Journal of Chromatography, 128 (1976) 199–203
© Elsevier Scientific Publishing Company, Amsterdam — Printed in The Netherlands

CHROM. 9346

Note

An attempt to predict elution behaviour in a liquid–liquid chromatographic model system

SHINTARO FUDANO, SAKIKO TERAI and KAZUO KONISHI

Wakayama Research Laboratories, Kao Soap Co., Ltd., 1334 Minato-yakushubata, Wakayama-shi (Japan)

(First received January 13th, 1976; revised manuscript received April 22nd, 1976)

In liquid–liquid chromatography (LLC), it is difficult to select the optimal phase system for the separation of a given mixture. The phase system for a particular separation in LLC has mostly been chosen from the wide range of available LLC systems by trial and error by considering the solubility of the solute in the solvent, polarity, molecular structure, etc. Recently, several papers[1–6] on the prediction of distribution coefficients have been published.

On the other hand, regarding the LLC system as an equilibrium between solvent and solute, Locke[7] expressed the distribution coefficient as a function of the infinite activity coefficient (γ), from which the following equation could be derived by considering that the solute is very dilute:

$$V_g = \frac{\gamma^m M_m}{\gamma^s M_s \varrho_m}$$

where V_g is the specific retention volume, m and s represent the mobile and stationary phases, respectively, and M and ϱ are the molecular weight and the density. If the infinite activity coefficients of the solute are known, V_g can be estimated from the equation.

This paper describes an attempt to investigate the possibility of predicting elution behaviour in a simple LLC model system by confirming the validity of the above equation.

EXPERIMENTAL

The instrument used for liquid chromatography was a commercial liquid chromatograph (Model ALC-201, Waters Assoc., Milford, Mass., U.S.A.) equipped with a differential refractometer as a detector. The separation columns used consisted of a 6-ft. length of 1/4 in. O.D. stainless-steel tubing, and were preceded in the eluent flow-line by a pre-column packed with the same material. These columns were equipped with a jacket to control the column temperature. The column support for liquid chromatography was 60–80 mesh Gas-Chrom P (Applied Science Labs., State College, Pa., U.S.A.). The combinations of stationary and mobile phases investigated as model systems were glycerol–hydrocarbon (*n*-hexane, *n*-heptane and *n*-octane), β,β'-oxydipropionitrile (ODPN)–*n*-heptane, and *n*-hexadecane–water.

The infinite dilution activity coefficients of the solute in the mobile and stationary phases were calculated from the expression reported by Pierotti *et al.*[8]. In order to obtain activity coefficients at any desired temperature, the quadratic equations in temperature were derived from their data by the least-squares method by means of a mini-computer. For alcohols and ketones in glycerol and ODPN, activity coefficients were measured according to Martire's method[9] using gas chromatography. On the basis of these data, the equations for the estimation of activity coefficients at any desired temperature were obtained by the least-squares method.

RESULTS

Table I gives the coefficients of the equations for the estimation of activity coefficients of alcohols and ketones in hydrocarbons (*n*-hexane, *n*-heptane and *n*-octane), while those in glycerol and ODPN are given in Table II. Table III gives the coefficients of the equations for activity coefficients in *n*-hexadecane and water. Activity coefficients at any desired temperature were calculated from these equations in order to estimate the V_g values.

TABLE I

COEFFICIENTS IN EQUATIONS FOR ESTIMATION OF ACTIVITY COEFFICIENTS IN HYDROCARBONS

*Sample**	*Hydrocarbon*	*Coefficients in equation*** $\gamma = a(1/T)^2 + b(1/T) + c$		
		a	*b*	*c*
MeOH	*n*-Hexane	187.25	−1016.9	1393.1
EtOH		95.712	−511.94	692.33
1-PrOH		77.432	−412.68	556.75
1-BuOH		69.652	−370.48	499.12
MeOH	*n*-Heptane	178.79	−965.13	1313.6
EtOH		94.911	−507.76	686.80
1-PrOH		76.937	−410.11	553.33
1-BuOH		69.377	−369.07	497.29
2-BuOH		39.722	−209.12	279.80
tert.-BuOH		24.933	−130.11	172.77
MMK		1.5802	−4.3418	3.6613
MEK		0.9068	−1.7929	0.9942
MPK		0.6652	−0.9226	0.1177
MBK		0.5468	−0.5172	−0.2722
DEK		0.4751	−0.2851	−0.4910
MeOH	*n*-Octane	176.54	−953.12	1297.4
EtOH		93.945	−502.69	680.04
1-PrOH		76.318	−406.88	549.04
1-BuOH		68.931	−366.75	494.21

* Abbreviations: MMK, acetone; MEK, methyl ethyl ketone; MPK, methyl *n*-propyl ketone; MBK, methyl *n*-butyl ketone; DEK, diethyl ketone.

** $T = (273.2 + t) \cdot 10^{-3}$ (°K).

TABLE II

COEFFICIENTS IN EQUATIONS FOR ESTIMATION OF ACTIVITY COEFFICIENTS IN GLYCEROL AND ODPN

Sample	*Coefficients in equation* $\log \gamma = a(1/T) + b$			
	In glycerol		*In ODPN*	
	a	*b*	*a*	*b*
MeOH	0.1249	−0.1711	0.3873	−0.8960
EtOH	0.1541	0.0380	0.3501	−0.6161
1-PrOH	0.1264	0.4435	0.4986	−0.9452
1-BuOH	0.3567	0.0003	0.5868	−1.0853
2-BuOH	0.3103	0.0700	0.5228	−0.9328
tert.-BuOH	0.2791	0.0817	0.4971	−0.8786
MMK	0.2446	0.1657	0.0500	−0.0693
MEK	0.0558	1.0504	0.0731	0.0190
MPK	0.2566	0.7342	0.1176	0.0604
MBK	0.1273	1.3830	0.1011	0.2704
DEK	0.1859	1.0015	0.1062	0.1045

TABLE III

COEFFICIENTS IN EQUATIONS FOR ESTIMATION OF ACTIVITY COEFFICIENTS IN *n*-HEXADECANE AND WATER

Sample	*Coefficients in equation* $\gamma = a(1/T)^2 + b(1/T) + c$					
	In n-hexadecane			*In water*		
	a	*b*	*c*	*a*	*b*	*c*
MeOH	149.07	−806.94	1100.5	−0.88745	4.4741	−3.4933
1-BuOH	61.343	−327.30	441.91	−19.489	105.91	−93.108
1-AmOH	58.652	−312.45	421.40	−117.86	719.87	−920.14
1-C$_6$OH	57.217	−304.44	410.27	−561.55	3612.1	−5122.0
1-C$_7$OH	56.386	−299.71	403.61	−2339.9	15662.	−23465.
MMK	1.7950	−6.2866	6.6779	−1.5223	0.70018	22.548
MEK	1.0935	−3.3116	3.2568	−22.938	117.31	−108.55
MPK	0.82327	−2.1580	1.9262	−140.34	805.56	−102.09
MBK	0.76257	−2.0592	2.0345	−686.71	4123.3	−5700.5
DEK	0.62978	−1.4483	1.1886	−130.34	738.54	−918.06

Table IV compares the predicted specific retention volumes of alcohols and ketones in glycerol–hydrocarbon systems with the observed values in LLC. The observed V_g values, especially for methanol and ethanol, were higher than the predicted values, probably because of adsorption on the liquid–liquid interface. A comparison of both values in the ODPN–*n*-heptane system is given in Table V; the agreement is within the experimental error. It is predicted that 2-butanol, which has a functional group inside the molecular chain, will give a smaller V_g value than that of 1-butanol. This prediction agrees with the experimental results. Table VI compares predicted and observed V_g values in *n*-hexadecane–water as a model of reversed-phase chromatography. In this system, it is expected that elution delays will occur with increasing column temperature, which is confirmed by the observed V_g values.

TABLE IV

PREDICTED AND OBSERVED V_g VALUES FOR ALCOHOLS AND KETONES

Stationary phase, glycerol (30.0%); mobile phase, hydrocarbons.

Sample	*V_g (ml/g)**								
	In n-hexane		*In n-heptane*					*In n-octane*	
	26.7 °C	*38.1 °C*	*25.7 °C*	*26.7 °C*	*34.9 °C*	*37.4 °C*	*38.1 °C*	*26.7 °C*	*38.1 °C*
MeOH	75.05 (68.51)	53.00 (50.26)		80.11 (75.90)	65.09 (61.04)		60.13 (55.75)	90.00 (82.80)	60.01 (61.03)
EtOH	24.00 (19.87)	17.83 (15.11)		25.90 (22.03)	21.01 (18.15)		18.92 (16.73)	32.84 (24.11)	21.52 (18.36)
1-PrOH	8.23 (8.11)	5.89 (6.18)		9.27 (9.03)	7.27 (7.44)		7.20 (6.87)	10.44 (9.89)	7.19 (7.55)
1-BuOH	2.94 (3.53)	2.49 (2.88)		3.00 (3.94)	2.74 (3.41)		2.56 (3.21)	4.00 (4.32)	2.83 (3.54)
2-BuOH							2.29 (2.50)		
tert.-BuOH							2.05 (2.18)		
MMK			1.29 (1.13)			1.11 (1.10)			
MEK			0.38 (0.48)			0.34 (0.44)			
MPK			0.18 (0.18)			0.16 (0.18)			
MBK			0.09 (0.10)			0.08 (0.10)			
DEK			0.13 (0.15)			0.10 (0.14)			

* Predicted V_g values are given in parentheses.

TABLE V

PREDICTED AND OBSERVED V_g VALUES FOR ALCOHOLS AND KETONES

Stationary phase, ODPN (10.0%); mobile phase, *n*-heptane.

Sample	*V_g (ml/g)**					
	24.5 °C	*27.0 °C*	*34.1 °C*	*34.9 °C*	*37.4 °C*	*38.1 °C*
MeOH		40.01 (39.64)		32.05 (33.84)		27.50 (31.51)
EtOH		18.12 (16.28)		15.13 (14.04)		14.98 (13.14)
1-PrOH		10.60 (9.39)		9.31 (8.37)		8.97 (7.95)
1-BuOH		5.50 (6.06)		5.31 (5.51)		5.20 (5.31)
2-BuOH						3.51 (3.88)
tert.-BuOH						3.08 (2.94)
MMK	7.02 (6.38)		6.33 (6.07)		6.04 (5.93)	
MEK	3.79 (3.36)		3.27 (3.17)		3.22 (3.11)	
MPK	2.12 (1.88)		1.95 (1.80)		1.91 (1.78)	
MBK	1.19 (1.21)		1.13 (1.16)		1.11 (1.14)	
DEK	1.69 (1.61)		1.61 (1.54)		1.58 (1.52)	

* Predicted V_g values are given in parentheses.

TABLE VI

PREDICTED AND OBSERVED V_g VALUES FOR ALCOHOLS AND KETONES

Stationary phase, *n*-hexadecane (30.0%); mobile phase, water.

Sample	*V_g (ml/g)**	
	25.0 °C	*40.0 °C*
1-BuOH	0.13 (0.10)	0.18 (0.17)
1-AmOH	0.44 (0.41)	0.72 (0.65)
1-C_6OH	1.91 (1.65)	2.80 (2.56)
1-C_7OH	7.90 (6.73)	11.20 (10.05)
MMK	0.13 (0.11)	0.18 (0.15)
MEK	0.53 (0.48)	0.74 (0.67)
MPK	2.31 (2.07)	3.11 (2.82)
MBK	9.62 (8.73)	14.01 (11.52)
DEK	2.52 (2.18)	3.33 (3.00)

* Predicted V_g values are given in parentheses.

CONCLUSION

Activity coefficients of alcohols and ketones in a few simple LLC model systems were estimated, and the validity of the above equation for the prediction of elution was confirmed in these model systems. Although the method is not general, its application may be expanded by relating activity coefficients with solubility parameters.

REFERENCES

1 J. F. K. Huber, C. A. M. Meijers and J. A. R. J. Hulsman, *Anal. Chem.*, 44 (1972) 111.
2 J. F. K. Huber, E. T. Alderlieste, H. Harren and H. Poppe, *Anal. Chem.*, 45 (1973) 1337.
3 P. Menheere, C. Devillez, C. Eon and G. Guiochon, *Anal. Chem.*, 46 (1974) 1375.
4 R. M. Carlson, R. E. Carlson and H. L. Kopperman, *J. Chromatogr.*, 107 (1975) 219.
5 C. Eon, B. Novosel and G. Guiochon, *J. Chromatogr.*, 83 (1973) 77.
6 J. F. K. Huber, *J. Chromatogr. Sci.*, 9 (1971) 72.
7 D. C. Locke, *Advan. Chromatogr.*, 8 (1969) 47 pp.
8 G. J. Pierotti, C. H. Deal and E. L. Derr, *Ind. Eng. Chem.*, 51 (1959) 95.
9 D. E. Martire, *Anal. Chem.*, 38 (1966) 244.