to 0.1 mL · min^{-1} increased the retention time of tetrabenzylgermanium to 28.475 min (for RP Si-PB column) and 15.522 min (for RP Si-PGC column). It is necessary to underline, that only aryl columns yielded the proper separation and correct shape of peaks (Figures 5–7).

The naphthylpropyl column was characterized by slightly longer retention times, compared with the Hypercarb column. Obtained results

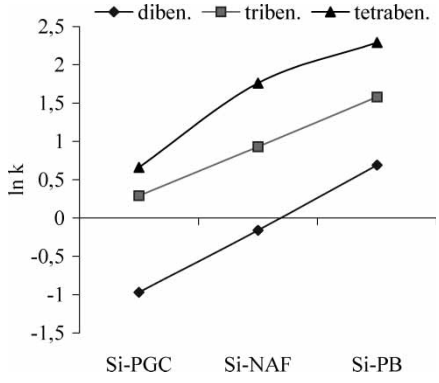

Figure 5. Effect of the separation of di-, tri-, and tetrabenzylgermanium with the use of stationary phases RP Si-NAF, RP Si-PB, and RP Si-PGC. Mobile phase: dichloromethane (100 vol.%).

confirm an existence of strong π-π type interactions. Comparable effects were received, when anhydrous methanol was used. The stationary phase RP Si-PB (possessing merely one aromatic ring in one unit) was characterized by relatively the weakest π-π interactions. Retention time of tetrabenzylgermanium was in this case prolonged to 26.38 min. Methanol, as the mobile phase showed in some measure, had less elution power and caused an extension of retention time of determined compounds.

Data presented in the Table 2 show, that aryl stationary phase RP Si-PGC is characterized by the highest selectivity, independently of the used mobile phase. Except for the best selectivity, this phase yields the shortest retention times of determined compounds (Figure 7). The naphthylpropyl phase

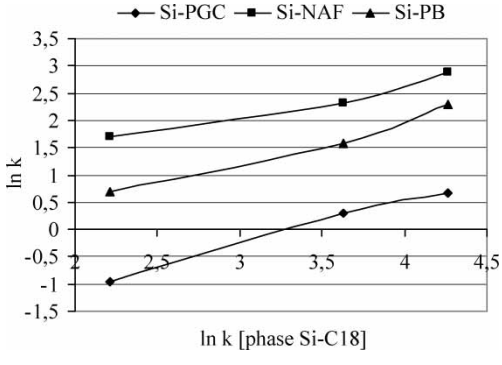

Figure 6. Dependence of ln k of the RP Si-PGC, RP Si-NAF, and RP Si-PB phases on ln k obtained for the octadecyl phase for di-, tri-, and tetrabenzyl derivatives of germanium.

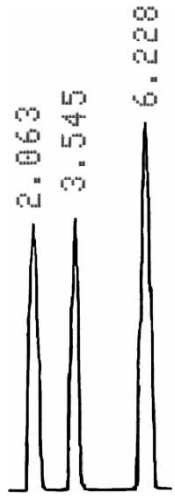

Figure 7. A chromatogram of separation of the di-, tri-, and tetrabenzyl derivatives of germanium on the stationary RP Si-NAF phase. Mobile phase: dichloromethane (100 vol.%); flow $-0.3\ \text{mL} \cdot \text{min}^{-1}$, wavelength -242 nm, temperature -20°C.

shows slightly lower separation factors (α) and longer retention times. Retention times obtained by means of aryl stationary phases are six-seven times shorter than retention times of corresponding substances obtained using the standard, octadecyl phase. The octadecyl phase showed the largest peak dissymmetry, the weakest separation, and the longest retention times of the separated compounds.[5]

Increasing of a flow intensity larger than $0.3\ \text{mL} \cdot \text{min}^{-1}$ did not improve separation on the RP Si-PB column, independent of which mobile phase was used.

CONCLUSIONS

Determination of compounds belonging to a group of benzylgermanium derivatives is connected with numerous difficulties during chromatography. They exhibit an ability of modification of the stationary phase surface. This ability decreases with increasing of a number of the benzyl groups. Optimization of the separation of these compounds by HPLC showed that their determination should be carried out, first of all, with the help of aryl phases. An application of the Hypercarb column enabled performing an accurate separation, and compared with the analysis based on the octadecyl phase, made the length of time of analysis, seven times shorter.

REFERENCES

1. Science of Synthesis; In *Houben-Weyl Methods of Molecular Transformations*; Thieme Verlag: 2003, Vol. 4, Vol. 5.
2. Rappoport, Z. *The Chemistry of Organic Germanium, Tin and Lead Compounds*; Wiley: 2002, Vol. 2.
3. Majors, R.E. Anal. Chem. **1971**, *44*, 1722.
4. Pidegon, C.; Venkatarum, U.V. Anal. Biochem. **1989**, *176*, 36.
5. Kluska, M.; Pypowski, K.; Erchak, N. Chromatography **2007** (in press).
6. Uszyńska, I. Master's thesis; University of Podlasie: Poland, 2005, 94.
7. Gadzała-Kopciuch, R.M.; Kluska, M.; Wełniak, M.; Buszewski, B. Elsevier – Mat. Chem. & Phys. **2005**, *89*, 228.
8. Kluska, M.; Pypowski, K.; Erchak, N. Anal. & Bioanal. Chem. **2007** (in press).
9. Jinno, K.; Yamamoto, K.; Kuwamato, T.; Nagashima, H.; Uedo, Y.; Tajima, S.; Kimura, E.; Itoh, K.; Fetrez, J.C.; Biggs, R.W. Chromatography **1992**, *34*, 381.
10. Buszewski, B.; Gilpin, R.K.; Jaroniec, M. Chem. Anal. **1994**, *39*, 653.
11. Kluska, M.; Pypowski, K.; Erchak, N. J. Liq. Chrom. & Rel. Technol. **2007**, *30*, 2059.

Received June 3, 2007
Accepted July 16, 2007
Manuscript 6170