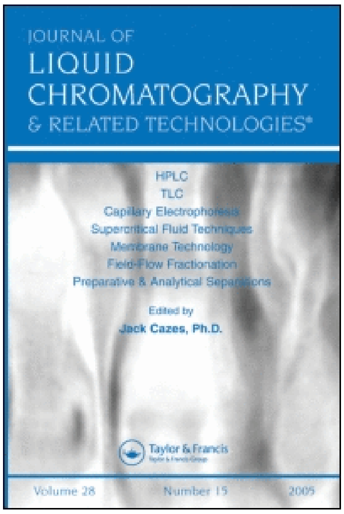

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# Liquid-Solid Chromatography with Computer-Selected Mobile Phases on the Basis of Snyder Theory

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# LIQUID-SOLID CHROMATOGRAPHY WITH COMPUTER-SELECTED MOBILE PHASES ON THE BASIS OF SNYDER THEORY

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## ABSTRACT

The thin layer chromatographic (TLC) retention, $R_M$, and separation, α, on silica of esters of the natural (2R,3R)-tartaric acid, $RO_2C\ CH(OH)\ CH(OH)\ CO_2\ R$, and related 1,3-dioxolanes were studied. Twenty mobile phases were used, being selected by the previously elaborated computer program LSChrom based on the Snyder parameters strength, ε, localization, *m*, and polarity, *P'*.

The available values of ε made it possible to derive conclusions about the adsorption pattern of the samples and to calculate their energy of adsorption, S. The relationships $R_M(m, P')$ and $R_M(S, E_s)$ were quantitatively studied where $E_s$ is the steric constant of group R.

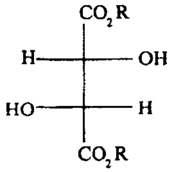
The conclusions summarize the application of LSChrom to TLC of 66 compounds with 161 mobile phases.

## INTRODUCTION

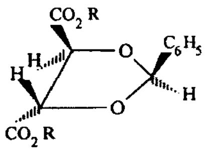
Liquid-solid chromatography (LSC) or, simply, LC such as HPLC, TLC and low or medium pressure LC is of great importance in separation and isolation of organic compounds. The stationary phases are limited, namely silica, modified silicas and alumina. Thus, the variety of mobile phases enables, in principle, the separation of the numerous organic compounds. The mobile phases have to possess an adsorptivity similar to that of the samples (solutes). They are pure solvents or, in the majority of the cases, mixtures of two and more solvents. The choice of the mobile phase for a given separation is usually done by the trial-and-error approach or by optimization approaches in separate cases (for instance, see ref. 1-4).

Recently, we have developed a computer program LSChrom[5] calculating the parameters strength, ε, localization, m, and polarity P' (see below) on the basis of Snyder theory.[6-8] This program simplifies the choice of mobile phases in LSC as shown by its application to TLC on silica or alumina of 54 compounds of different classes mainly diastereoisomers with 141 mobile phases composed of two to six solvents.[9-15] TLC, rather than HPLC, has been used because TLC enables an easy work with multicomponent mobile phases.

Trying to outline the utility of LSChrom, this paper reports its application to TLC of two other classes of compounds, namely the esters of (2R,3R)-2,3-dihydroxybutanic acid **1-6** and the related (4R,5R)-2-phenyl-4,5-dialkoxycarbonyl-1,3-dioxolanes **7-12**. The natural (2R,3R)-tartaric acid and its esters **1-6** are important building blocks for the synthesis of chiral compounds. The presence of the ester groups with an increasing effective volume of group R as in our previous studies[12,13] enabled us to elucidate the role of steric effects and adsorption energy in the cases studied.



**1-6**



**7-12**

R = $CH_3$, $CH_2CH_3$, $CH_2CH_2CH_3$, $CH(CH_3)_2$, $CH_2CH_2CH_2CH_3$ and $CH(CH_3)CH_2CH_3$

## THEORY

The TLC retention, $R_M$, HPLC retention factor, k', and separation factor, α, are related by the well-known equations:

$$R_M \equiv \log k' = \log\left(\frac{1}{R_F} - 1\right) \tag{1}$$

$$\log \alpha = \log \frac{k'_m}{k'_n} = R_{M_m} - R_{M_n} \tag{2}$$

where $R_F$ is the directly measured parameter in TLC and the subscripts m and n correspond to the number of the first and second compound of the solute pair, respectively. Snyder theory defines the following dimensionless parameters which characterize the mobile phase:

**strength**, ε, measuring the dimensionless Gibbs energy ($\Delta G° / RT\ln 10$) of adsorption of the mobile phase per unit area of the adsorbent surface; the greater the ε value, the weaker is the sample retention.

**localization**, m, measuring the capability of the mobile phase for interaction *via* the available functional group/s of the composing solvent/s with specific adsorbent sites; it determines, to a great extent, the selectivity of the mobile phase as measured by α of solute pairs; the theory predicts a linear relationship between logα and *m* as best separation is expected with either minimum or maximum *m* being established in many but not all cases.[8-13]

**polarity**, *P'*, measuring the total interaction ot the mobile phase with the sample; it tunes the mobile phase strength; a greater P' value means a better dissolution of the sample in the mobile phase and, therefore, a weaker retention.

The adsorptivity of a group *i* in the solute molecule is measured by the dimensionless Gibbs energy of adsorption, $Q°_i$, with pentane as a mobile phase having $\varepsilon = 0$. If the mobile phase has ε greater than zero, then the net energy of adsorption, $Q_i$, is reduced by the energy loss for desorption of mobile phase molecule/s from the adsorbent surface:

$$Q_i = Q^o{}_i - \varepsilon a_i \tag{3}$$

where $a_i$ is the relative effective area under adsorption of group i.

To a first approximation, the dimensionless Gibbs energy of adsorption, *S*, of a solute molecule containing more than one group i when $\varepsilon > 0$ is given by

$$S = \sum_{i} Q_i \tag{4}$$

This approximation is correct in discussion of the retention of compounds of a given class on same adsorbent.

## EXPERIMENTAL

The synthesis of compounds **1-12** studied and their spectral characteristics will be published elsewhere.[16] Compounds **1-6** show intramolecular hydrogen bonds of the type OH···OH, while compounds **7-12** are free from intramolecular hydrogen bonding.

TLC was performed on silica $60GF_{254}$ (Merck, Germany) using the procedure given in ref. 17. The solvents used were of analytical-reagent grade. The $R_F$ values were arithmetic means of two to three measurements showing a reproducibility of ±0.02.

The computer program[5] used was LSChrom Ver.2 for Windows. The strength graph given in ref. 18 is an alternative to this program but, with a limitation in the precision of the reading within the graph and a limitation in the variety of the mobile phases.

## RESULTS AND DISCUSSION

The mobile phases used in TLC on silica are shown in Table 1 together with their computer calculated[5] values of ε, m and P'. Mobile phases 1-10, with $\varepsilon = 0.348$, were used for the acyclic compounds **1-6** and mobile phases 11-20, with $\varepsilon = 0.288$, were applied to the cyclic compounds **7-12**. Independently of the constant value of ε, the mobile phases within any of these two cases are not equivalent because of the variation in their values of m and P'. The total variation is $0.10 \leq m \leq 0.91$ and $0.25 \leq P' \leq 2.92$.

Table 2 shows the data for the experimental $R_F$ values and the statistical quantities average $R_F$, $\bar{R}_F$, and standard deviation *(S.D.)*. Figure 1 represents the relationship between S.D. and $\bar{R}_F$.

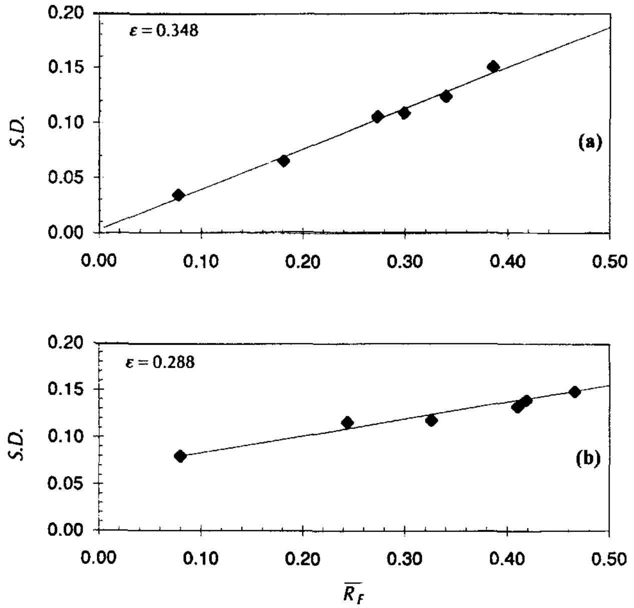


*Figure 1.* Relationship between *S.D.* and $\overline{R_F}$ values obtained for a given compound and all mobile phases used with equal calculated values of ε. The values of *S.D.* and $\overline{R_F}$ are from Table 2. The slope, intercept and correlation coefficient are (a) 0.37, 0.003, 0.995 and (b) 0.18, 0.065, 0.933.

Table 3 summarizes the values of the retention, $R_M$, and separation, α, of the compounds obtained by eqns. 1 and 2 from the experimental $R_F$ values. The average values of log α for any solute pair with all mobile phases used are also included. The values of log α are usually positive, i.e. the first compound of the solute pair is better retained than the second compound.

The expected linear relationship between log α and *m* was not clearly seen. The variation of the mobile phases showed that the mobile phases 1,3,4,7,10,15 and 17 separate all solute pairs studied as the absolute values of log α are in the range 0.05-0.47. Mobile phase 6, composed of hexane and isopropanol, leads to best separation (log α = 0.68) of solute pair 1-2.

Table 4 shows data according to Snyder[6] for the adsorption properties of groups *i* participating in the compounds studied. The values of $Q_i$ obtained by eqn.3 refer to the conditions used (ε = 0.348 or ε = 0.288). These data enabled

## Table 1

### Mobile Phases Used in TLC and their Computer-Calculated[5] Values of Strength, ε, Localization, *m*, and Polarity, *P′*

| No. | Mobile Phase | % | ε | *m* | *P′* |
|---|---|---|---|---|---|
| | *For TLC of Compounds 1-6* | | | | |
| 1 | Hexane-ethyl acetate | 70.00 : 30.00 | 0.348 | 0.59 | 1.39 |
| 2 | Hexane-diethyl ether | 48.90 : 51.10 | 0.348 | 0.65 | 1.48 |
| 3 | Hexane-diisopropyl ether | 1.60 : 98.40 | 0.348 | 0.10 | 2.36 |
| 4 | Hexane-dioxane | 81.50 : 18.50 | 0.348 | -- | 0.97 |
| 5 | Hexane-acetone | 84.90 : 15.10 | 0.348 | 0.92 | 0.86 |
| 6 | Hexane-isopropanol | 96.00 : 4.00 | 0.348 | -- | 0.25 |
| 7 | Toluene-ethyl acetate | 86.50 : 13.50 | 0.348 | 0.45 | 2.67 |
| 8 | Toluene-diethyl ether | 80.00 : 20.00 | 0.348 | 0.48 | 2.48 |
| 9 | Toluene-acetone | 94.30 : 5.70 | 0.348 | 0.53 | 2.55 |
| 10 | Toluene-isopropanol | 98.15 : 1.85 | 0.348 | -- | 2.43 |
| | *For TLC of compounds 7-12* | | | | |
| 11 | Hexane-ethyl acetate | 88.00 : 12.00 | 0.288 | 0.58 | 0.62 |
| 12 | Hexane-diethyl ether | 79.30 : 20.70 | 0.288 | 0.63 | 0.66 |
| 13 | Hexane-dioxane | 91.60 : 8.40 | 0.288 | -- | 0.50 |
| 14 | Hexane-acetone | 95.30 : 4.70 | 0.288 | 0.88 | 0.34 |
| 15 | Toluene-methylenechloride | 26.50 : 73.50 | 0.288 | 0.10 | 2.92 |
| 16 | Toluene-ethyl acetate | 95.00 : 5.00 | 0.288 | 0.20 | 2.50 |
| 17 | Toluene-diethyl ether | 92.30 : 7.70 | 0.288 | 0.20 | 2.43 |
| 18 | Toluene-acetone | 97.60 : 2.40 | 0.288 | 0.24 | 2.47 |
| 19 | Toluene-isopropanol | 99.28 : 0.72 | 0.288 | -- | 2.41 |
| 20 | Toluene-acetonitrile | 96.50 : 3.50 | 0.288 | 0.20 | 2.52 |

the calculation of the energy of adsorption, S, of the compounds studied by eqn. 4. The values obtained, together with the data about the steric constant, $E_s$,[19] of group R are given in Table 5.

Three-dimensional representations of the retention, $R_{Mf}$, as a function of the mobile phase parameters *m* and *P′* are shown in Figure 2 and Figure 3. This relationship concerns the TLC of a given compound with all mobile phases used.

Figure 4 illustrates another 3-dimensional function, namely $R_{Mf}$ of compounds studied with a given mobile phase vs. the solute parameters $E_s$ and *S*.

### Table 2

### Experimental Values of $R_F$ and Average Values of $R_F$, $\bar{R}_F$ and Standard Deviation (S.D.) for a Given Compound and All Mobile Phases Used for its TLC

| Solute | | $R_F$ of compounds 1-6 for indicated mobile phase | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. | R | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | $\bar{R}_F$ | S.D. |
| 1 | $CH_3$ | 0.13 | 0.12 | 0.12 | 0.06 | 0.05 | 0.03 | 0.06 | 0.10 | 0.07 | 0.04 | 0.08 | 0.03 |
| 2 | $C_2H_5$ | 0.30 | 0.25 | 0.27 | 0.14 | 0.12 | 0.13 | 0.16 | 0.20 | 0.14 | 0.10 | 0.18 | 0.07 |
| 3 | $C_3H_7$-n | 0.43 | 0.38 | 0.45 | 0.26 | 0.17 | 0.19 | 0.25 | 0.27 | 0.21 | 0.12 | 0.27 | 0.11 |
| 4 | $C_3H_7$-iso | 0.47 | 0.37 | 0.49 | 0.32 | 0.21 | 0.20 | 0.27 | 0.29 | 0.23 | 0.14 | 0.30 | 0.11 |
| 5 | $C_4H_9$-n | 0.52 | 0.39 | 0.58 | 0.34 | 0.23 | 0.23 | 0.32 | 0.36 | 0.27 | 0.16 | 0.34 | 0.12 |
| 6 | $C_4H_9$-sec | 0.56 | 0.48 | 0.69 | 0.43 | 0.25 | 0.23 | 0.37 | 0.38 | 0.29 | 0.18 | 0.39 | 0.15 |
| | | $R_F$ of compounds 7-12 for indicated mobile phase | | | | | | | | | | | |
| | | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | $\bar{R}_F$ | S.D. |
| 7 | $CH_3$ | 0.14 | 0.17 | 0.14 | 0.08 | 0.41 | 0.34 | 0.40 | 0.33 | 0.14 | 0.29 | 0.24 | 0.12 |
| 8 | $C_2H_5$ | 0.23 | 0.30 | 0.24 | 0.13 | 0.47 | 0.45 | 0.47 | 0.40 | 0.19 | 0.38 | 0.33 | 0.12 |
| 9 | $C_3H_7$-n | 0.32 | 0.40 | 0.32 | 0.20 | 0.54 | 0.54 | 0.67 | 0.47 | 0.25 | 0.47 | 0.42 | 0.14 |
| 10 | $C_3H_7$-iso | 0.33 | 0.42 | 0.34 | 0.19 | 0.52 | 0.53 | 0.64 | 0.44 | 0.23 | 0.46 | 0.41 | 0.13 |
| 11 | $C_4H_9$-n | 0.39 | 0.47 | 0.36 | 0.22 | 0.58 | 0.59 | 0.74 | 0.49 | 0.28 | 0.54 | 0.47 | 0.15 |
| 12 | $C_4H_9$-n | 0.39 | 0.49 | 0.39 | 0.24 | 0.61 | 0.73 | 0.76 | 0.51 | 0.30 | 0.50 | 0.49 | 0.16 |

## Computer-aided Choice of the Mobile Phases

As adopted in our previous studies,[9-15] we started TLC of compounds **1-6** with the experimentally found mobile phase 1 giving $R_F$ values in the favorable range $0.13 \leq R_F \leq 0.56$. This mobile phase is composed of hexane and ethyl acetate in a ratio 70:30 and is characterized by strength, $\varepsilon = 0.348$ calculated by LSChrom. We were interested to keep $\varepsilon$ constant. Using LSChrom, we were able to calculate the ratios in which the solvents of mobile phases 2- 10 have to be taken ensuring $\varepsilon = 0.348$. Such a procedure was also applied to compounds **7-12** and thus mobile phases 11-20 were selected having $\varepsilon = 0.288$.

Using mobile phases of equal $\varepsilon$, $R_F$ of all compounds vary in the region 0.03-0.76, i.e., there is no case when the compounds remain at the start line or move with the front line.

Moreover, the $R_F$ values for any compound and all mobile phases used vary in a limited range owing to the variation in $m$ and $P'$, the possible difference between the calculated and experimental values of $\varepsilon$ and the presence of complicating factors in TLC as demixing of the solvents composing the

## Table 3

### Values of the Retention, $R_M$, and Separation, α, Established for Acyclic Compounds 1-6 and Cyclic Compounds 7-12

| Solute No. | R | $R_M$ of compounds 1-6 for indicated mobile phase 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | $CH_3$ | 0.83 | 0.87 | 0.87 | 1.19 | 1.28 | 1.51 | 1.19 | 0.95 | 1.12 | 1.38 | |
| 2 | $C_2H_5$ | 0.37 | 0.48 | 0.43 | 0.79 | 0.87 | 0.83 | 0.72 | 0.60 | 0.79 | 0.95 | |
| 3 | $C_3H_7$-n | 0.12 | 0.21 | 0.09 | 0.45 | 0.69 | 0.63 | 0.48 | 0.43 | 0.58 | 0.87 | |
| 4 | $C_3H_7$-iso | 0.05 | 0.23 | 0.02 | 0.33 | 0.58 | 0.60 | 0.43 | 0.39 | 0.52 | 0.79 | |
| 5 | $C_4H_9$-n | -0.03 | 0.19 | -0.14 | 0.29 | 0.52 | 0.52 | 0.33 | 0.25 | 0.43 | 0.72 | |
| 6 | $C_4H_9$-sec | -0.10 | 0.03 | -0.35 | 0.12 | 0.48 | 0.52 | 0.23 | 0.21 | 0.39 | 0.66 | |
| | | **Log α for indicated mobile phase** | | | | | | | | | | |
| **1-2** | | 0.46 | 0.39 | 0.43 | 0.41 | 0.41 | 0.68 | 0.47 | 0.35 | 0.34 | 0.43 | **0.44** |
| **2-3** | | 0.25 | 0.26 | 0.34 | 0.33 | 0.18 | 0.20 | 0.24 | 0.17 | 0.21 | 0.09 | **0.23** |
| **3-4** | | 0.07 | -0.02 | 0.07 | 0.13 | 0.11 | 0.03 | 0.05 | 0.04 | 0.05 | 0.08 | **0.06** |
| **4-5** | | 0.09 | 0.04 | 0.16 | 0.04 | 0.05 | 0.08 | 0.10 | 0.14 | 0.09 | 0.07 | **0.09** |
| **5-6** | | 0.07 | 0.16 | 0.21 | 0.17 | 0.05 | 0.00 | 0.10 | 0.04 | 0.04 | 0.06 | **0.09** |
| | | **$R_M$ of compounds 7-12 for indicated mobile phase** | | | | | | | | | | |
| | | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | |
| 7 | $CH_3$ | 0.79 | 0.69 | 0.79 | 1.06 | 0.16 | 0.29 | 0.18 | 0.31 | 0.79 | 0.39 | |
| 8 | $C_2H_5$ | 0.52 | 0.37 | 0.50 | 0.83 | 0.05 | 0.09 | 0.05 | 0.18 | 0.63 | 0.21 | |
| 9 | $C_3H_7$-n | 0.33 | 0.18 | 0.33 | 0.60 | -0.07 | -0.07 | -0.31 | 0.05 | 0.48 | 0.05 | |
| 10 | $C_3H_7$-iso | 0.31 | 0.14 | 0.29 | 0.63 | -0.03 | -0.05 | -0.25 | 0.10 | 0.52 | 0.07 | |
| 11 | $C_4H_9$-n | 0.19 | 0.05 | 0.25 | 0.55 | -0.14 | -0.16 | -0.45 | 0.02 | 0.41 | -0.07 | |
| 12 | $C_4H_9$-sec | 0.19 | 0.02 | 0.19 | 0.50 | -0.19 | -0.43 | -0.50 | -0.02 | 0.37 | 0.00 | |
| | | **Log α for indicated mobile phase** | | | | | | | | | | |
| **7-8** | | 0.26 | 0.32 | 0.29 | 0.24 | 0.11 | 0.20 | 0.12 | 0.13 | 0.16 | 0.18 | **0.20** |
| **8-9** | | 0.20 | 0.19 | 0.17 | 0.22 | 0.12 | 0.16 | 0.36 | 0.12 | 0.15 | 0.16 | **0.19** |
| **9-10** | | 0.02 | 0.04 | 0.04 | -0.03 | -0.03 | -0.02 | -0.06 | -0.05 | -0.05 | -0.02 | **-0.02** |
| **10-11** | | 0.11 | 0.09 | 0.04 | 0.08 | 0.11 | 0.11 | 0.20 | 0.09 | 0.11 | 0.14 | **0.11** |
| **11-12** | | 0.00 | 0.03 | 0.06 | 0.05 | 0.05 | 0.27 | 0.05 | 0.03 | 0.04 | -0.07 | **0.05** |

The values of $R_M$ and log α are calculated from the experimental $R_F$ values of Table 2 by eqns. 1 and 2, respectively.

mobile phase.[6] For instance, compound **8** and mobile phases 11-20 having calculated value of ε equal to 0.288 and different values of *m* and *P'* give $R_F$ in the interval 0.13-0.47. To receive a measure for the similarity of the mobile phases owing to their equal ε, we calculated the values of average $\bar{R}_F{}'$ $R_F{}'$ and standard deviation *(S.D.)* for any compound and all mobile phases used for its TLC. A well seen linear relationship between *S.D.* and $\bar{R}_F$ reflecting the structure of the compounds was established (see Figure 1). Thus, the similarity

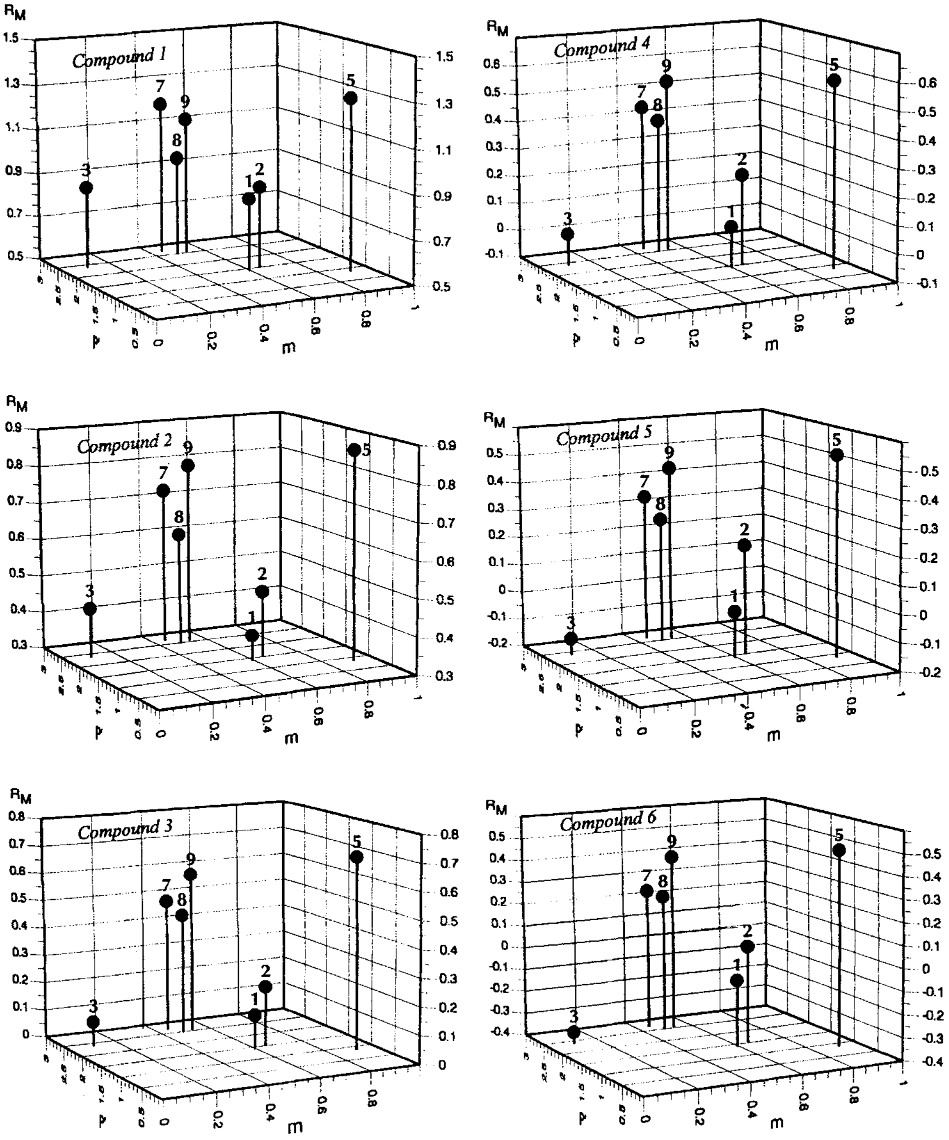


**Figure 2.** Three-dimensional representations of the retention, $R_M$ , of any compound from **1-6** obtained with all mobile phases used as a function of the mobile phase parameters $m$ and $P'$. The values of $R_M$ are taken from Table 3. The number near any point specifies the mobile phase. The data for mobile phases 4, 6 and 10 are not included because of the absence of values for $m$.

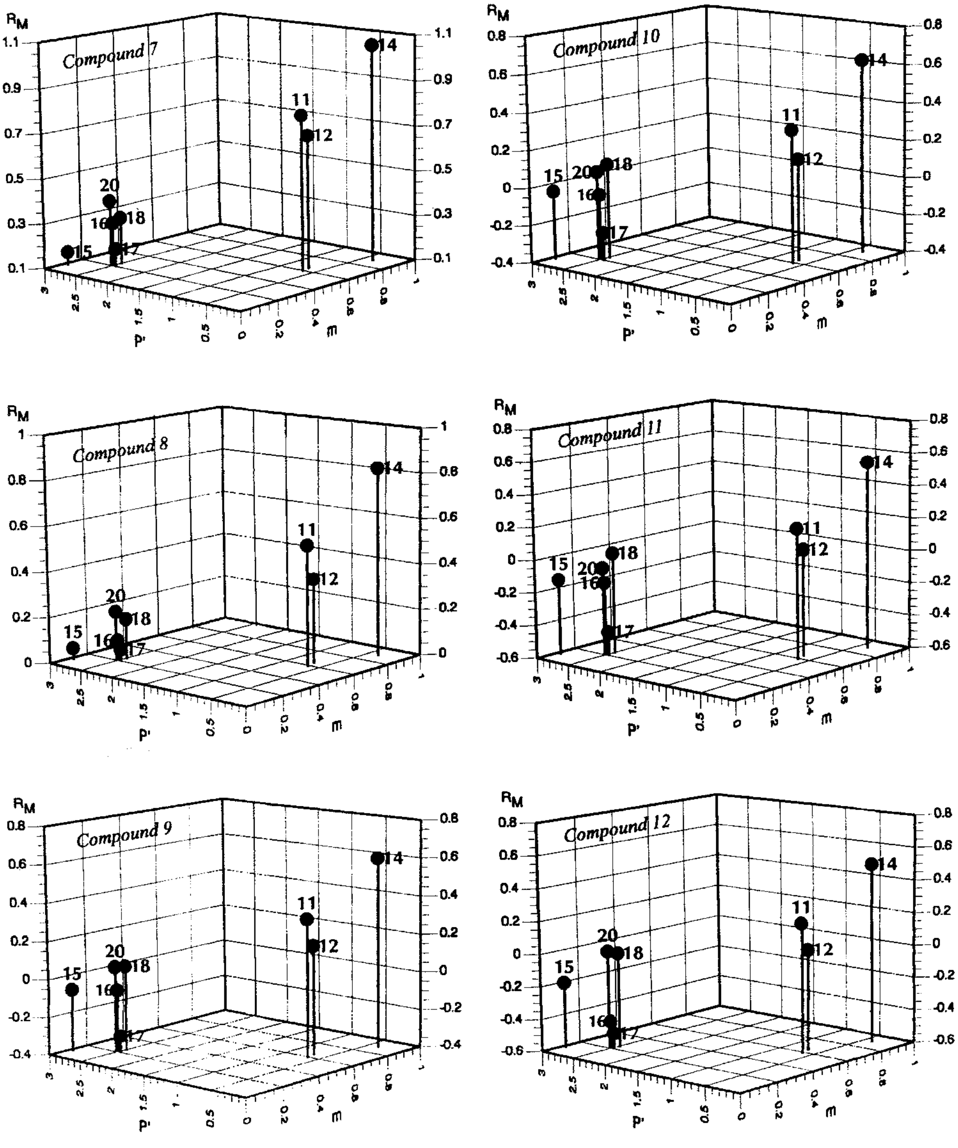


**Figure 3.** Three-dimensional representations of the retention, $R_M$ , of any compound from **7-12** obtained with all mobile phases used as a function of the mobile phase parameters $m$ and $P'$. The values of $R_M$ are taken from Table 3. The number near any point specifies the mobile phase. The data for mobile phases 13 and 19 are not included because of the absence of values for $m$.

## Table 4

### Data According to Snyder[6] for the Adsorption Properties of Groups *i* Participating in the Compounds Studied

| Group *i* | $Q^\circ_i$ | $a_i$ | $Q_i = Q^\circ_i - \varepsilon a_i$<br>$\varepsilon$=0.348 | $\varepsilon$=0.288 |
|---|---|---|---|---|
| $C_6H_5$ | 1.50 | 6.00 | -0.59 | -0.23 |
| OH | 5.60 | 8.50 | 2.64 | 3.15 |
| O | 3.61 | 9.00 | 0.48 | 1.02 |
| $CO_2CH_3$ | 5.27 | 10.50 | 1.62 | 2.25 |
| $CO_2C_2H_5$ | 5.22 | 11.40 | 1.25 | 1.94 |
| $CO_2C_3H_7$-n | 5.17 | 12.30 | 0.89 | 1.63 |
| $CO_2C_3H_7$-iso | 5.29 | 13.00 | 0.77 | 1.55 |
| $CO_2C_4H_9$-n | 5.12 | 13.20 | 0.53 | 1.32 |
| $CO_2C_4H_9$-sec | 5.24 | 13.90 | 0.40 | 1.24 |

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The data for $Q^\circ_i$ and $a_i$ are taken from ref. 6, p. 200 and p. 264. The values of $Q_i$ refer to the cases studied when the mobile phase has $\varepsilon$=0.348 or 0.288.

## Table 5

### Data for Steric Constant, $E_s$, of Group R and Energy of Adsorption, *S*, of the Compounds Studied

| Group R | $E_s$ | Cpd. | $S = 2Q_{OH} + 2Q_{COOR}$<br>for $\varepsilon$=0.348 | Cpd. | $S = 2Q_O + 2Q_{COOR}$<br>for $\varepsilon$=0.288 |
|---|---|---|---|---|---|
| $CH_3$ | 0.00 | **1** | 8.52 | **7** | 6.53 |
| $C_2H_5$ | 0.07 | **2** | 7.79 | **8** | 5.91 |
| $C_3H_7$-n | 0.36 | **3** | 7.06 | **9** | 5.29 |
| $C_3H_7$-iso | 0.47 | **4** | 6.82 | **10** | 5.13 |
| $C_4H_9$-n | 0.39 | **5** | 6.34 | **11** | 4.67 |
| $C_4H_9$-sec | 1.13 | **6** | 6.09 | **12** | 4.51 |

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The data for steric constant, $E_s$, are taken from ref. 19, p. 298. The values of *S* are obtained on the basis of the data of Table 4 and eqn. 4.

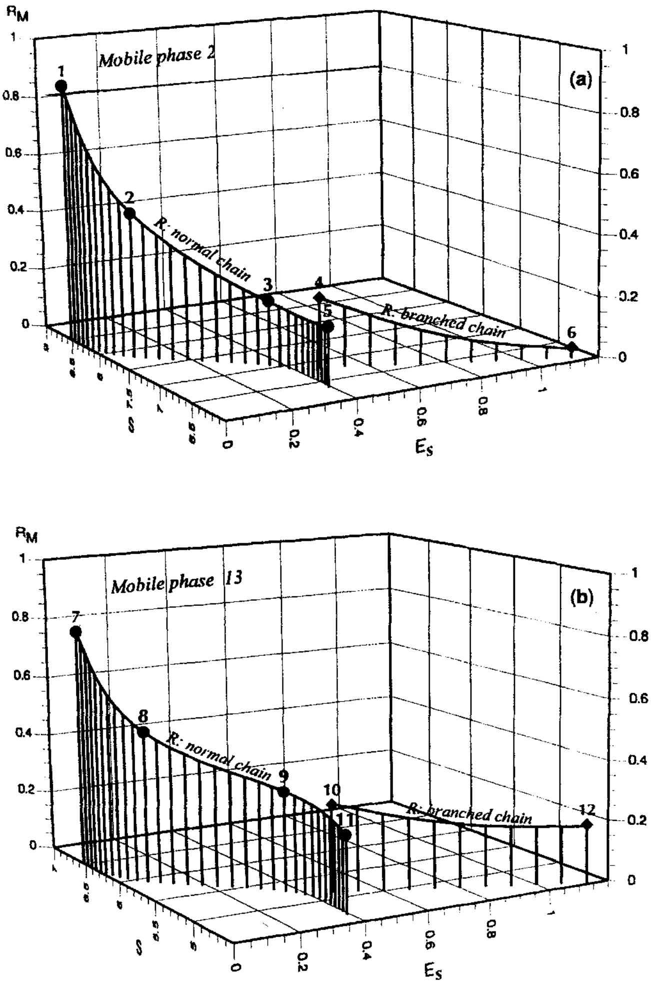

**Figure 4.** Three-dimensional representations of the retention $R_M$ of (a) compounds **1-6** and (b) compounds **7-12** with the indicated mobile phase as a function of the solute parameters $E_s$ and $S$. The values of $R_M$ are taken from Table 3. The data for $E_s$ and $S$ are from Table 5. The number near any point denotes the compound.

of the mobile phases of equal calculated values of ε is expressed by *S.D.* at the corresponding $R_F$.

## Expected Adsorption Patterns and Calculation of Solute Adsorption Energy, S

The adsorption pattern is determined by the adsorbing group/s of a solute molecule. The available values of ε for mobile phases used enabled us to deduce the adsorption patterns in the cases studied. As seen from Table 4, all groups *i* participating in the compounds studied, except the phenyl group, show $Q_i > 0$, i.e., the adsorption pattern of compounds **1-6** includes the two hydroxyl groups and the two ester groups and the adsorption of compounds **7-12** occurs *via* the two etherial oxygen atoms and the two ester groups. Then, the energy of adsorption, *S*, of any compound was calculated on the basis of eqn. 4 and the corresponding values of $Q_i$ for the adsorbing groups. Being with greater values of $Q_i$, the hydroxyl groups in the case of compounds **1-6** and the ester groups in the case of compounds **7-12** have a greater contribution to S, than the remaining groups in solute molecules. *S* varied in the range 6.09-8.52 for the acyclic compounds **1-6** and in the range 4.51-6.53 for the cyclic compounds **7-12**. The greater adsorption energy of the first compounds explains the use of mobile phases with a greater value of ε for their TLC (see Table 1).

## Retention, $R_M$, as a Function of Mobile-Phase Localization, m, and Polarity, P'

This relationship has not been quantitatively studied so far. The data of ref. 6, p. 277, are not sufficient to calculate the localization of all compounds studied, but it is apparently significant. The same is valid for the localizing solvents[8] such as ethyl acetate, diethyl ether, diisopropyl ether, dioxane, acetone, isopropanol and acetonitrile participating in the mobile phases used. Thus, the difference in the localization of the solute and mobile phase is expected to change the solute retention in comparison with the case when such a phenomenon is absent. The expected influence of *P'* on retention is given under Theory.

Figure 2 and Figure 3 represent $R_M$ *vs.* *m* and *P'* in optimum $R_M$ scales which permits a better visualization of some particularities. Thus, the retention of any compound from **1-6** is always greater with mobile phases 5 and 7-9 than that with mobile phases 1-3. This steady retention pattern is probably due to the greater contribution of the hydroxyl groups to adsorption in comparison with the ester groups as mentioned above. The influence of *m* and *P'* on $R_M$ is not straightforward, which can be attributed to various specific interactions between the mobile phases and the hydrogen bonded solutes, i.e., the so-called secondary effects.

Within compounds **7-12**, the retention pattern is not so steady, especially with mobile phases 15, 16 and 18 revealing, probably, the increased role of the varying ester groups in the adsorption. A tendency for a stronger retention with mobile phases of smaller values of *P'* (as it is expected) and greater values of *m* is seen.

### Retention, $R_M$, as a Function of Solute Steric Constant, $E_s$, and Energy of Adsorption, S

Steric constant, $E_s$, is one of the measures for the size of a group. Energy of adsorption, S, depends both on electronic and steric effects under LSC.[6]

The compounds within any of the two classes studied differ only in the size of group R, which varies from methyl to *sec.*-butyl. According to Table 5, this variation leads to an increase of the steric constant, $E_s$, of group R, which should hinder the retention and a decrease of energy of adsorption, *S*, which should reduce the retention. As seen from Figure 4, the compounds with a normal and a branched chain of group R form two independent series. The retention gradually decreases as it is expected in these two series and also in all remaining cases. This decrease is greatest for solute pairs 1-2 and 7-8 with a change of group R from $CH_3$ to $C_2H_5$. It determines the best separation of the two solute pairs as seen from the average values of log α of 0.44 and 0.20, respectively.

## CONCLUSIONS

Our previous studies[9-15] and the present study report the application of the computer program LSChrom based on Snyder theory to TLC of 66 compounds of different classes, mainly diastereoisomers, with 161 mobile phases composed of two to six solvents. These studies lead to the following conclusions which show unequivocally the utility of the practical application of Snyder theory in LSC.

1. Similar in strength and different in selectivity mobile phases are easily selected by LSChrom. This approach makes it possible to avoid the unfavorable cases when the compounds remain at the start line or move with the front.

2. The separation, α, of a solute pair at a constant ε depends, in many cases, linearly on localization, *m*, of the mobile phase, being maximum at either minimum *m* or maximum *m*. In the cases when this linearity is masked by other effects, the best mobile phases giving maximum value of α are experimentally specified from various mobile phases with constant or increasing ε.

3. The computer calculated values of ε, *m* and *P'* enable to elucidate the adsorption pattern of the solutes and to study quantitatively various relationships such as $R_M(m,P')$ and $R_M(E_S,S)$. This is important for configurational determinations within diastereoisomers and for a better understanding of the separation process.

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