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Short communication

Chromatographic retention behaviour of *n*-alkylbenzenes and pentylbenzene structural isomers on porous graphitic carbon and octadecyl-bonded silica studied using molecular modelling and QSRR

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ABSTRACT

The retention behaviour of a series of 15 *n*-alkylbenzenes and pentylbenzene structural isomers and benzene were investigated using porous graphitic carbon (PGC) and octadecyl-bonded silica (ODS) stationary phases. Shorter chain *n*-alkylbenzenes and benzene (n = 0–6), and all the pentylbenzene isomers were more strongly retained on ODS, although the selectivity was greater with PGC. For the pentylbenzene analytes the degree of branching in the alkyl chain at the position adjacent to the aromatic ring affects retention on PGC, with higher retention in less branched molecules. Molecular modelling studies have provided new insights into the geometry of aromatic π–π stacking interactions in retention on PGC. For alkylbenzenes with high branching at the position adjacent to the ring, the preferred geometry of association with the surface is with the branched chain directed away from the surface, a geometry not seen in the other alkylbenzenes. The most energetically favoured orientation for interaction between analytes and the PGC surface was found to be cofacial for toluene and ethylbenzene, whereas for other analytes this interaction was in a face-edge orientation. The alternative geometry of association observed with both toluene and ethylbenzene may explain the enhanced retention of these two analytes on PGC compared with their longer chain analogues. Quantitative structure–retention relationships revealed the importance of compactness in analyte structure during retention on PGC, with decreased compactness (associated with longer chain length and reduced chain branching) improving retention.

1. Introduction

Porous graphitic carbon (PGC) is an established stationary phase for high-performance liquid chromatography, originally intended as a substitute for reversed-phase silica in areas where this bonded phase is inadequate (e.g. at extremes of pH) [1–6]. However PGC has been found to possess a number of unexpected properties which have not been fully explained, and which have expanded its area of application and opened up new avenues for research [7]. The chemistry of the graphite surface plays a significant role in analyte retention [8,7], an effect greater than originally expected by the developers of PGC [1], who had predicted a near perfect reversed-phase mechanism [2,7].

A number of studies have shown the importance of hydrophobicity, polarity, size and topology on retention behaviour at PGC [9–16]. One key aspect of retention on PGC is the rigid planar graphite surface which results in strong retention of large planar molecules [10,13,17,18] and reduced retention in very branched molecules, where steric hindrance limits the degree of contact between the analyte and PGC surface [19]. The surface of PGC is crystalline and made up of flat sheets of hexagonally arranged sp^2 hybridised carbon atoms [16,20]. As such it is structurally similar to large polycyclic aromatic molecules, which are also flat and have high degrees of electron delocalisation. It is well established that aromatic rings adopt two preferred dimeric structures, these being the cofacial and face-edge geometries [21,22], but no studies have been carried out to probe the role of such geometries in separations on PGC. Clearly the three dimensional geometric and electronic properties of the PGC surface are likely to strongly influence retention on this material.

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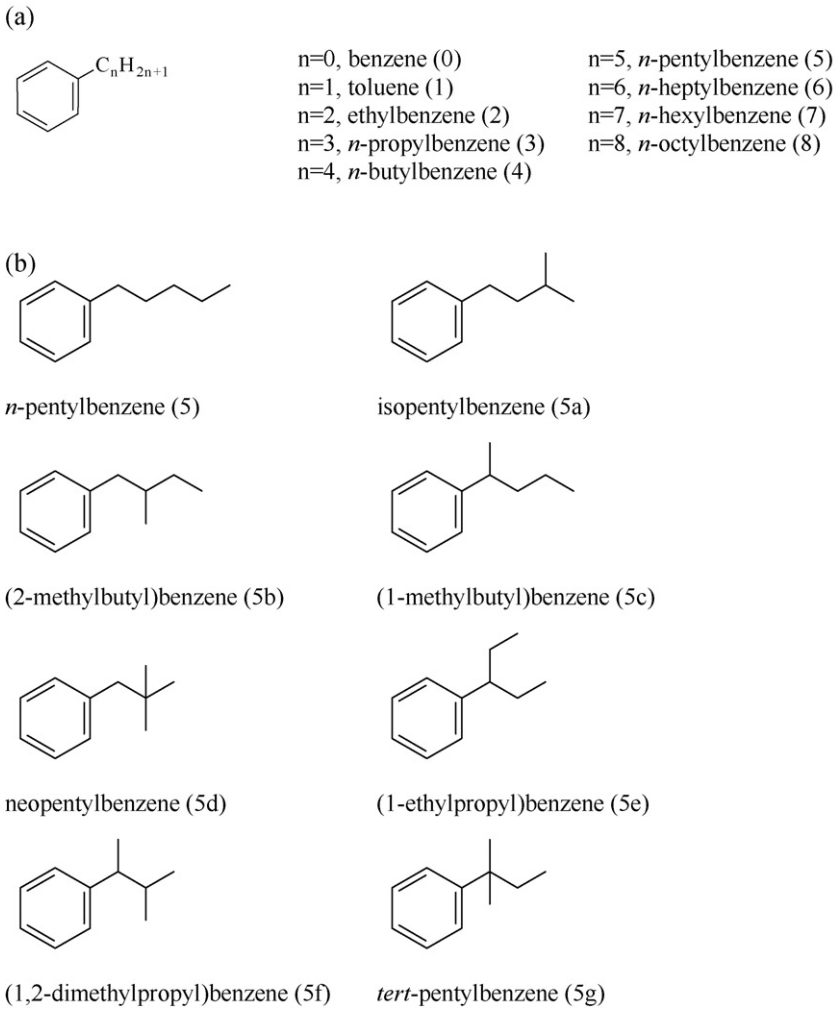

Fig. 1. Structures of (a) *n*-alkylbenzenes (*n* = 0–8) and (b) pentylbenzene structural isomers, with compound numbering in parentheses.

Whilst extensive studies have been carried out exploring the role of key aspects of analyte structure on separation on PGC, less is known about the combined effect of these structural features to retention. The aim of this work was to use both chromatographic and computational approaches to investigate the mechanisms of retention of a series of *n*-alkylbenzenes and pentylbenzene structural isomers on PGC. Benzene and 15 derivatives were chosen (Fig. 1) so that the contribution to retention of different structural features could be explored, and their combined contribution to retention assessed. In particular, the role of aromaticity, planarity, topology and hydrophobicity in retention on PGC were explored. This simple series of non-polar benzene derivatives is ideal in this context since a planar aromatic moiety is present in all the analytes, with different molecular topologies depending on the extent of branching in the alkyl substituent, and with a minimal polar retention effect on graphite (PREG), as described by Knox and Ross [15,16]. Molecular modelling calculations, i.e. simulations of 3D molecular structure, have been used, for the first time, to explore the aromatic π–π stacking interactions between aromatic analytes and the PGC surface.

The retention characteristics of the benzene derivatives were measured on both PGC and ODS, a comparison thought to be relevant, since ODS represents the standard stationary phase used in these separations. Molecular modelling calculations were designed to explore the geometries of interaction between the analytes and a model PGC surface, and to provide hitherto unavailable insights into the role of aromatic stacking interactions in separations on PGC. Given the difficulties in modelling aromatic π–π stacking interactions using molecular mechanics methods, and the likely involvement of electronic effects in the interaction between the analyte and PGC, semi-empirical molecular orbital methods were chosen as the preferred computational model. Whilst some modelling studies have previously been reported, where analyte-PGC surface interactions have been explored [23], no modelling has been reported of aromatic π–π stacking interactions. Quantitative structure–retention relationship (QSRR) studies were used to explore the structural features of most importance to retention, with particular emphasis on topological features, given the likely influence of molecular branching and topology on the geometry of association between the aromatic moieties in the analyte and surface.

2. Materials and methods

2.1. Chromatography

2.1.1. Materials

Details are provided in the supplementary material.

2.1.2. Instrumentation

HPLC analysis was performed on an Integral Micro-Analytical 100Q Workstation (PerSeptive Biosystems, now part of Applied